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Assessment of Witch Flounder (*Glyptocephalus cynoglossus*) in the Gulf of St. Lawrence (NAFO Divisions 4RST), March 2022

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Foreword

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

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ABSTRACT

Witch Flounder (*Glyptocephalus cynoglossus*) are a slow growing and late maturing deepwater flatfish. In the 1970s, the mean length of a 12-year-old female in the southern Gulf of St. Lawrence was only 41 cm, and the age at 50% maturity of females was 10 years. These life-history characteristics make the species particularly vulnerable to overexploitation. A fishery for Witch Flounder was developed in the Gulf of St. Lawrence (NAFO Divisions 4RST) in the 1950s. Annual landings averaged over 3,500 t in the 1960s and 1970s, declining to an average of 1,800 t in the 1980s. Landings declined further in the early 1990s to a low of 320 t in 1995. Landings then increased to an average of 850 t annually in 1998-2008 but declined again in 2009-2010. While the total allowable catch (TAC) remained at 1,000 t until 2011, landings in 2011 were 425 t. The TAC was reduced to 500 t in 2012, further reduced to 300 t in 2013 and then increased back to 500 t in 2017. Landings have closely matched the TAC for the period 2013-2016 and have been below the TAC since 2017. A research vessel (RV) survey index of commercial biomass (fish 30 cm or longer) was constructed for 4RST based on the August RV survey of the northern Gulf and the September RV survey of the southern Gulf. This index, available since 1987, declined sharply in the early 1990s, increased to an intermediate level in 1999 and 2000, but then declined again, fluctuating around 40% of the 1987-1990 for the period 2001-2010 and has shown an increasing trend since. A sentinel survey index of fish 30 cm or longer, based on the July sentinel survey of the northern Gulf and the August sentinel survey of the southern Gulf, is available for the period 2003 to 2019. This index declined after 2006, was at its lowest level in 2011 and has shown an increasing trend since. A Bayesian surplus production model indicates a 90% decline in commercial biomass between 1961 and 2011 and an increasing trend since. The limit reference point (LRP) for this stock is estimated to be 10,700 t of commercial sized fish (30 cm and longer) and the Upper Stock Reference (USR) is estimated to be 21,400 t of commercial sized fish. The estimate of the biomass of fish 30 cm and longer in 2021 is 17,770 t. Based on the uncertainties in the estimates of both the 2021 biomass, the LRP and the USR, the probability that the biomass is above the LRP in 2021 is 77%. Projections of the population model indicate that the biomass is expected to increase, with probabilities of 60% that the biomass will be above the USR in 2026 with no catches, 52% with annual catches of 500 t and 44% with annual catches of 1,000 t.

1. INTRODUCTION

Witch Flounder (*Glyptocephalus cynoglossus*) is a righteye flounder species distributed over the northern Atlantic Ocean. In the western Atlantic Ocean, the species occurs from Cape Hatteras to the Labrador Sea. These fish most commonly occur in deep holes and channels and along the shelf slope on muddy bottom. Juveniles tend to occupy deeper water than adults, especially during summer (Powles and Kohler 1970; Markle 1975). Adults undertake seasonal migrations, moving into deeper water in winter and shallower water in summer (Powles and Kohler 1970). Powles and Kohler (1970) noted that the geographic extent of these migrations may be small, as little as 8-16 kilometers (5-10 miles).

In the Gulf of St. Lawrence (Figure 1), Witch Flounder form dense concentrations in deep water in winter months and become more widely dispersed throughout the Gulf in the summer (Bowering and Brodie 1984). In the early 1950s, a commercial fishery for Witch Flounder developed at the south side of St. George's Bay, Newfoundland, where boats with Danish seines fished during the summer months (Bowering and Brodie 1984). In the late 1970s, large quantities of Witch Flounder were landed by offshore otter trawlers fishing in the winter months in the Esquiman Channel southwest of St. George's Bay. This led to the first catch quota for this stock, set in 1977 at a precautionary level of 3,500 t for Northwest Atlantic Fisheries Organization (NAFO) Divisions 4RS. An assessment at this time revealed large numbers of old, slow-growing fish which were frequently landed in a "jellied" condition (Bowering 1978). In 1979, the total allowable catch (TAC) was raised to 5,000 t to reduce the numbers of these old fish and stimulate stock growth. The TAC was reduced back to 3,500 t in 1982, once this objective appeared to have been met (Bowering and Brodie 1980; Bowering 1981).

From 1977 to 1994, the fishery for Witch Flounder in the Gulf of St. Lawrence was regulated within NAFO Divisions 4RS. Landings in 4T were not subject to catch quotas, a concern given expected increases in effort for other groundfish species following the closure of the Atlantic Cod (*Gadus morhua*) fisheries in the Gulf in 1993 (R. Morin, pers. comm.). Following an analysis of the distribution of Witch Flounder in the Gulf of St. Lawrence (Morin and Hurlbut 1994), the Fisheries Resource Conservation Council (FRCC) recommended that the management unit for Witch Flounder in the Gulf be redefined to include 4T (FRCC 1994). This recommendation was implemented in 1995 and a 4RST stock unit was assumed in subsequent assessments of stock status.

The stock structure of Witch Flounder in NAFO Subarea 4 was reviewed in January 2001 (O'Boyle 2001). This review examined a proposal that Witch Flounder moving into the Cape Breton Trough in eastern 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 Div. 4T were uncertain but concluded that there was insufficient evidence to warrant a revision of the management units for Witch Flounder. Thus, assessments of stock status since then have been based on a 4RST management unit (Figure 2).

The previous full assessments of this stock took place in 2017 (DFO 2017; Ricard and Swain 2018), in 2012 (Swain et al. 2012b) and in 2006 (Swain and Morin 2006). An interim update of indicators to 2019 was provided in 2020 (DFO 2020). The current document presents stock status using data up to 2021 and provides advice for the 2022 to 2026 period.

2. FISHERY-DEPENDENT DATA

2.1. LANDINGS

Landings data are available from NAFO statistics for years 1960 to 1995, and from the Statistics Division of Fisheries and Oceans Canada for years 1985 to 2020. The landings data in Zonal Interchange File Format (ZIFF) provided nationally by the Statistics Division of Fisheries and Oceans Canada are usually available a year or so after commercial fishery logbooks and fish sales slips are received. As such, estimates of landings for 2021 were obtained from quota monitoring systems operated and maintained by the Fisheries and Aquaculture Management Division of Fisheries and Oceans Canada, namely the Atlantic Quota Management System (AQMS) and the Gulf Quota Reports, both available from Fisheries and Oceans Canada computer network.

Landings of Witch Flounder in the Gulf of St. Lawrence averaged 3,400 t from 1960 to 1975 (Figure 3;Table 1). Fisheries in 4R and 4T contributed roughly equally to these landings, with relatively minor contributions from 4S (Figure 3). Landings rose sharply in 1976 with the onset of a winter fishery by large otter trawlers exploiting winter concentrations of Witch Flounder in the Esquiman Channel. Landings dropped sharply in 1981 when these large trawlers were excluded from the northern Gulf Atlantic 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. Landings were near this low level from 1994 to 1997, when catches remained below the allocated quotas for all gear sectors. The decline in landings was particularly strong for 4R-based Danish seiners, whose landings reached only about one quarter of their allocation during the 1994 to 1997 period. This decline in landings reflected a sharp decrease in fishing effort in 4R (see below). In this period, a high incidence of crab gear interfered with the fishery for Witch Flounder in 4R in early summer, a period when fishing effort was traditionally high (Swain and Poirier 2001). The fishery during the 1994-1997 period was dominated by landings in 4T (Figure 3). In 1996 and 1997, 4T-based vessels caught about 75-80% of their allocation. Restrictions on fishing practices may have contributed to landing shortfalls during this period. For example, delays in the opening of the fishery until June precluded traditional fisheries during spring movements of Witch Flounder when catch rates tend to be high and may have contributed to the 1997 shortfall (R. Hébert, DFO Moncton, pers. comm.). Landings increased in the 1998-2000 period (Figure 3) when quotas were caught or exceeded by the fleets targeting Witch Flounder in 4R and eastern 4T. In 2000, the TAC was set at 1,000 t. Landings remained near the TAC until 2003 when they declined to 65% of the TAC. Total landings in 2004 were 750 t, 75% of the TAC. In 2004, seine fleets targeting Witch Flounder caught their quota in 4R but only 74% of their quota in 4T. In 2004, the late opening in the spring combined with bad weather in the fall prevented the 4T fleet from catching its quota. Landings were near the TAC in 2005, with the fleets targeting Witch Flounder in 4RST catching or exceeding their quota. Landings began to decline again in 2008, falling to a low of 229 t in 2010, less than 25% of the TAC. In 2011, landings increased in 4R to about 75% of the quota allocation, but landings by the 4T fleet remained low, at about 25% of the quota allocation. The TAC was reduced to 500 t in 2012 and then to 300 t in 2013 where it remained until 2017. In 2017, following the last stock assessment, the TAC was increased to 500 t. 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 for the 2013 to 2018 period. In recent years (2019 to 2021), the 4T fleet only landed a portion of its quota while the 4R fleet has landed the near totality of its quota.

Since 1960, the fishery for Witch Flounder has been conducted almost entirely by mobile gears (Table 1). Danish seines have dominated the landings, except during the 1976-1980 period when winter catches by offshore trawlers contributed heavily to the landings. Since 1991, 87-100% of landings have been from unit areas 4Rd, 4Tf, 4Tg and 4Tk (Figure 4). The proportion of landings was highest from 4Rd until 1994 when landings in this unit area declined sharply (Figure 4). Landings in 4Rd remained low from 1994 to 1997, returning to their earlier levels in 1998-2008. Landings have remained fairly steady in 4Tf and 4Tg. These areas dominated the fishery in the 1994-1997 period (Figure 4). Since 1998, 4Rd and 4Tfg have contributed roughly equal portions of the landings, though 4Rd dominated the landings in 2011. Contributions from 4Tk and 4Tnoq (labelled “Other” in Figure 4) are now fairly minor.

While landings during the period 1976-1981 were primarily from the trawl fishery operating in the winter months, the fishery for Witch Flounder has steadily moved to a directed fishery prosecuted by seine between May and September (Figure 5). The fishery for Atlantic Cod ceased in 1993, explaining the disappearance of this species as the Target Species in the bottom panel of Figure 5. Similarly, the fishery for American Plaice (*Hippoglossoides platessoides*) was greatly reduced between the mid 1980s to the mid 2000s, such that almost 100% of Witch Flounder landings now come from the directed fishery. The 4R and 4T fleets now land the bulk of 4RST Witch Flounder (Figures 5 and 6). Witch Flounder are also caught by the gillnet fishing fleet targeting Greenland Halibut (*Reinhardtius hippoglossoides*) on the northern edge of the Esquiman Channel and west of Anticosti Island (appearing as green squares on Figure 6) and by the trawl fleet targeting Redfish in the Laurentian Channel and Esquiman Channel (appearing as red triangles on Figure 6). The number of fishing vessels annually active in the NAFO 4RST Witch Flounder fishery was determined by counting the number of unique Commercial Fishing Vessel Number (CFVN) with landings in the ZIFF database that identified Witch Flounder as the main species sought. While the fishery was prosecuted by 20 to 40 fishing vessels in the late 1990s and early 2000s, less than 10 fishing vessels have been active in the directed Witch Flounder fishery since 2014 (Table 2).

Table 3 provides annual fishing year landings of Witch Flounder in the Gulf of St. Lawrence (computed from April 1st of year y to March 31 of year $y+1$). Table C1 contains additional yearly landings computed from September of year $y-1$ to August of year y . The modelling approach introduced in section 4 will use this time-series of landings as model inputs as they match the timing of the model biomass estimates.

2.2. CATCH-AT-LENGTH

The length composition of samples from the commercial fishery differed dramatically between samples collected in the 1970s and early 1980s and those collected in the 2000s (Figures 7 and 9). The proportion of fish 40 cm and longer was around 80% for the period 1975-1978 and dropped to around 30% for the period 1986-2000. For the period 2007-2012, the proportion of fish 40 cm and longer was below 20% and has been increasing since in both NAFO Divisions 4R and 4T (Figure 8). In recent years the totality of the Witch Flounder landings have come from NAFO Divisions 4R and 4T from mobile gear (shown yearly in Figure 9). Because of restrictions imposed by COVID-19, commercial landings were not sampled in 2020, and sampling was limited to NAFO Division 4R in 2021, so the values appearing in Figures 8 and 9 might not provide a good representation of the fisheries landings for those years.

2.3. CATCH COMPOSITION OF THE DIRECTED WITCH FLOUNDER FISHERY

To examine how the targeted fishery for Witch Flounder catches other species, the ZIFF data was used to compute the composition of the catch for each available landing event. A landing event consists of the total landings by a given fishing boat on a given day. For each landing event, the proportion of each species landed was then calculated and is reported for a number of species of interest in Table 4. The fishery has recently achieved a very high proportion of

Witch Flounder in its landings. Other species that appear in the fishery landings include American Plaice, Atlantic Cod, Greenland Halibut, White Hake (*Urophycis tenuis*), Redfish (*Sebastes* species) and Atlantic Halibut (*Hippoglossus hippoglossus*).

3. FISHERY-INDEPENDENT DATA

3.1. RESEARCH TRAWL SURVEY DATA

Two stratified random bottom-trawl surveys were available to provide fisheries-independent information about Witch Flounder in NAFO Divisions 4RST. One survey has been conducted in the estuary and the northern Gulf of St. Lawrence in August since 1984 (Figure 10), while the second has been conducted in the southern Gulf of St. Lawrence each September since 1971 (Figure 11). For the August survey, Witch Flounder length frequency data (required for standardization between the two surveys) are only available since 1987.

In the August survey, fishing was conducted by the *Lady Hammond* using a Western IIA trawl from 1984 to 1989, by *CCGS Alfred Needler* using a URI shrimp trawl from 1990 to 2003, and by *CCGS Teleost* using a Campelen 1800 trawl since 2004. Comparative fishing occurred between the *Lady Hammond* with a Western IIA and *CCGS Alfred Needler* with the URI during the 1990 survey and between *CCGS Alfred Needler* and *CCGS Teleost* during the 2005 survey. Target fishing procedures in the August survey were a 30 minute (min) tow at 3.5 knots in 1984-1989 (standard tow = 1.75 nautical miles), a 20 min tow at 2.5 knots in 1990-1992 (standard tow = 0.83 nautical miles), a 24 min tow at 2.5 knots in 1993 (standard tow = 1.0 nautical mile), a 24 min tow at 3.0 knots from 1994 to 2003 using the URI trawl (standard tow = 1.2 nautical miles), and a 15 min tow at 3.0 knots using the Campelen 1800 trawl since 2004 (standard tow = 0.75 nautical miles).

Fishing in the September survey was conducted by the *E.E.Prince* from 1971-1985, by the *Lady Hammond* from 1985-1991, by *CCGS Alfred Needler* in 1992–2002 and 2004-2005, by *CCGS Wilfred Templeman* in 2003, and by *CCGS Teleost* since 2004. Comparative fishing occurred between the *E.E.Prince* and *Lady Hammond* during the 1985 survey, between the *Lady Hammond* and *CCGS Alfred Needler* prior to the 1992 survey and between *CCGS Alfred Needler* and *CCGS Teleost* during the 2004 and 2005 surveys. The *E.E.Prince* used a Yankee-36 trawl and subsequent vessels used a Western IIA trawl. In all years, the target fishing procedure was a 30 min tow at 3.5 knots, for a standard tow of 1.75 nautical miles. Fishing was conducted only during the daylight hours (between sunrise and sunset) by the *E.E.Prince* and throughout the 24-h day by the other vessels. Further details of procedures for the southern Gulf survey are given by Hurlbut and Clay (1990).

Based on analyses of the comparative fishing experiments (Swain and Poirier 1998; Benoît and Swain 2003a, 2003b; Benoît 2006), and additional analyses on diel variation in catchability of Witch Flounder (Swain et al. 1998a), 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. Diel and vessel effects were independent of fish length, whereas differences in fishing efficiency were length-dependent between the Western IIA and URI trawls and between the URI and Campelen 1800 trawls. For some analyses restricted to lengths greater than 23 cm, adjustments between the Western IIA and URI trawls were independent of length because differences in fishing efficiency between these two gears varied little with length at these larger sizes. For analyses restricted to the August survey data since 1990, standardization was to the fishing efficiency of the URI trawl (D.P. Swain, unpublished analyses). Details on these adjustments are given in Appendix A of this document.

Survey indices were calculated using a set of strata sampled in most years; 401 to 414, 801 to 824, and 827 to 832 in the August survey (Figure 10) and 415 to 429 and 430 to 439 in the September survey (Figure 11). The details of how estimated values for missed strata were obtained to perform the stratified calculations are described in Appendix A.

An additional index was computed for fish of lengths between 16 and 30 cm, to provide a recruitment indicator (Figure 12). Recruitment in recent years is on an increasing trend but is at levels below those observed between 2010 and 2013.

3.1.1. Growth estimates

Witch Flounder otoliths collected during the 1974-1981 September surveys were aged (n = 301 males and 445 females). Growth was slow for both sexes, with a mean length at age 12 years of 40 cm for males and 41 cm for females. Data of age *a* and length *L* pairs were used to fit a single von Bertalanffy growth model separately by sex s (only identified males and females were considered, unsexed individuals were not considered):

$$L_{a,s} = L_{\infty_s}\left(1 - exp\left(k_s\left(a - t_{0_s}\right)\right)\right) \quad (1)$$

where $L_{a,s}$ is the length at age *a* and sex s, L_{∞_s} is the asymptotic length for sex *s*, k_s is the rate parameter for sex *s* and t_{0_s} is the age at length 0 for sex *s*. The fitted model estimates the asymptotic length, rate parameters and age at length 0 separately for males and females. The fitting was done using the non-linear least-square optimizer “nls” in R version 4.1.2 (R Core Team 2021) and provided an adequate fit to provide length-at-age predictions for both sexes (Figure 13; Table 5). Estimated asymptotic lengths (L_{∞_s}) were 68.2 cm for females and 53.5 cm for males. Size-at-age began to diverge between males and females at ages 12-15 years, consistent with the earlier maturation of males.

Bowering and Brodie (1984) reported growth rates for Witch Flounder collected from the northern Gulf during the same period (1975-1981). Their estimated growth rates were somewhat faster than those reported here, with their predicted lengths at age 12 years varying between 40 and 47 cm for males and 41 and 49 cm for females. However, the maximum ages in their data were considerably lower than those in the September data, 26 versus 34 in 1976 and declining to 16 versus 25 in 1980/1981, suggesting the possibility that ages may have been underestimated in their study.

While otoliths of Witch Flounder are collected during the annual trawl surveys and through port sampling and observers programs, the species is not aged routinely and the only available ageing information comes from the 1974-1981 period. Because of its relatively slow growth and the small size of its otoliths, the species is difficult to age using normal visual examination of the otoliths.

3.1.2. Maturity estimates

The main source of maturity data for Witch Flounder in the Gulf of St. Lawrence is the biological data collected during the September surveys. For late winter – early spring spawners such as Witch Flounder, there is concern about the reliability of maturity staging in September, mainly due to the difficulty in distinguishing between immature individuals and mature individuals in recovering/resting state. Studies on other species (e.g. Atlantic Cod) have indicated that maturity staging of these species was reliable for September surveys prior to 1983, when the group conducting the survey changed (Swain 2011). Based on comparisons with samples collected in the spring, maturity staging of Atlantic Cod was found to be unreliable in the September surveys from 1983 to the early 1990s, but appeared to be reliable in surveys conducted in the 2000s (Swain (2011), Supporting Information S3 and S4). The reliability of the Witch Flounder maturity data from the September survey was examined by Swain et al. (2012b) which determined that staging was reliable in 1970-1982 but not in 1983-1999, consistent with results for Atlantic Cod (Swain 2011) and white hake (Swain et al. 2012a). Therefore, maturity information for the 1983 - 1999 period are excluded from the current analyses.

The maturity of individuals captured in the scientific trawl surveys is determined by macroscopic examination of gonad tissues. The different maturity stages identified are re-coded as either immature or mature individuals, allowing the examination of the proportion mature as a function of age and length. The available maturity data was used to fit a logistic regression (binomial regression with logit link) that estimated the maturation of males and females. For individuals that were aged, the maturity-at-age was determined using the model:

$$log\left(\frac{p_{as}}{1-p_{as}}\right) = \alpha + \beta_s a \tag{1}$$

where p_{as} is the proportion of mature individuals at age *a* and sex *s*, α is the model intercept and β_s is the model slope for each sex.

Maturity-at-length was determined using the model:

$$log\left(\frac{p_{ls}}{1-p_{ls}}\right) = \alpha + \beta_s l \tag{3}$$

where p_{ls} is the proportion of mature individuals at length *l* and sex *s*, α is the model intercept and β_s is the model slope for each sex.

For individuals that were not aged, the maturity-at-length was determined using a model that estimates the maturation of males and females for the different decades when data was available:

$$log\left(\frac{p_{lsd}}{1-p_{lsd}}\right) = \alpha + \beta_{sd} l \tag{4}$$

where p_{lsd} is the proportion of mature individuals at length *l* ,sex *s* and decade *d*.

Based on the 1971-1982 data, the estimated lengths and ages at 50% maturity (L_{50}, A_{50}) were 37 cm and 10.4 years for females and 30.9 cm and 7.5 years for males (Figure 14). These values are similar to those reported by Bowering and Brodie (1984), based on Witch Flounder collected in January 1978-1981 in the northern Gulf; averages of 41.4 cm and 10.3 years for females and 31.5 cm and 6.9 years for males.

The data from surveys in the 2000s suggest that maturation is now earlier than in the 1970s, with L_{50} estimated to have declined from 33 and 39.6 cm to 26.2 and 28.3 cm for males and females respectively based on the 2000-2009 data and to 27.3 and 31.2 cm based on the 2010-2019 data (Figure 15). The reliability of the recent September data is improving as histological samples have been analysed to assign precise maturity levels to match the macroscopic examination of gonads. Additional evidence of earlier maturation comes from sampling in the Cape Breton Trough in late April and early May in 2009 to 2011 which also indicates earlier maturation than in the 1970. Of 490 individuals sampled at lengths of 26 to 54 cm, all but one fish were mature including 30 males less than 31 cm in length and 32 females less than 35 cm in length. Earlier maturation is an expected evolutionary response to increased mortality at larger sizes, such as that imposed by fishing (Law and Grey 1989; Law 2000) or by predation (Reznick and Ghalambor 2005; Swain 2011).

3.1.3. Geographic distribution

The distribution of Witch Flounder is presented using the combined data from the August and September surveys and in standard units of a night tow on the *Lady Hammond* using a Western IIA trawl. 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 (Figures 1 and 16). Densities of these small Witch Flounder tended to be high in the Estuary in all time periods. Densities of these small fish in both the Estuary and in the channels have been high since 2008.

Larger commercial-sized Witch Flounder (30+ cm) 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 Gaspé Peninsula and the shelf off western Newfoundland, as well as in the Estuary (Figure 17).

A number of distribution indices are also developed to assist the interpretation of Witch Flounder distribution in the Gulf of St. Lawrence. First, the design-weighted area of occupancy (DWAO) for each year *t* (A_t) is calculated as:

$$A_t = \sum_{k=1}^{S} \sum_{j=1}^{N_k} \frac{a_k}{N_k} I \ \ where\ I = \begin{cases} 1 & if\ Y_{kj} > 0 \\ 0 & otherwise \end{cases} \tag{5}$$

where N_k is the number of tows undertaken in stratum *k*, a_k is the surface area of stratum *k* and Y_{kj} is the number of fish 30+ cm caught in tow *j* in stratum *k*. The indicator function *I* denotes the presence of Witch Flounder 30+ cm in each stratum. This equation computes the proportion of tows with non-zero catch in each stratum *k* and sums these proportions multiplied by the surface area of each stratum. Additionally, the methods described in Swain and Sinclair (1994) were used to compute the distribution indices that account for various percentage of the biomass. Figure 18 shows the yearly area surveyed, the DWAO and the distribution accounting for 75% and 95% of the total biomass ($D_{75\%}$ and $D_{95\%}$, respectively). A shortcoming of these distribution indices is that when biomass levels are low and a few large catches take place, a large portion of the total biomass is calculated to be coming from these few sets, leading to small values of the distribution indices. This is the case for year 1999 when the value of $D_{75\%}$ is very low because of a single tow with large catch in stratum 437 of the southern Gulf survey (Table A13). Nonetheless, the distribution indices indicate that the distribution of commercial-sized Witch Flounder decreased between 1987 and the mid-1990s and has been on an slightly increasing trend since 2010.

3.1.4. Length composition

The stratified numbers-at-length for the combined surveys appears in Figure 19. While there are obvious year effects in the stratified numbers-at-length, the surveys are still able to provide indications of cohorts replenishing the stock at regular intervals.

3.2. MOBILE SENTINEL SURVEY DATA

3.2.1. Background

Two mobile-gear sentinel surveys have been conducted in the northern Gulf of St. Lawrence beginning in 1995, one in early summer (usually mostly in July) and one in fall (late September and October). Each survey is conducted by nine otter-trawlers, each equipped with the same trawl and rockhopper gear. Since 1997, a restrictor cable has been used to standardize the horizontal opening of the trawl. The survey follows 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. Additional discretionary tows conducted on observed fish concentrations were not included in this analysis. The target fishing procedure is a 30 min tow at 2.5 knots, giving a standard tow of 1.25 nautical miles. Tows in the NAFO Division 3Pn strata were omitted for these analyses. The fall survey was discontinued after 2002 and results presented here are for the July survey only. The strata used in the July Sentinel survey are 401 to 410, 801 to 824, 827 to 833 and 835 to 841 (Figure 20).

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 (Savoie 2016). This survey uses the same strata as the September RV survey and strata 415 to 429 and 431 to 439 are used (Figure 11).

The southern Gulf of St. Lawrence sentinel survey did not take place in 2020 and 2021, so the index used in the population model only spans the period 2003 to 2019. Further details about the computation of the NAFO 4RST Sentinel index can be found in Appendix B.

3.2.2. Geographic distribution

The geographic distribution of Witch Flounder catches in the mobile-gear sentinel surveys is summarized in Figures 21 and 22. There is evidence for an increase in fish 30 cm and longer along the Gaspe coast as well as in western Newfoundland. In the Cape Breton Trough, following higher catches in 2003 to 2006, catches appear fairly constant since 2007.

4. SURPLUS PRODUCTION MODEL

Bayesian state-space Schaefer surplus production model (Schaefer 1954) was implemented using JAGS (Plummer 2021a) and interfaced with the R package “rjags” (Plummer 2021b). The “state-space” aspect of the model means that there are two coupled components, a state process and an observation model. The state process represents the unobservable stochastic processes governing the population dynamics. The observation model describes the observation errors. The Schaefer surplus production model was used as the process model:

$$B_t = \left[B_{t-1} + rB_{t-1}\left(1 - \frac{B_{t-1}}{K}\right) - C_t\right] e^{\eta_t} \quad (6)$$

where B_t is the biomass in the late summer/early fall of year *t*, C_t is the catch for the period spanning from September in year *t-1* to August in year *t*, *r* is the intrinsic rate of population growth and *K* is the carrying capacity. The parameter *r* was fixed at a constant level over the whole time period (model 1, M1, hereafter), or allowed to vary each decade (model 2, M2, hereafter). The parameter η_t is the process error, an independent normal random variable representing process stochasticity with mean zero and variance σ^2 (i.e. $\eta_t \sim N(0, \sigma^2)$). Models incorporated as much of the catch history as possible by starting in 1961. An additional parameter is estimated during the model fitting, the initial biomass B_0, which allows for the biomass at the beginning of the available time-series to be different than the carrying capacity *K*.

The observation component related the biomass indices $I_{i,t}$ to population biomass B_t:

$$I_{i,t} = q_i B_t e^{\epsilon_{i,t}} \quad (7)$$

where q_i is the catchability for index *i* and $\epsilon_{i,t}$ are independent normal random variables with mean zero and variance τ^2 (i.e. $\epsilon_{i,t} \sim N(0, \tau^2)$) representing observation errors in each biomass index *i*. The model was fit to three indices of biomass of fish 30 cm and longer. To estimate the joint posterior distribution of the model parameters, 275,000 samples were generated in each of two chains, the first 200,000 samples were discarded as a “burn-in”, and every 30th sample thereafter was retained to reduce autocorrelation, yielding 5,000 samples from the joint posterior distribution.

4.1. BIOMASS INDICES

Index 1 was the trawlable biomass of Witch Flounder 30 cm and longer (30+ cm trawlable biomass hereafter) in the September RV survey of 4T from 1971 to 1992 (top panel of Figure 23). This index does not cover the entire stock area but assumes that availability to the September survey (i.e. the proportion of the stock occurring within the September survey area) does not change over the 1971 to 1992 time period. The index was used only for the 1971 to 1992 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. 2012b). Index 2 was the combined August and September RV index for 4RST 30+ cm trawlable biomass from 1987 to 2021 (middle panel of Figure 23). Index 3 was 30+ cm trawlable biomass in the combined July and August sentinel surveys from 2003 to 2019 (bottom panel of Figure 23). The September survey data is used in both indices 1 and 2 for the period 1987 to 1992, which provides a temporal overlap between the two indices.

Both Index 2 and Index 3 are combined indices and required the merging of data coming from a variety of research vessels and gear types to produce Gulf-wide indices. More details about the computation of these indices can be found in Appendices A and B.

4.2. MODELS PRIORS

The prior probability distributions used for the Schaefer model parameter *r* and B_0, and for the catchability coefficients of the different surveys (q_i) were the same as those used in the previous assessments (Swain et al. 2012b; Ricard and Swain 2018).

An informative prior for *r* was derived using methods by McAllister et al. (2001) using life history characteristics of Witch Flounder in Divisions 4RST. The prior for *r* was normally distributed with a mean of 0.1687 and a standard deviation (SD) of 0.05 ($r \sim N(\mu = 0.1687,\ \sigma = 0.05)$). The prior for B_0 was derived using the *q*-corrected combined 4RST RV index in year 11 (Sept. 1971) minus the expected total net production (production minus catch) from 1961 to 1971 (expected based on the average of the results of previous models), yielding $B_0 \sim N(log(62), 0.35)$ (Swain et al. 2012b). The prior for the catchability coefficient of the combined 4RST RV index (q_2) was constructed based on the selectivity curve for catchability-at-length of flatfish to RV surveys estimated by Harley and Myers (2001). The prior for q_2 was lognormal with a mean of 0.4776 and a SD of 0.325 ($log(q_2) \sim N(\mu = 0.4776,\ \sigma = 0.325)$). Uniform priors were used for catchability of indices 1 and 3. For Index 1, the prior was uniform between 0.1 and 0.6 ($q_1 \sim U(0.1,0.6)$); *q* for this index is expected to be about 20-30% of q_2. For Index 3, the prior was uniform between 0.1 and 1.0 ($q_3 \sim U(0.1,1.0)$); *q* for this index is expected to be lower than q_2 because of the lower catchability of the sentinel trawl for small fish.

Priors on the standard deviation (SD) of observation error were uniform, extending from the survey coefficient of variation (CV) to about three times this level, i.e. $\sim U(0.35,1)$, $\sim U(0.35,1)$, and $\sim U(0.25,0.75)$ for indices 1-3, respectively. Uniform priors were also placed on $log(K)$ ($\sim U(2,6)$), and the SD of process error ($\sim U(0.05,1)$).

The JAGS code and the data inputs used to fit the model can be found in Appendix C. Note that the parameterisation of prior distributions in JAGS uses “precision” instead of variance or SD. “Precision” is defined as $1/\sigma^2$.

4.3. RESULTS - SINGLE PRODUCTIVITY REGIME

The first model examined (model M1, hereafter) corresponding to model 7 in the 2012 assessment (Swain et al. 2012b), consisted in a single productivity regime and was parameterised in terms of biomass instead of proportion of carrying capacity. This parameterisation allowed the development of a prior distribution for the starting biomass, and took into account the catch data back to 1961 and the 4T index back to 1971. The 30+ cm biomass of 4RST Witch Flounder estimated by the single productivity regime model M1, the resulting exploitation rate (catch divided by biomass) and the fit to the three biomass indices can be found in Figures 24, 25 and 26 respectively. The bottom panel of Figure 24 also shows the estimated probability that the 30+ cm biomass is below the Limit Reference Point (LRP, see Section 5). The process and observation errors of model M1 can be found in Figure 27. There was no strong pattern to the residuals from the three biomass indices, indicating a satisfactory model fit. Process error was autocorrelated, although there was no long term trend in process error which would indicate a serious problem in model structure. The model accounted for the long term trend but had difficulty fitting the higher frequency bumps and valleys in the indices, resulting in a pattern in the process error.

The yearly median estimates of 30+ cm biomass suggest that the stock went below the LRP in 1991 and remained in the critical zone until 2014. The median estimates of 30+ cm biomass have been increasing since 2009. A notable result is the estimated drop in biomass in 2018, a trend that comes from lower values in both the 4RST RV index and the 4RST Sentinel index for that year. This drop in biomass would not be expected under the population model used since the catch landings for that year were well below the surplus production. For the year 2018, the state-space model estimates a negative residual for the state process error (Figure 27).

Figure 28 summarises the temporal evolution of the catch and the estimated biomass of 4RST Witch Flounder, and also reports the estimates of catch at maximum sustainable yield (C_{msy}), biomass at maximum sustainable yield (B_{msy}), and the biomass in 2021 (B_{2021}). The model estimates suggested that the median 30+ cm biomass was above the LRP but still below the USR in 2021. Estimates of several quantities of management interest (with 80% credible limits in parentheses for the 2021 estimates) and those obtained from the 2012 and 2016 assessments are summarized in Table 6. A more traditional Precautionary Approach plot (PA, a.k.a. Kobe plot) showing the estimated biomass and exploitation rate over the 1961 to 2021 period appears in Figure 29.

Priors and posteriors of the model parameters and some estimated variables are shown in Figures 30 to 32. The prior and posterior distributions for B_0 were almost identical (Figure 30). The strongly informative prior on the 4RST RV index q_2 was updated slightly by the data with the posterior shifted slightly to a higher median value of 0.5224 from a prior value of 0.4776 (Figure 31). The posterior distribution of q_1, the catchability of the southern Gulf 4T RV index in 1971 to 1992, had a median value of 0.1408, which is equivalent to 27% of the median value of q_2. This percentage essentially indicates the proportion of the trawlable biomass that was present in NAFO Division 4T during the 1971 to 1992 time period. The median value for the 4RST Sentinel index q_3 was 0.1757, corresponding to 34% of the median value of q_2, confirming the lower catchability of the sentinel trawl for small fish.

To examine model robustness, the biomass index data for the four most recent years was removed (while retaining the landings data) and the model was projected forward over the years of missing data, comparing the revised predictions of population biomass to those obtained using all the available data. The revised model predictions with the missing data compared well with those obtained using all the available data (Figure 33). As expected, the uncertainty around the predicted biomass trajectory increased greatly for the years without index data since the model is not fitted to observations for that four-year time period.

4.4. RESULTS – CHANGING PRODUCTIVITY REGIMES

The second model evaluated (model2, M2 hereafter) addressed the possibility of changes in the productivity regime experienced by the stock and was implemented by allowing *r* to vary at a decadal scale. The model was the same as model M1 except that *r* was allowed to differ between the following four periods: 1961-1979, 1980-1989, 1990-1999, and 2000-2021. The prior for *r* in the first period was the same as the prior used in model M1. The prior for *r* in the other three periods was uniform between -0.2 and 0.5 (i.e. $r \sim U(-0.2, 0.5)$).

Median estimates of *r* for the 1990s were somewhat lower than those for the other periods (Figure 34). Posterior medians for *r* declined from 0.177 and 0.186 in the 1961-1979 and 1980-1989 periods to 0.078 and 0.146 in 1990-1999 and 2000-2021, respectively. However, the posterior distributions for *r* overlapped broadly between all four periods, which does not provide strong evidence of a decline in productivity. The single productivity model M1 is therefore used to provide science advice for this stock, as was done in the two previous assessments (Swain et al. 2012b; Ricard and Swain 2018).

5. REFERENCE POINTS

The population model provides the basis for the estimation of upper stock reference and limit reference points for this stock. The biomass at which the Maximum Sustainable Yield (MSY) is achieved is $K/2$, and MSY can be computed as:

$$MSY = rK/4 \tag{8}$$

where *r* and *K* are the model parameters estimated from the data. Under Fisheries and Oceans Canada (DFO) policies (DFO 2009), the Upper Stock Reference (USR) is defined as $0.8B_{MSY}$ and the Limit Reference Point (LRP) as $0.4B_{MSY}$. For NAFO 4RST Witch Flounder these estimated reference points can be found in Table 6. The median estimate of the 2021 biomass is 17,768 t, which is 166% of the median estimate of the LRP (10,700 t) and 83% of the median estimate of the USR (21,399 t).

Since the USR is at 80% of B_{MSY}, the equilibrium catch level at the USR is below C_{MSY}. If the target reference point is defined as the USR instead of B_{MSY}, the maximum sustainable catch that the stock could sustain under the current model estimates would be 1,822 t, which is slightly lower than the C_{MSY} value of 1,961 t. Note that under the equilibrium conditions defined by the Schaefer surplus production model used in this assessment, the same equilibrium level of catch can be associated with a biomass value of 80% of B_{MSY} (the USR) and also at 120% of B_{MSY} (well above the USR).

6. PROJECTIONS

Five-year projections (2022 to 2026) were made at four levels of catch corresponding to 0 t (no catch), 500 t (status quo TAC), 1,000 t, and 1,500 t. The projected 30+ cm biomass is shown for the four levels of catch in Figure 35. Median estimates of 30+ cm biomass increased over the five year period at all catch levels of 0 t to 1,000 t. The probability that the 30+ cm biomass will be below the LRP by 2026 is 13% with no catch, 16% under a catch level of 500 t, 22% under a catch level of 1,000 t and 29% under a catch level of 1,500 t (Table 7 and Figure 36). The probability that the 30+ cm biomass will exceed the USR by 2026 is 60% with no catch, 52% under a catch level of 500 t, 44% under a catch level of 1,000 t and 37% under a catch level of

1,500 t (Table 7 and Figure 36). Under the different catch scenarios, the percentage of the surplus production removed by harvesting ranges from 27% to 29% for a catch of 500 t, from 55.8% to 58.6% for a catch of 1,000 t and from 88.8% to 89.2% for a catch of 1,500 t (Table 7).

A large uncertainty is present in the projections, and the uncertainty increases with each year of projection. This can be seen by the widening interval of the 2.5th and 97.5th posterior median quantiles in Figure 35. The side effect of this increased uncertainty is that the median estimate of surplus production levels off at values similar to those estimated for 2021 instead of steadily increasing as the 30+ cm biomass approaches B_{MSY}. The projected 30+ cm biomass levels off at catch levels around 1,500 t (Figures 35 and 37), even though the median estimates of the model suggest that the stock could sustainably be harvested at levels closer to 2,000 t (the estimated value of C_{MSY} is 1,960 t).

Also reported in Table 7 is the surplus production in each projection year and the percentage of the surplus production removed by the fishery under the four different TAC scenarios considered. Under the Schaefer model used, the surplus production in year *t* (SP_t) can be calculated using the following equilibrium equation:

$$SP_t = \hat{r}B_t\left(1 - \frac{B_t}{\hat{K}}\right) \quad (9)$$

where is $\hat{r}$ the median estimate of *r*, $\widehat{K}$ is the median estimate of *K* and B_t is the biomass in year *t*. This equation corresponds to the solid black line shown on Figures 37, it is the catch level at different biomass values that maintains the population at its current level. Catches below this level will lead to an increase in biomass over time, and catches above this level will lead to a decrease in biomass over time.

7. DISCUSSION

The NAFO 4RST stock has recently been exploited by fleets in Division 4R and in the Cape Breton trough portion of Division 4T, with limited catches in other areas. However, the August-September distribution of individuals >= 30 cm suggests that commercial-sized individuals are also present along the Gaspé peninsula and in the St. Lawrence estuary. This raises two issues: 1) can the stock sustain a higher level of exploitation if harvesting is restricted to the Cape Breton trough and the west coast of Newfoundland around the Esquiman Channel and 2) can the stock sustain additional exploitation in other areas where surveys suggest it is present at high densities? The exploitation history of the stock suggests that it is prone to overexploitation so any expansion of the fishery should be closely monitored in order to keep the stock on its recovery trajectory.

One challenge faced in this assessment was to reconcile the landings data obtained from ZIFF data and those obtained from quota monitoring. If ever an increase in TAC is considered by Fisheries and Aquaculture Management (FAM), it is imperative that information on landings be available within a few months and at an appropriate geographic resolution.

The model used is a biomass dynamics model that doesn’t incorporate any age-structure information and that simplifies all population processes to a few estimated parameters. This means that growth, recruitment, natural mortality, and any other determinants of population dynamics are integrated in the *r* and *K* parameters which essentially determine the population productivity and the carrying capacity of the stock. This type of model is useful in situations where a limited amount of data are available to evaluate a stock. The stock under scrutiny is not productive and has shown signs of episodic recruitment. As such, there are some potential shortcomings to using a biomass dynamics model for this stock and a more elaborate methodology would allow better insight into its population dynamics. However, the science advice coming from the current assessment is not in doubt, the perception of stock status is coherent with the observations made in landings and in the surveys used in model fitting.

The indices used in the population model fitting are used as error-free estimates of stock status. It is clearly not the case that these indices are error free, and common stratified calculations include a variance estimate. While the indices can be presented along with their error estimates, the model fitting minimizes the residuals using the mean values only. The state-space model partitions the residuals between process error and observation error, but the implicit assumption is that the indices are observations without error. The inclusion of the variance around the mean values of the indices in the modelling would require additional complexities to the fitting procedures.

7.1. STOCK STATUS INDICATORS

The NAFO 4RST Witch Flounder stock is currently assessed and managed on a five-year cycle. Indicators are needed to characterise stock status in years between assessments. Because of their perenniality and representativeness of stock status, the indicators suggested are the biomass indices from the RV surveys conducted in the northern and southern Gulf of St. Lawrence, combined into a single population index for NAFO Divisions 4RST. These indices can have significant observation error and changes in stock biomass should not be inferred from annual estimates only. As noted above, the variance estimates from the stratified calculations is usually presented but is not used in the population model fitting, nor in the determination of stock status based on an index value. Moving averages are therefore suggested, with a three-year moving average recommended for tracking Witch Flounder stock biomass. Important changes in the indicator, e.g. a large change in the moving average from its value in the last assessment year, would trigger a re-assessment before the five-year period has elapsed. Alternatively, an unexpected trajectory in stock status and/or the crossing of a reference point could also justify a re-assessment.

In order to implement this approach it is necessary to relate the defined reference points (LRP and USR) from their population scale in September to the scale of the RV indices 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 of the index. The median value of the index's catchability coefficient is 0.5224 (q_2 in Figure 31) and the LRP is 10,700 t (Figure 24), resulting in a scaled LRP of 5,590 t of trawlable biomass. A similar scaling can be done for the USR (21,400 t), giving a scaled USR of 11,180 t of trawlable biomass (Figure 26). Additionally, the reference points can be expressed in tow-level units of kg of 30+ cm biomass per tow by dividing the trawlable biomass by the number of trawlable units in the entire survey area.

Under this approach, the 2021 value of the three-year moving average is 9,659 t of trawlable biomass, which yields a value of B_{2021}/LRP equal to 1.7. This value provides a stock status indicator that is favourably comparable to the median estimate of 1.6 from the population model (Table 6). The two values are not expected to be exactly the same since the three-year moving average smooths out the variability in the observed index values while the model estimates are based on the 5,000 Markov Chain Monte Carlo (MCMC) samples of the Bayesian surplus production model. However, their values are very similar and the proposed stock status indicator is an appropriate measure to use as an update of stock status.

The three-year moving average could be computed at the mid-point of the five-year cycle (after the 2023 trawl surveys in the northern and southern Gulf of St. Lawrence are completed) and an assessment would be triggered if its value falls outside of the confidence limits estimated in the projections (Section 6) or if the three-year moving average goes below the scaled LRP. Currently, the 3-year moving average of the stock status indicator sits above the scaled LRP value and below the scaled USR (Figure 38). The current TAC for this stock is set at 500 t and the projected biomass under various catch scenarios follow increasing trends at TAC levels up to 1,000 t (Figure 35).

Because of the recent entry in service of new offshore fisheries science vessels (*CCGS Captain Jacques Cartier* and *CCGS John Cabot*), the computation of stock status indicator for years to come will be dependent on the prior analysis of the comparative fishing experiments started in 2021 and continuing in 2022. While these changes in vessels and gear have occurred in the past and the results of comparative fishing experiments have been successfully included in the computation of population indices that maintain the continuity of the time-series, the change to new vessels will add an additional layer of complexity to the computation of the Gulf-wide population index. The change in the northern Gulf survey is from *CCGS Teleost* to the *CCGS John Cabot*, but the trawl used in the survey will still be the Campelen 1800. In the southern Gulf survey, the change from *CCGS Teleost* to *CCGS Captain Jacques Cartier* is concomitant with a change from the Western IIA trawl to the Northeast Fisheries Science Center Ecosystem Survey Trawl (NEST). This change in trawl is taking place to achieve a better comparability between surveys conducted by DFO Maritimes Region in the Scotian Shelf and Bay of Fundy and those conducted by the United States National Marine Fisheries Service, part of the National Oceanic and Atmospheric Administration.

7.2. ECOSYSTEM CONSIDERATIONS

Like many other marine ecosystems, the Gulf of St. Lawrence is experiencing warming trends in both surface and bottom water temperatures (Galbraith et al. 2022). The diet of Witch Flounder mainly consists of small benthic organisms and it is unclear what effects a warming trend in water temperature would have. The species is distributed as far south as Cape Hatteras and is likely able to withstand warmer temperatures, but the energetic costs associated are unknown. Similarly, the prey field could be altered by warming temperatures but the overall effects on the population dynamics of Witch Flounder in the Gulf of St. Lawrence are unknown.

Unlike a number of other groundfish stocks in the Gulf of St. Lawrence that have failed to rebuild despite large reductions in fishing mortality, the Witch Flounder stock has been rebuilding since 2010. The most probable reason for the lack of rebuilding of others stocks is the increased natural mortality imposed by grey seals. In the case of Atlantic Cod, the last stock assessment indicated an increase in natural mortality on older fish (Swain et al. 2019). Similar situations have been observed for American Plaice (Ricard et al. 2016), White Hake (Swain et al. 2016), Yellowtail Flounder (*Limanda ferruginea*, Rolland et al. 2022), Winter Flounder (*Pseudopleuronectes americanus*, Surette and Rolland 2019) and Winter Skate (*Leucoraja ocellata*, Swain and Benoît 2016)

In the Gulf of St. Lawrence, Witch Flounder are found in deeper waters than other groundfish species. This distribution makes it less likely that they would be a prey for grey seals, whose foraging behaviour based on telemetry data was found to be restricted to water above 150 m (Breed et al. 2009). The other stock that is showing clear signs of rebuilding is Redfish in Unit 1 (Senay et al. 2021), which is another stock whose distribution is in deep waters.

7.3. RESEARCH RECOMMENDATIONS FOR NAFO DIVISIONS 4RST WITCH FLOUNDER

The computations of combined population indices for NAFO Division 4RST Witch Flounder used in this assessment are based on the work of Swain et al. (1998b) and Swain et al. (2012b). A number of advances have since taken place in the analytical treatment of comparative fishing experiments. Notably, integrated analyses that use the comparative fishing experiments, normal trawl catches, and catches in overlapping areas have been developed to make better use of all the available data when computing population indices (e.g. Yin and Benoît (2022), Yin and Benoît (2021)). The application of these methods to the Gulf-wide population indices could be undertaken. As noted above, a vessel change is taking place in the northern Gulf survey, and a vessel and gear change is taking place in the southern Gulf survey, so the development of an integrative approach to analysing the trawl survey data is further justified.

Because of their slow growth and the small size of their otoliths, ageing of NAFO 4RST Witch Flounder by visual examination of whole otoliths has proven to be difficult. A number of otolith preparation methods are being investigated to provide ageing information for this stock. Ultimately, the availability of ageing data would allow the computation of catch-at-age matrices for fish landings as well as survey catches, and this information could be used in an age-structured population model. Additionally, having detailed age information would allow an examination of whether changes in growth patterns have occurred over time for this stock.

A length-based model could also be explored for this stock since length frequencies are available from a number of sources. This approach has been used for other stocks where ageing is difficult or impossible, and allows the explicit analysis of lengths instead of relying on length as a proxy for age.

8. CONCLUSIONS

Witch Flounder is an unproductive species. Growth is very slow and maturation is at a late age. In the 1974 to 1981 period, the mean length at an age of 12 years is 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. Species with such low productivity are particularly vulnerable to overexploitation. An apparent shift towards earlier maturation in the NAFO Divisions 4RST stock in the 2000s suggests that this stock experienced unusually high adult mortality until the TAC was reduced in 2012 and 2013. The stock has been rebuilding since and is showing signs of recovery, the biomass of the spawning component of the population is on an increasing trend and there are signs of renewed recruitment to the population.

Commercial (30+ cm) biomass of 4RST Witch Flounder declined sharply in the early 1990s. There appeared to be some recovery in biomass following a reduction in landings to levels of 300 to 500 t. However, this partial recovery ceased and eroded following an increase in landings to the 700 t to 900 t level in the early 2000s. Thus, the stock appeared to no longer be able to support landings of only 700 t to 900 t even though annual landings averaged over 3,500 t in the 1960s and 1970s. The population model estimates put the stock well below the LRP for this period, meaning that the productivity of the stock was impaired at these low levels of biomass. Current biomass estimates indicate that the stock is now above the LRP. Under current productivity conditions and harvest levels (below the TAC for the last few years), the stock appears on an increasing trend. Model predictions suggest that the stock can sustain harvest levels above the current TAC without impairing its recovery trend. Regular updates to the proposed stock status indicator is essential to ensure that the stock continues its predicted recovery and to ensure it moves out of the cautious zone and above the USR.

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10. TABLES

Table 1. Annual landings (t) of Witch Flounder in NAFO Divisions 4RST by gear type for the period 1960 to 2021. OTB=otter trawl, OTB1=side otter trawl, OTB2=stern otter trawl, SNU=seine, GNS=gillnet, LLS=longline. Total allowable catch (TAC) is also shown. NA indicates that no TAC was defined for years prior to 1977.

Year	OTB	OTB1	OTB2	SNU	GNS	LLS	Other	Total	TAC
1960	1,912	0	0	1,309	0	72	45	3,338	NA
1961	1,428	0	0	1,907	7	19	135	3,496	NA
1962	1,342	0	0	2,012	0	28	5	3,387	NA
1963	1,561	0	0	2,612	37	25	15	4,250	NA
1964	1,377	0	0	1,657	0	86	230	3,350	NA
1965	1,137	0	0	2,389	1	67	14	3,608	NA
1966	0	1,620	39	1,845	93	5	110	3,712	NA
1967	1	964	33	1,647	36	23	10	2,714	NA
1968	0	1,227	102	1,995	46	13	7	3,390	NA
1969	3	1,286	294	3,179	0	1	0	4,763	NA
1970	12	1,203	504	3,078	8	0	0	4,805	NA
1971	17	1,108	183	2,352	11	137	13	3,821	NA
1972	30	968	329	636	2	7	29	2,001	NA
1973	68	613	56	1,330	39	12	106	2,224	NA
1974	0	707	946	1,569	15	0	10	3,247	NA
1975	82	771	371	1,449	25	4	20	2,722	NA
1976	111	1,606	4,303	730	9	0	116	6,875	NA
1977	102	962	1,248	715	4	0	8	3,039	3,500
1978	3	616	2,767	938	69	3	114	4,510	3,500
1979	62	1,065	1,970	1,309	120	14	21	4,561	5,000
1980	106	548	1,618	1,100	98	30	27	3,527	5,000
1981	108	446	267	1,032	24	33	2	1,912	5,000
1982	93	105	122	934	24	4	0	1,282	3,500
1983	137	116	52	829	27	10	6	1,177	3,500
1984	75	110	314	536	51	19	2	1,107	3,500
1985	27	89	161	1,127	28	7	221	1,660	3,500
1986	49	63	79	1,216	6	2	408	1,823	3,500
1987	58	157	212	1,671	7	0	504	2,609	3,500
1988	56	177	177	1,835	34	1	250	2,530	3,500
1989	45	199	358	1,698	47	0	0	2,347	3,500
1990	12	120	236	873	16	8	7	1,272	3,500
1991	8	5	173	766	36	1	4	993	3,500
1992	11	3	129	825	16	2	3	989	3,500
1993	1	0	95	690	17	0	94	897	3,500
1994	0	0	27	387	5	0	26	445	1,000
1995	0	0	20	302	6	0	0	328	1,000
1996	0	1	12	479	0	0	1	493	1,000
1997	0	0	73	494	3	0	0	570	1,000
1998	0	0	48	816	1	0	0	865	800
1999	0	0	14	713	3	0	0	730	800

Year	OTB	OTB1	OTB2	SNU	GNS	LLS	Other	Total	TAC
2000	0	0	81	914	1	0	0	996	1,000
2001	0	0	111	705	0	0	0	816	1,000
2002	0	0	176	847	1	0	0	1,024	1,000
2003	0	0	36	622	0	0	0	658	1,000
2004	0	0	63	671	0	0	0	734	1,000
2005	0	3	100	832	0	0	0	935	1,000
2006	0	0	87	856	0	0	0	943	1,000
2007	0	0	72	834	1	7	0	914	1,000
2008	0	3	56	676	1	0	0	736	1,000
2009	0	0	28	440	0	0	0	468	1,000
2010	0	0	11	217	0	0	0	228	1,000
2011	0	0	2	423	0	0	0	425	1,000
2012	0	0	2	322	0	0	0	324	500
2013	0	0	5	274	0	0	0	279	300
2014	0	0	4	291	1	0	0	296	300
2015	0	0	1	248	1	0	0	250	300
2016	0	0	3	283	2	0	0	288	300
2017	0	0	0	347	2	0	0	349	500
2018	0	0	1	299	0	0	0	300	500
2019	0	0	1	297	1	0	0	299	500
2020	0	0	11	182	0	0	0	193	500
2021	0	0	0	212	0	0	0	212	500
MEAN	164	276	298	1,042	16	10	42		1,850

Table 2. Number of active fishing vessels in the directed Witch Flounder fishery by year and NAFO division. It is possible for a fishing vessel to have landings from more than one NAFO division in a given year.

Year	4R	4S	4T	Total
1996	5	0	28	33
1997	9	0	33	42
1998	6	3	36	45
1999	7	3	30	40
2000	10	0	22	32
2001	8	0	21	29
2002	5	0	16	21
2003	6	0	23	29
2004	5	1	19	25
2005	5	0	16	21
2006	4	0	25	29
2007	6	0	20	26
2008	5	0	16	21
2009	6	0	17	23
2010	3	0	14	17
2011	3	0	8	11
2012	4	0	8	12
2013	3	0	8	11
2014	2	0	7	9
2015	2	0	6	8
2016	1	0	4	5
2017	1	0	6	7
2018	1	0	3	4
2019	2	0	2	4
2020	2	0	0	2

Table 3. Annual landings (fishing year, from April 1st of year y to March 31st of year y + 1, in tonnes) of Witch Flounder in NAFO Divisions 4RST by gear type for the period 1960 to 2021. OTB=otter trawl, OTB1=side otter trawl, OTB2=stern otter trawl, SNU=seine, GNS=gillnet, LLS=longline. Total allowable catch (TAC) is also shown. NA indicates that no TAC was defined for years prior to 1977.

Year	OTB	OTB1	OTB2	SNU	GNS	LLS	Other	Total	TAC
1960	1,912	0	0	1,309	0	72	45	3,338	NA
1961	1,428	0	0	1,907	7	19	135	3,496	NA
1962	1,342	0	0	2,012	0	28	5	3,387	NA
1963	1,561	0	0	2,612	37	25	15	4,250	NA
1964	1,377	0	0	1,657	0	86	230	3,350	NA
1965	1,137	0	0	2,389	1	67	14	3,608	NA
1966	0	1,620	39	1,845	93	5	110	3,712	NA
1967	1	964	33	1,647	36	23	10	2,714	NA
1968	0	1,227	102	1,995	46	13	7	3,390	NA
1969	3	1,286	294	3,179	0	1	0	4,763	NA
1970	12	1,203	504	3,078	8	0	0	4,805	NA
1971	17	1,108	183	2,352	11	137	13	3,821	NA
1972	30	968	329	636	2	7	29	2,001	NA
1973	68	613	56	1,330	39	12	106	2,224	NA
1974	0	707	946	1,569	15	0	10	3,247	NA
1975	82	771	371	1,449	25	4	20	2,722	NA
1976	111	1,606	4,303	730	9	0	116	6,875	NA
1977	102	962	1,248	715	4	0	8	3,039	3,500
1978	3	616	2,767	938	69	3	114	4,510	3,500
1979	62	1,065	1,970	1,309	120	14	21	4,561	5,000
1980	106	548	1,618	1,100	98	30	27	3,527	5,000
1981	108	446	267	1,032	24	33	2	1,912	5,000
1982	93	105	122	934	24	4	0	1,282	3,500
1983	137	116	52	829	27	10	6	1,177	3,500
1984	75	110	314	536	51	19	2	1,107	3,500
1985	27	89	161	1,127	28	7	221	1,660	3,500
1986	49	63	79	1,216	6	2	408	1,823	3,500
1987	58	157	212	1,671	7	0	504	2,609	3,500
1988	56	177	177	1,835	34	1	250	2,530	3,500
1989	45	199	358	1,698	47	0	0	2,347	3,500
1990	12	120	236	873	16	8	7	1,272	3,500
1991	8	5	173	766	36	1	4	993	3,500
1992	11	3	129	825	16	2	3	989	3,500
1993	1	0	95	690	17	0	94	897	3,500
1994	0	0	27	387	5	0	26	445	1,000
1995	0	0	20	302	6	0	0	328	1,000
1996	0	1	12	479	0	0	1	493	1,000
1997	0	0	73	494	3	0	0	570	1,000
1998	0	0	48	816	1	0	0	865	800
1999	0	0	14	713	3	0	0	730	800
2000	0	0	81	914	1	0	0	996	1,000
2001	0	0	111	705	0	0	0	816	1,000

Year	OTB	OTB1	OTB2	SNU	GNS	LLS	Other	Total	TAC
2002	0	0	176	847	1	0	0	1,024	1,000
2003	0	0	36	622	0	0	0	658	1,000
2004	0	0	63	671	0	0	0	734	1,000
2005	0	3	100	832	0	0	0	935	1,000
2006	0	0	87	856	0	0	0	943	1,000
2007	0	0	72	834	1	7	0	914	1,000
2008	0	3	56	676	1	0	0	736	1,000
2009	0	0	28	440	0	0	0	468	1,000
2010	0	0	11	217	0	0	0	228	1,000
2011	0	0	2	423	0	0	0	425	1,000
2012	0	0	2	322	0	0	0	324	500
2013	0	0	5	274	0	0	0	279	300
2014	0	0	4	291	1	0	0	296	300
2015	0	0	1	248	1	0	0	250	300
2016	0	0	3	283	2	0	0	288	300
2017	0	0	0	347	2	0	0	349	500
2018	0	0	1	299	0	0	0	300	500
2019	0	0	1	297	1	0	0	299	500
2020	0	0	11	182	0	0	0	193	500
2021	0	0	0	212	0	0	0	212	500
MEAN	164	276	298	1,042	16	10	42		1,850

*Table 4. Composition of landings in the directed Witch Flounder fishery. The yearly average of the proportion of landings by species is reported for years 1996 to 2020. The species are ordered from left to right in decreasing order of the overall average of the proportion in landings. "Wolffish" can be either Altantic Wolffish (*Anarhichas lupus*) or Spotted Wolffish (*Anarhichas minor*).*

Year	Witch Flounder	American Plaice	Atlantic Cod	Greenland Halibut	White Hake	Redfish	Atlantic Halibut	Wolffish	Monkfish
1996	0.657	0.310	0.043	0.075	0.011	0.063	0.028	0.006	0.010
1997	0.620	0.308	0.093	0.053	0.021	0.006	0.055	0.003	0.006
1998	0.603	0.262	0.087	0.091	0.038	0.018	0.029	0.003	0.006
1999	0.626	0.184	0.119	0.099	0.052	0.036	0.034	0.026	0.007
2000	0.675	0.202	0.135	0.031	0.032	0.002	0.008	0.009	0.011
2001	0.565	0.250	0.206	0.025	0.016	0.021	0.013	0.009	0.005
2002	0.761	0.158	0.116	0.017	0.019	0.029	0.021	0.012	0.010
2003	0.786	0.122	0.082	0.030	0.015	0.018	0.007	0.006	0.005
2004	0.756	0.162	0.111	0.020	0.021	0.023	0.006	0.004	0.004
2005	0.821	0.087	0.089	0.010	0.028	0.002	0.007	0.004	0.003
2006	0.780	0.132	0.090	0.019	0.024	0.006	0.010	0.006	0.003
2007	0.747	0.155	0.098	0.018	0.021	0.043	0.013	0.006	0.005
2008	0.811	0.094	0.088	0.009	0.024	0.019	0.008	0.008	0.001
2009	0.754	0.131	0.114	0.014	0.031	0.006	0.009	0.011	0.008
2010	0.718	0.194	0.089	0.012	0.017	0.049	0.008	0.000	0.001
2011	0.841	0.093	0.061	0.013	0.021	0.003	0.008	0.000	0.003
2012	0.833	0.084	0.065	0.010	0.018	0.062	0.007	0.002	0.003
2013	0.868	0.060	0.052	0.003	0.043	0.001	0.012	0.001	0.009
2014	0.807	0.082	0.103	0.003	0.045	0.001	0.005	0.001	0.003
2015	0.854	0.054	0.074	0.008	0.029	0.016	0.016	0.000	0.005
2016	0.894	0.043	0.046	0.001	0.033	0.001	0.004	0.000	0.004
2017	0.901	0.032	0.043	0.002	0.041	0.014	0.010	0.000	0.002
2018	0.922	0.046	0.028	0.002	0.018	0.009	0.009	0.000	0.004
2019	0.928	0.032	0.022	0.003	0.022	0.041	0.008	0.000	0.006
2020	0.975	0.009	0.006	0.004	0.001	0.056	0.000	0.000	0.003
mean	0.780	0.131	0.082	0.023	0.026	0.022	0.013	0.005	0.005

Table 5. Estimated von Bertalanffy growth parameters for Witch Flounder from the southern Gulf of St. Lawrence, 1974 to 1981.

Parameter	Female	Male
L_{inf} (cm)	68.200	53.500
k (unitless)	-0.056	-0.098
t_0 (year)	-4.153	-2.117

Table 6. Fitted parameter values and model-derived estimates of relative stock status using reference points for NAFO Divisions 4RST Witch Flounder.

Parameter / quantity	2012 estimate	2016 estimate	2021 estimate
r	0.149	0.145	0.142 (0.097-0.193)
K	53.500	52.400	53.498 (34.128-138.752)
B_{msy}	26.700	26.200	26.749 (17.064-69.376)
C_{msy}	2.000	2.000	1.961 (1.242-4.151)
F_{msy}	0.072	0.072	0.071 (0.049-0.097)
LRP	10.700	10.500	10.700 (6.826-27.75)
USR	21.400	21.000	21.399 (13.651-55.501)
B_t	5.000	13.300	17.768 (12.057-26.452)
B_t/LRP	0.450	1.200	1.613 (0.607-2.94)
B_t/USR	NA	NA	0.806 (0.304-1.47)
$P(B_t \geq LRP)$	0.070	0.620	0.77
$P(B_t \geq USR)$	NA	NA	0.331

Table 7. Annual probabilities that the estimated biomass of NAFO Divisions 4RST 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 2022 to 2026. The four levels of catches considered are 0 t, 500 t, 1,000 t and 1,500 t. The projected surplus production (median values in tonnes; 80% credibility interval) and the percentages (median; 80% credibility interval) of the projected surplus production of biomass which would be extracted annually under each annual catch option are also presented.

Measure	**Year**	**0 t**	**500 t**	**1,000 t**	**1,500 t**
B_{year} < *LRP*	2021	23%	23%	23%	23%
	2022	21%	22%	23%	24%
	2023	18%	20%	22%	25%
	2024	16%	19%	22%	27%
	2025	15%	18%	22%	28%
	2026	13%	16%	22%	29%
B_{year} ≥ *USR*	2021	34%	34%	34%	34%
	2022	40%	38%	36%	34%
	2023	46%	42%	38%	35%
	2024	51%	46%	41%	35%
	2025	56%	49%	43%	36%
	2026	60%	52%	44%	37%
Surplus production	2021	1,678.2 (839.9-2,956.2)	1,678.2 (839.9-2,956.2)	1,678.2 (839.9-2,956.2)	1,678.2 (839.9-2,956.2)
	2022	1,745.9 (826.3-3,180.9)	1,726.2 (832.2-3,111.3)	1,705.0 (836.6-3,040.6)	1,682.1 (839.5-2,968.0)
	2023	1,801.3 (796.2-3,407.4)	1,769.2 (816.6-3,269.5)	1,730.1 (831.2-3,124.5)	1,688.6 (838.9-2,988.0)
	2024	1,842.5 (747.6-3,633.9)	1,807.6 (790.8-3,437.4)	1,756.8 (822.2-3,221.3)	1,696.8 (837.8-3,013.9)
	2025	1,864.9 (690.8-3,824.7)	1,831.8 (764.2-3,566.3)	1,772.2 (815.1-3,281.5)	1,689.7 (838.7-2,991.6)
	2026	1,875.0 (609.2-4,035.3)	1,853.6 (725.1-3,715.8)	1,792.7 (802.6-3,368.4)	1,689.5 (838.8-2,991.1)
Percent of surplus production removed	2021	12.6% (7.2-25.2)	12.6% (7.2-25.2)	12.6% (7.2-25.2)	12.6% (7.2-25.2)
	2022	0% (0-0)	29% (16.1-60.1)	58.6% (32.9-119.5)	89.2% (50.5-178.7)
	2023	0% (0-0)	28.3% (15.3-61.2)	57.8% (32-120.3)	88.8% (50.2-178.8)
	2024	0% (0-0)	27.7% (14.5-63.2)	56.9% (31-121.6)	88.4% (49.8-179)
	2025	0% (0-0)	27.3% (14-65.4)	56.4% (30.5-122.7)	88.8% (50.1-178.8)
	2026	0% (0-0)	27% (13.5-69)	55.8% (29.7-124.6)	88.8% (50.1-178.8)

11. FIGURES

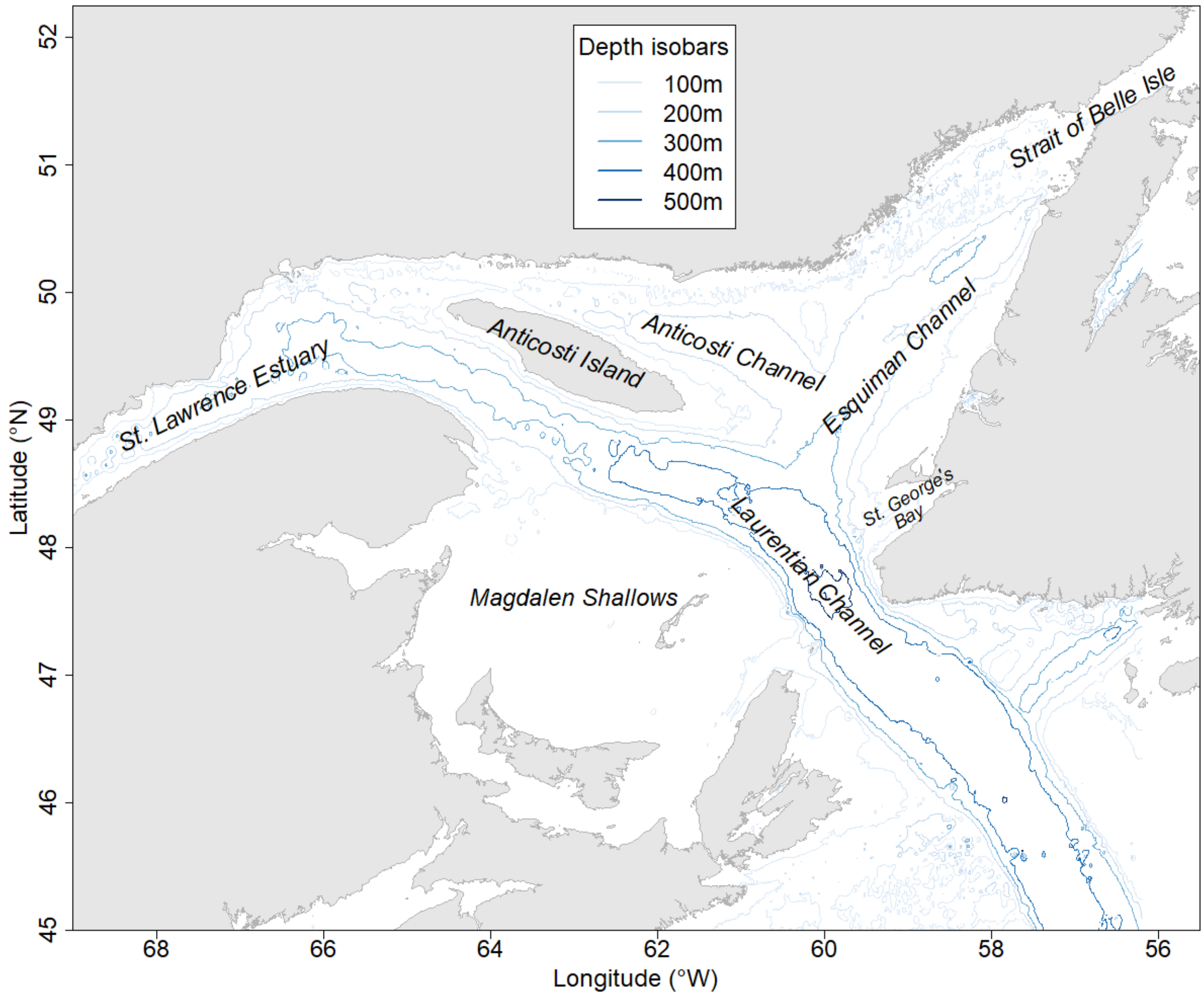

Figure 1. Map of the Gulf of St. Lawrence region showing the bathymetric features mentioned in the document text. Isobaths are drawn for depths down to 500 m by 100 m increments.

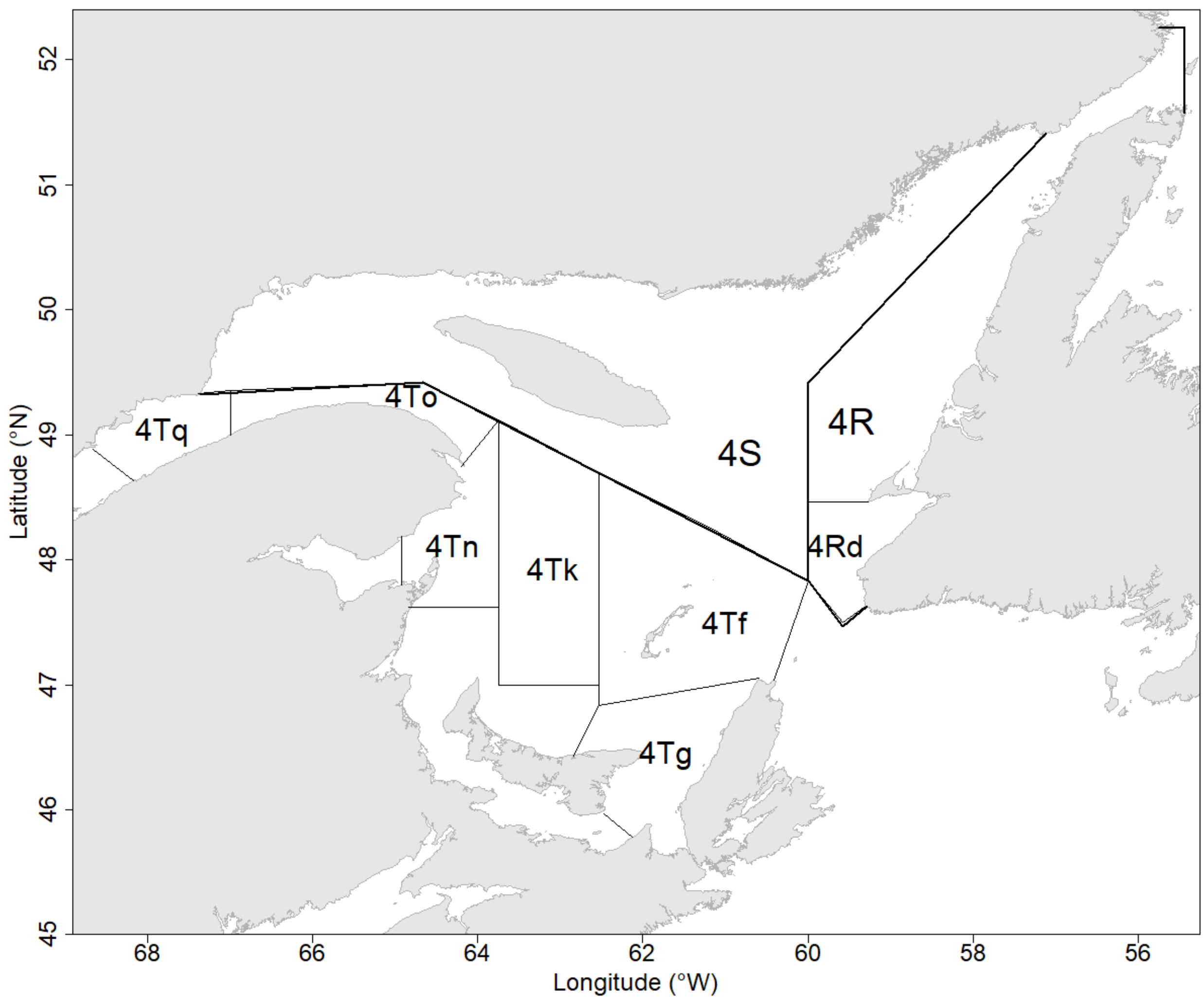

Figure 2. NAFO divisions in the Gulf of St. Lawrence. NAFO Divisions 4R, 4S and 4T are bordered by heavy solid lines. The NAFO unit areas where most Witch Flounder are caught in commercial fisheries are labelled in lower case.

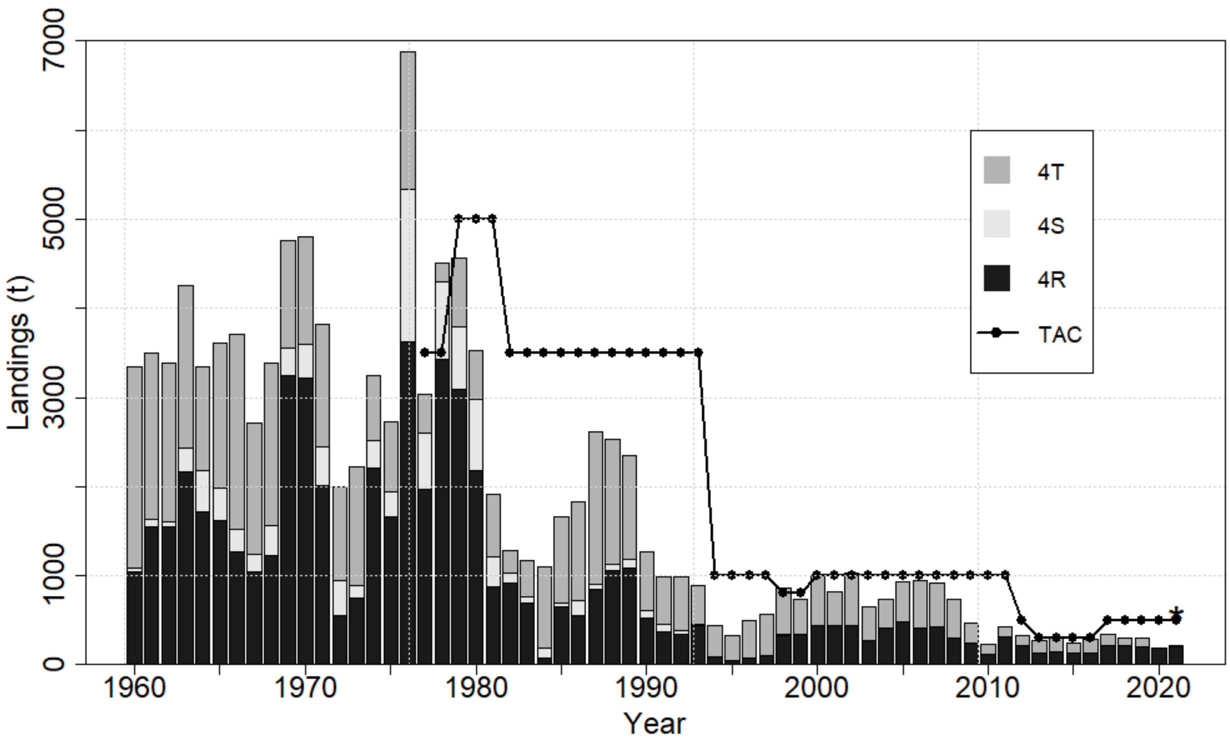

Figure 3. Landings and TAC of Witch Flounder in NAFO Divisions 4RST, 1960 to 2021. The asterisk indicates that landings for 2021 were obtained from Fisheries and Aquaculture Management quota monitoring systems and are preliminary.

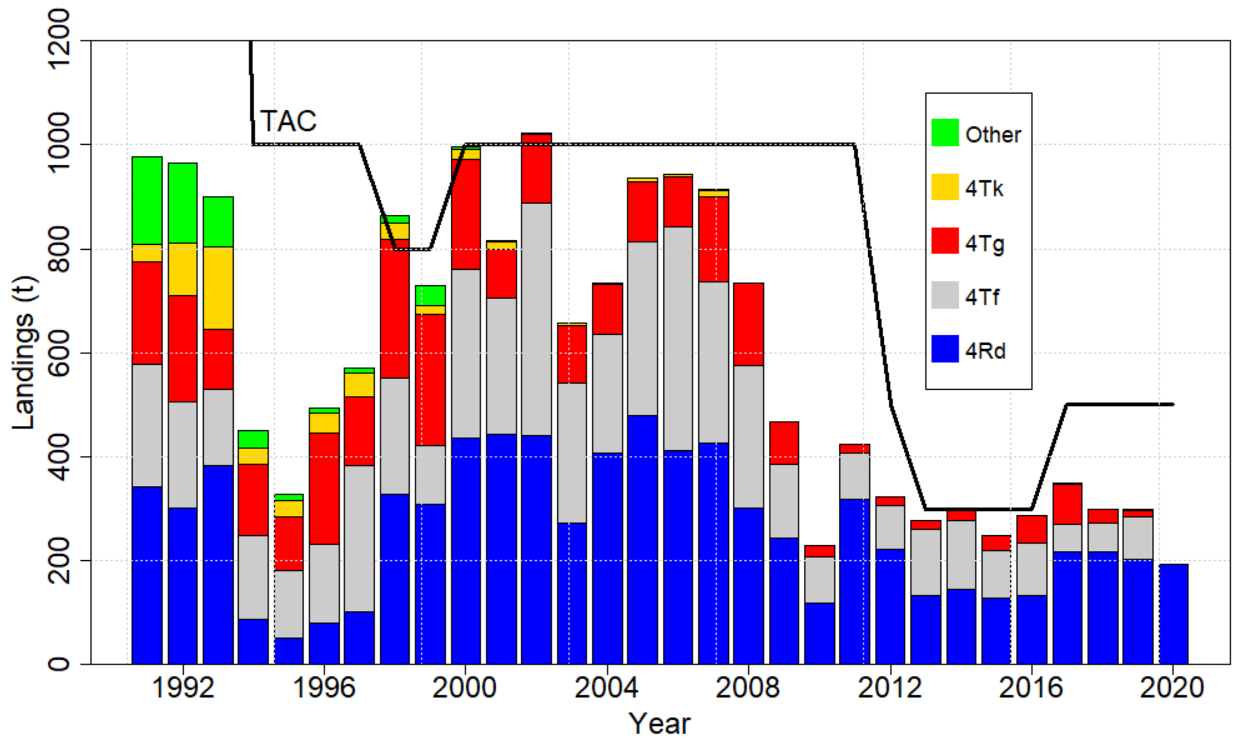

Figure 4. Landings and TAC of Witch Flounder in NAFO Divisions 4RST by NAFO unit area, 1991 to 2020. These landings data come from the Zonal Interchange File Format (ZIFF) and are only available to 2020. Note that this is a zoomed-in version of Figure 3, which is why the TAC prior to 1994 falls outside the figure.

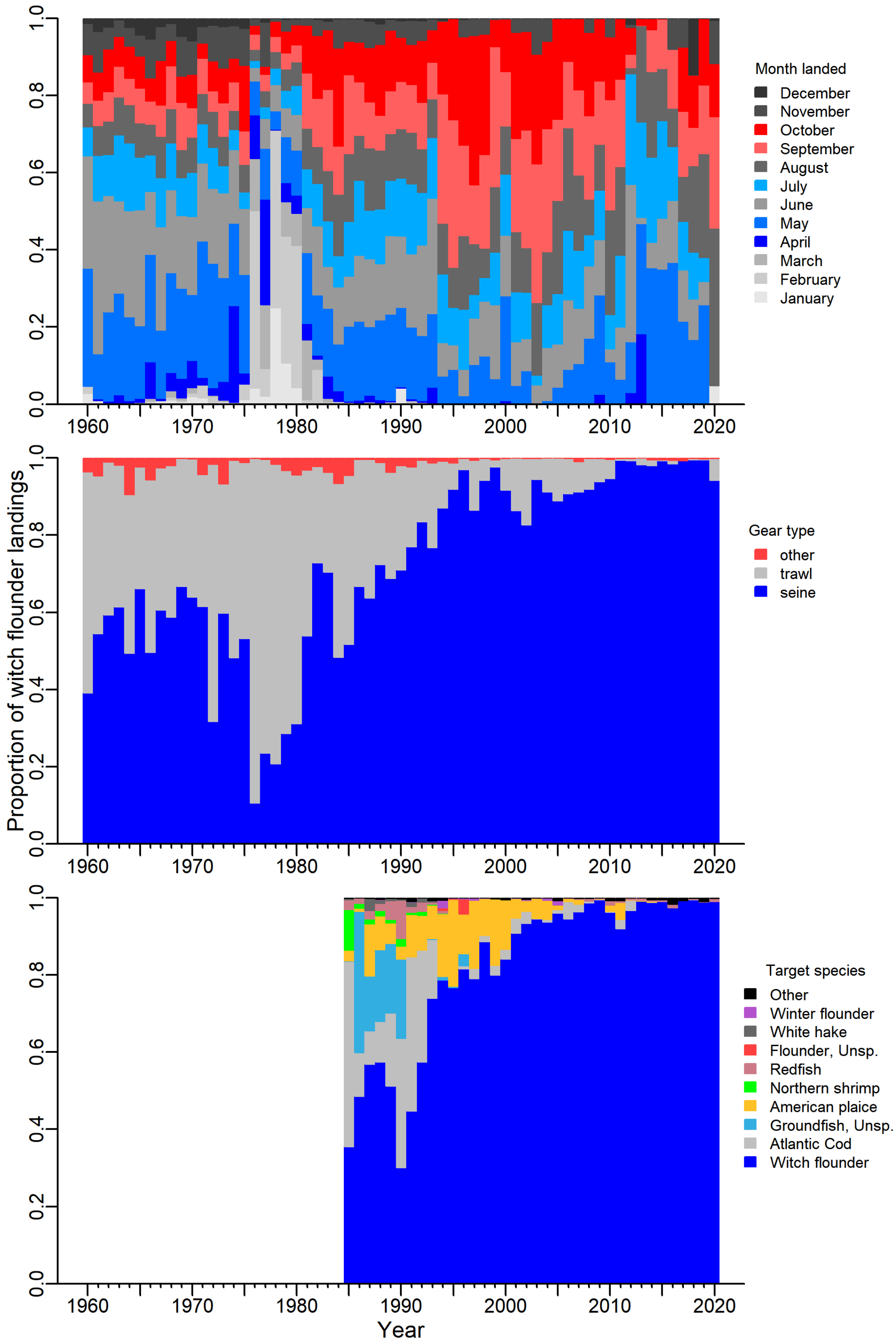

Figure 5. Proportion of annual Witch Flounder landings in NAFO Divisions 4RST by month (top panel), by type of fishing gear (middle panel) and by target fishing species (lower panel), 1960 to 2020. Data prior to 1985 come from the Northwest Atlantic Fisheries Organization (NAFO) catch statistics and did not include information about target species.

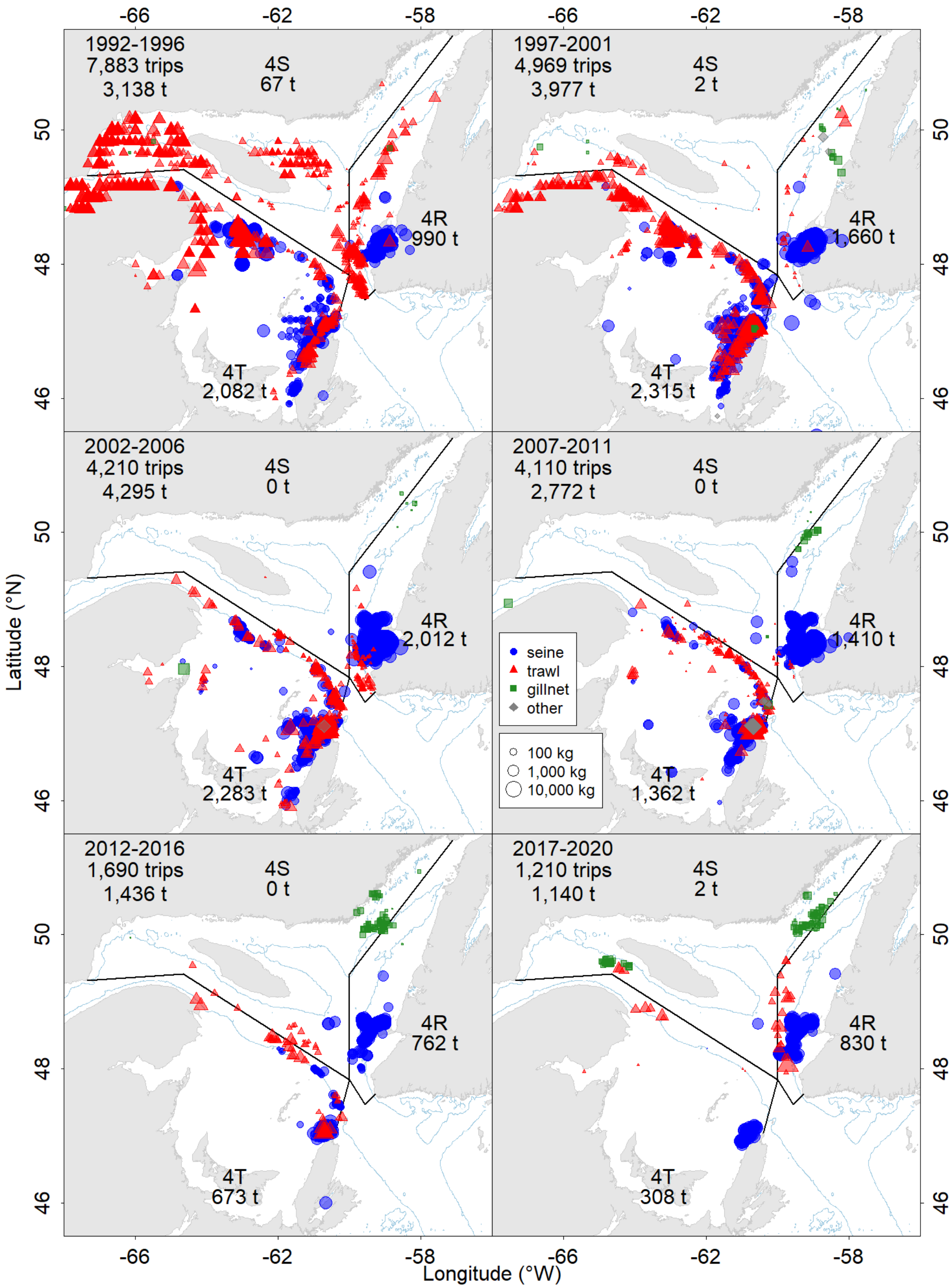

Figure 6. Geographic location of catches of Witch Flounder by gear type in NAFO Divisions 4RST, 1992 to 2020. Data for years 1992 to 2016 are presented for blocks of five years and data for the four years from 2017 to 2020 are presented in the bottom-right own panel. In each panel, the number of fishing trips and the total catch for NAFO Divisions 4RST are presented, and the breakdown by each NAFO division appears on each map. The 200 m isobath is drawn in light blue.

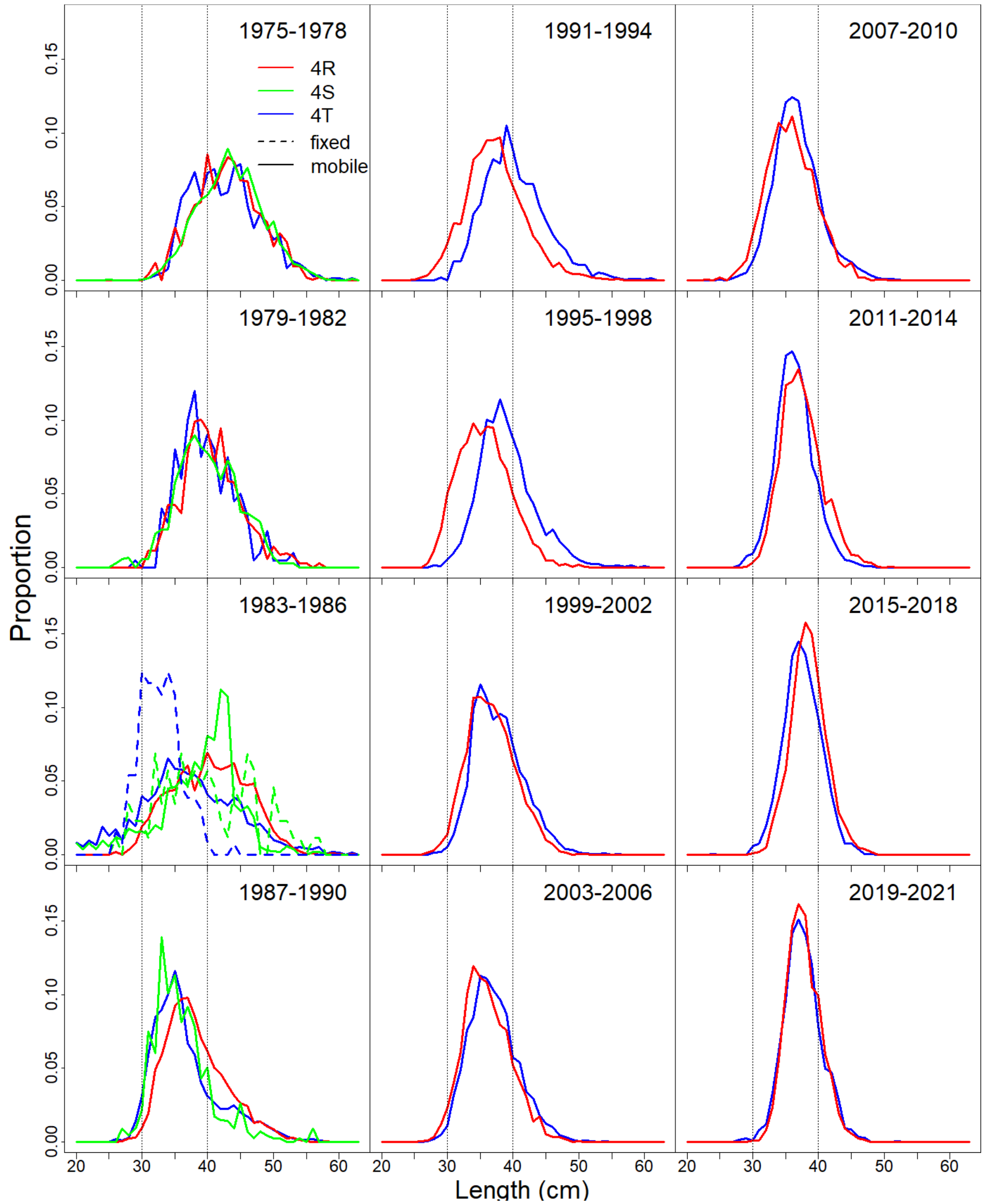

Figure 7. Average length frequencies (proportion) of Witch Flounder caught by gear type in NAFO Divisions 4RST in twelve four-year periods covering 1975 to 2021. Catches-at-length were weighted by the landings associated with each sample. The vertical dashed line at 30 cm represents the commercial length for Witch Flounder and the vertical dashed line at 40 cm is informally used to identify “large fish”. No commercial samples were available from NAFO Division 4R in 2012 and 2020, and from NAFO Division 4T in 2020 and 2021.

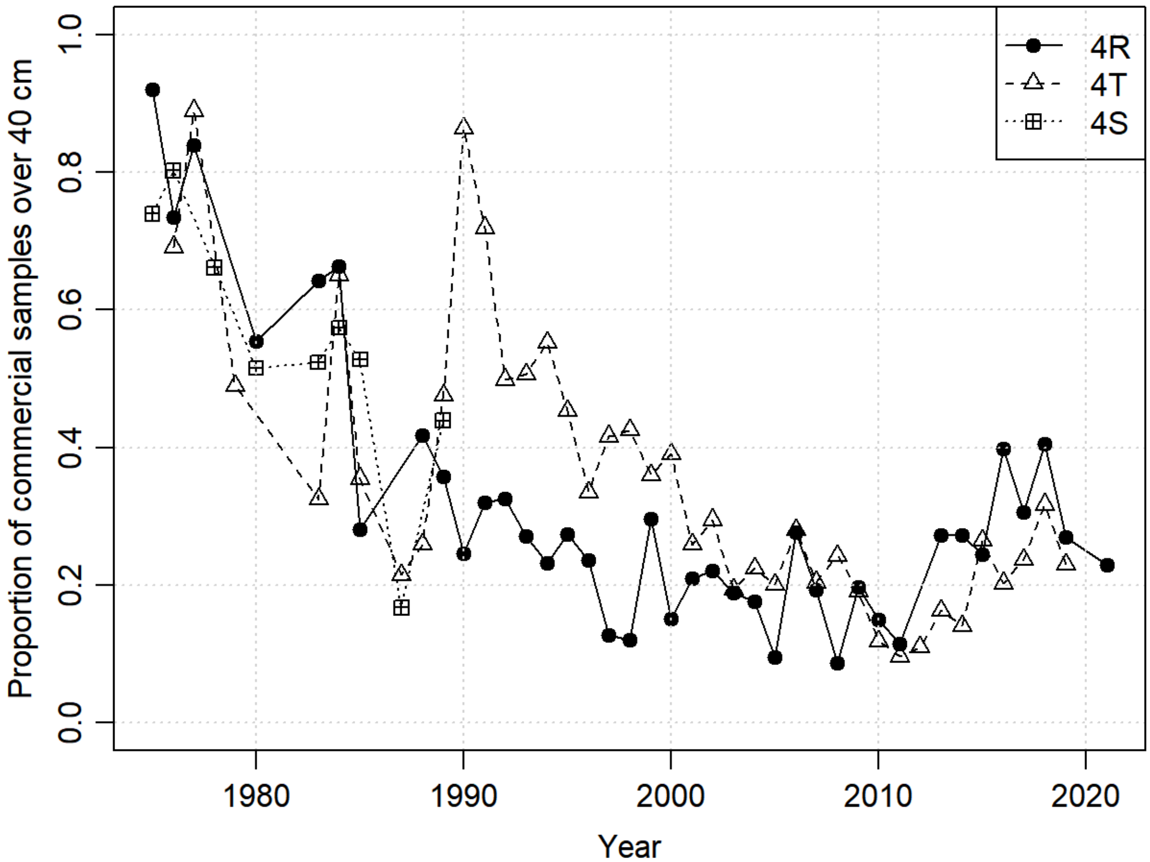

Figure 8. Proportion of fish from commercial samples that were over 40 cm. No commercial samples were available from NAFO Division 4R in 2012 and 2020, and from NAFO Division 4T in 2020 and 2021.

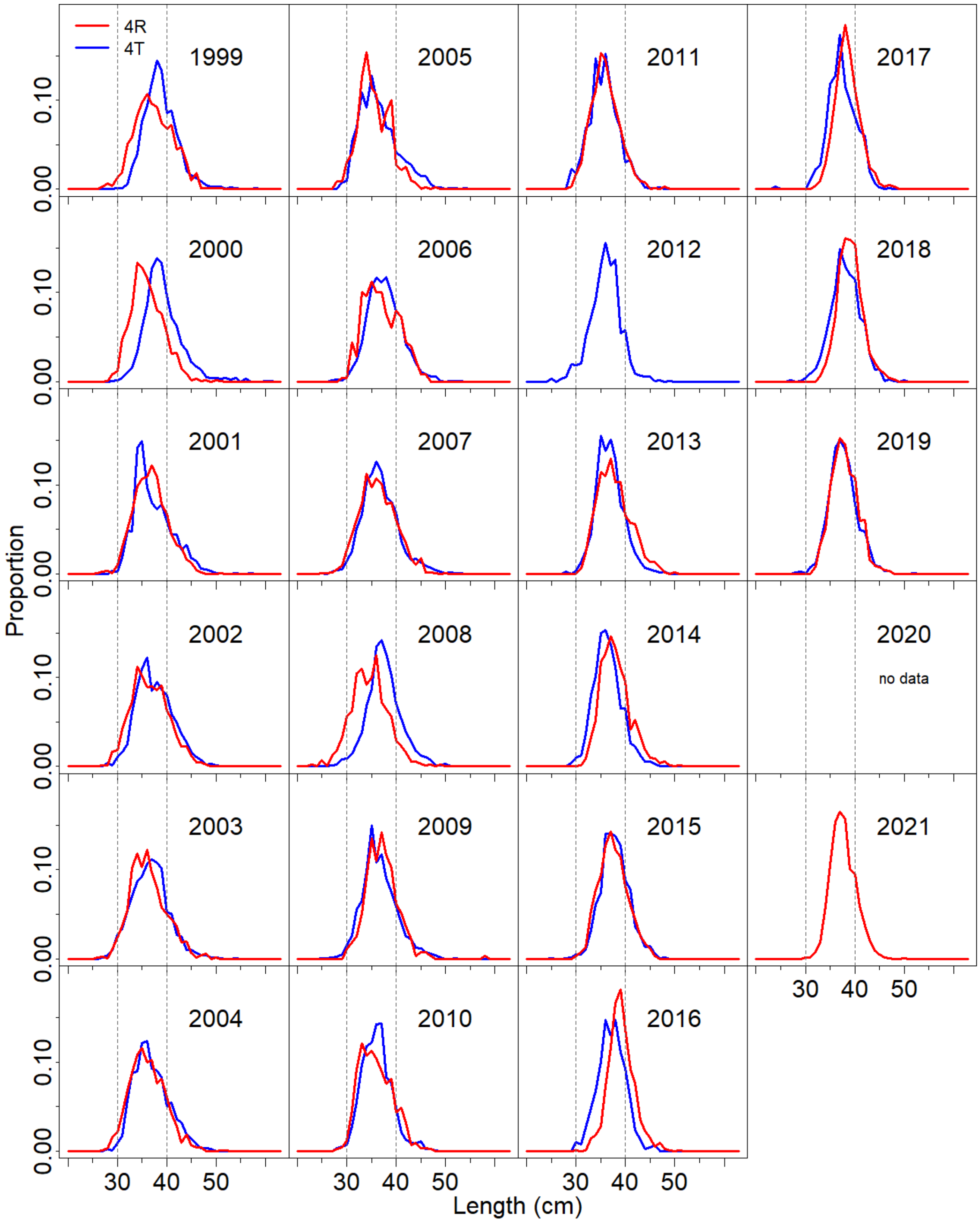

Figure 9. Yearly average length frequencies (proportion) of Witch Flounder caught by mobile gear and by NAFO Division in NAFO Divisions 4RST for the period 1999 to 2021. Catches-at-length were weighted by the landings associated with each sample. The vertical dashed line at 30 cm represents the commercial length for Witch Flounder and the vertical dashed line at 40 cm is informally used to identify “large fish”. No commercial samples were available from NAFO Division 4R in 2012 and 2020, and from NAFO Division 4T in 2020 and 2021.

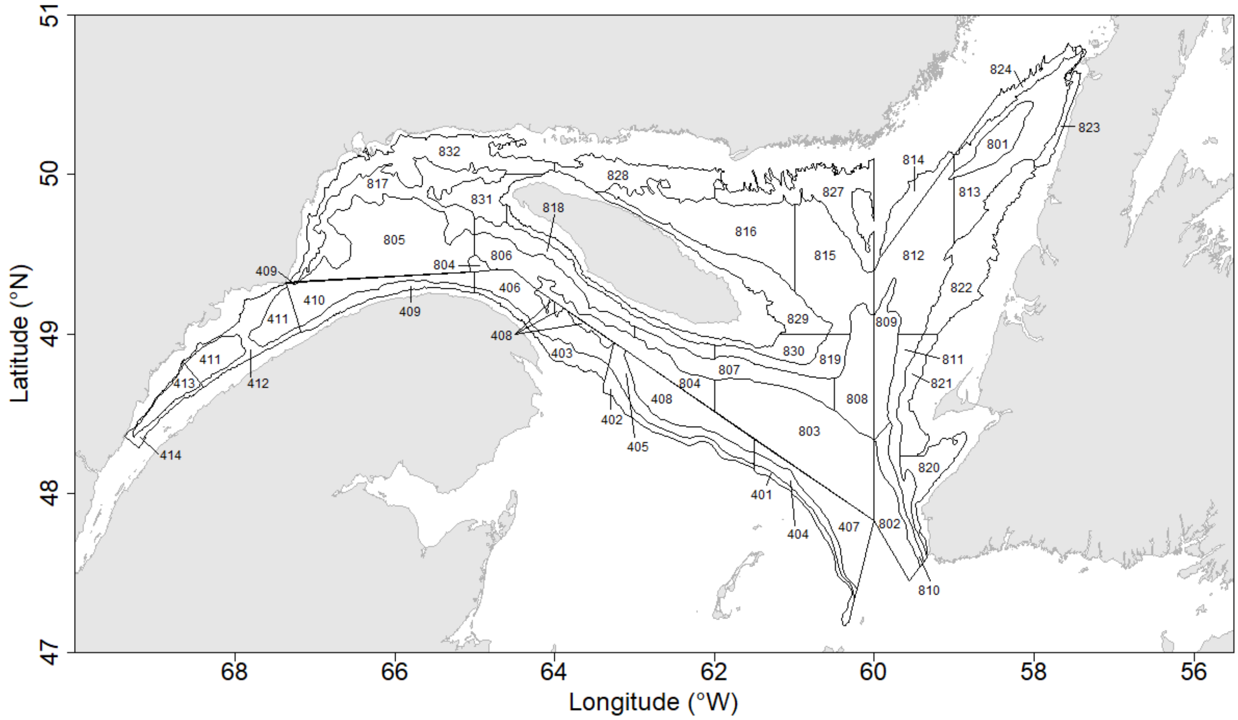

Figure 10. Stratum boundaries for the August bottom trawl survey of the northern Gulf of St. Lawrence. The strata appearing on the map are those used in the computation of the Gulf-wide RV index (strata 401 to 414, 801 to 824 and 827 to 832).

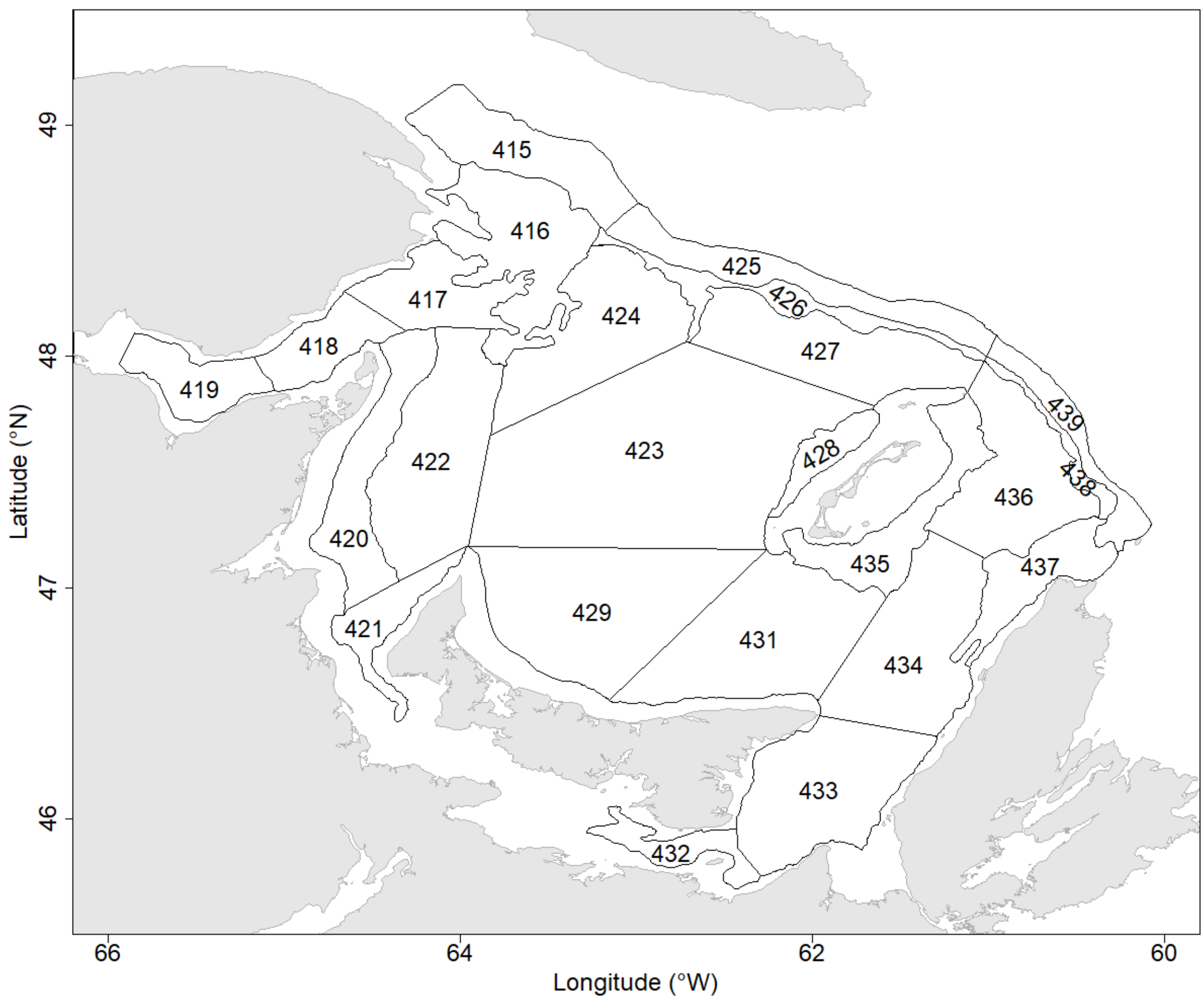

Figure 11. Stratum boundaries for the September bottom trawl survey of the southern Gulf of St. Lawrence. The strata appearing on the map are those used in the analyses (strata 415 to 429 and 431 to 439).

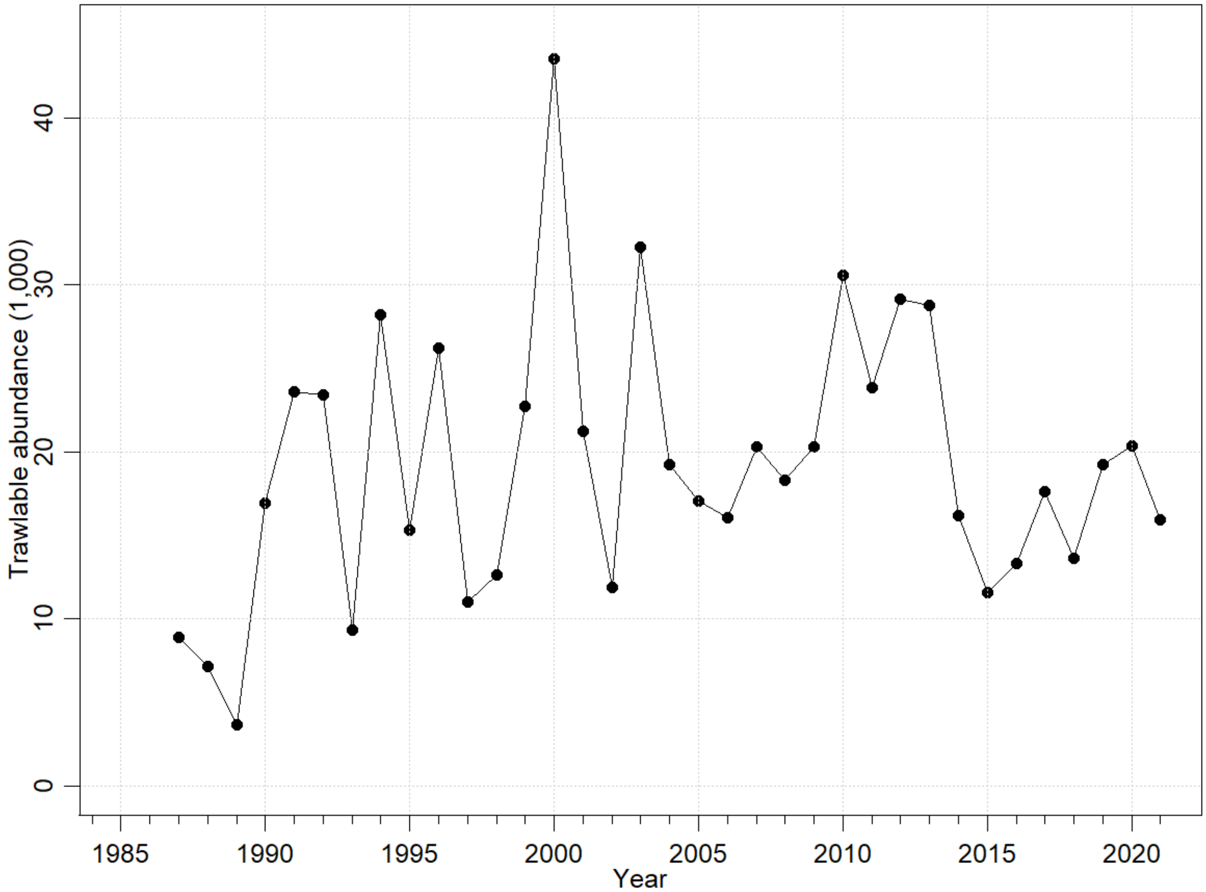

Figure 12. Combined recruitment index (trawlable abundance in thousands) of Witch Flounder < 30 cm length for the Gulf of St. Lawrence, 1987 to 2021.

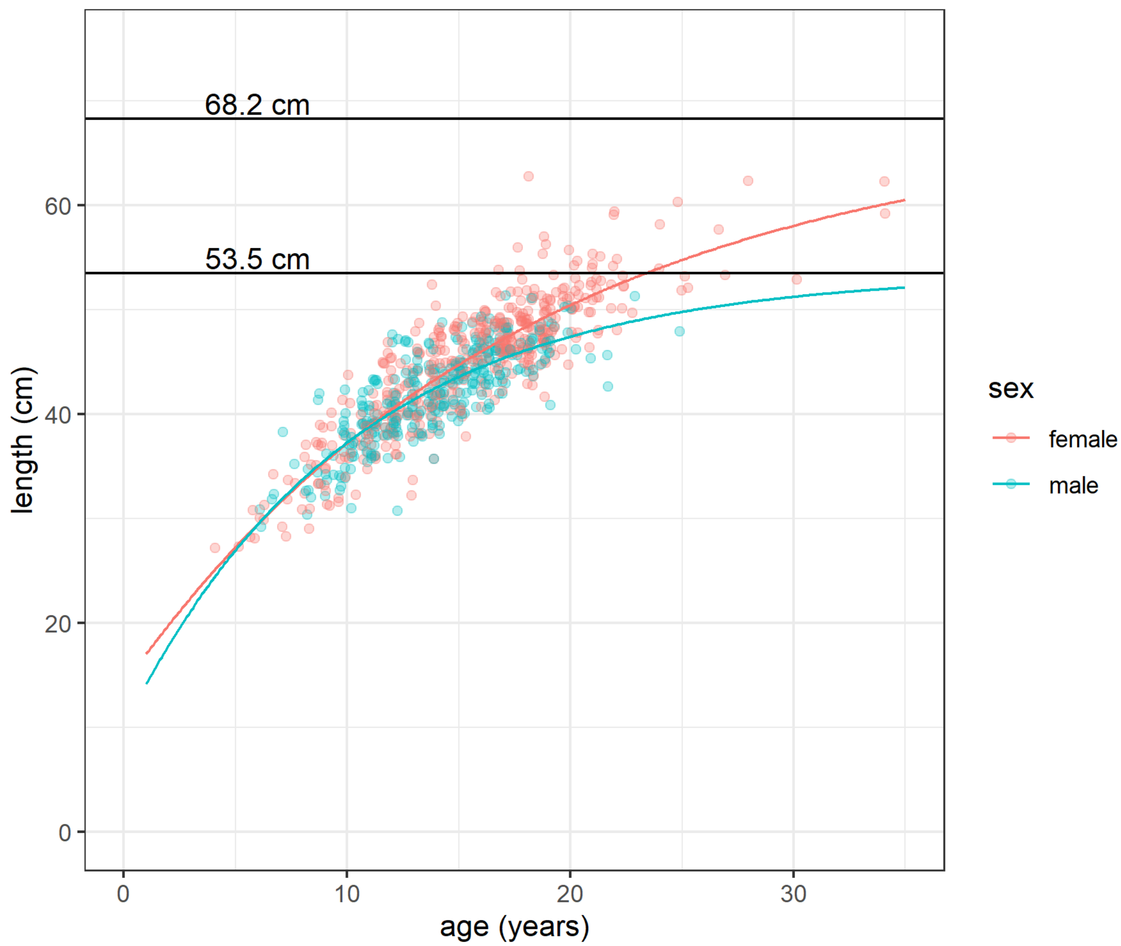

Figure 13. Von Bertallanfy estimates of growth of Witch Flounder by sex based on samples collected from the southern Gulf of St. Lawrence in September, 1974-1981. The values of L_{inf} are shown as horizontal lines for females (68.2 cm) and males (53.5 cm).

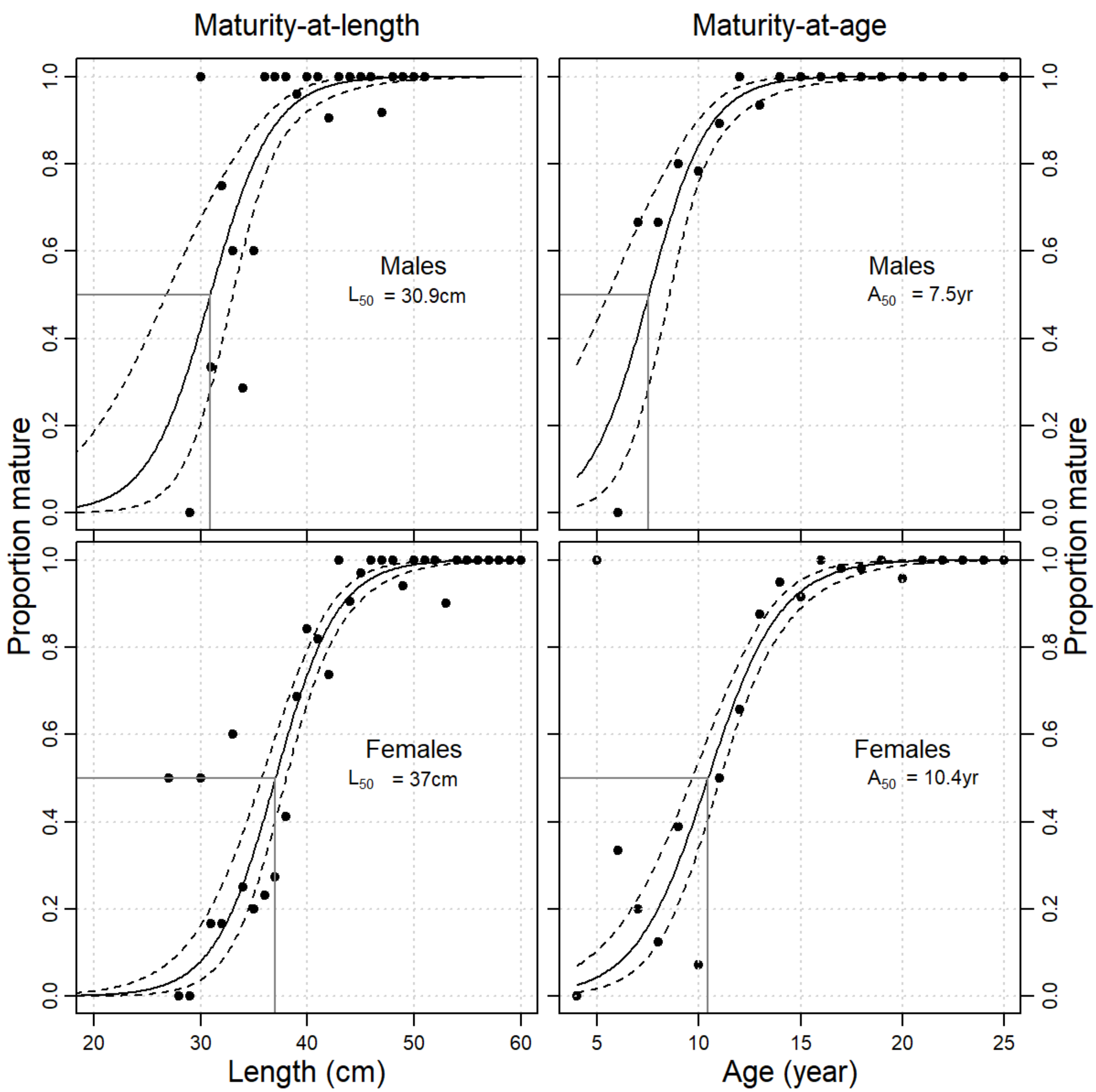

Figure 14. Maturity ogives by sex for aged Witch Flounder based on September survey data, 1974 to 1981. Circles are the observed proportions at length (left panels) or age (right panels) for females (top panels) and males (bottom panels). The solid lines show the fitted logistic regression models and the dashed lines show the 95% confidence intervals around the predictions. The predicted lengths and ages at 50% maturity (L_{50} and A_{50}) for males and females appear in each panel.

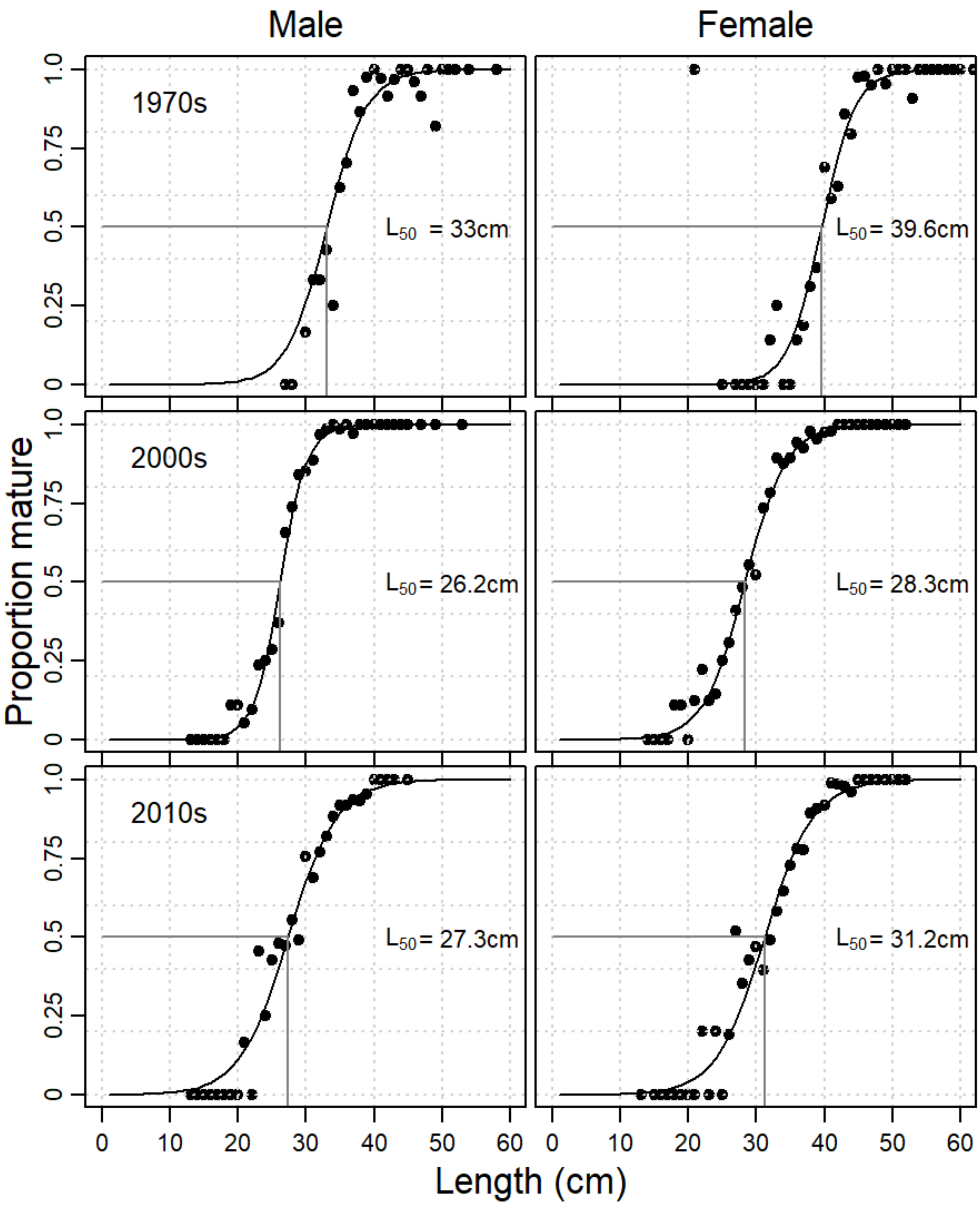

Figure 15. Maturity ogives by sex for Witch Flounder based on September survey data from the southern Gulf of St. Lawrence. The predicted length at 50% maturity is presented for males (left column) and females (right column) for the period 1970 to 1979 (1970s, top row), 2000 to 2009 (2000s, second row) and 2010 to 2019 (2010s, third row).

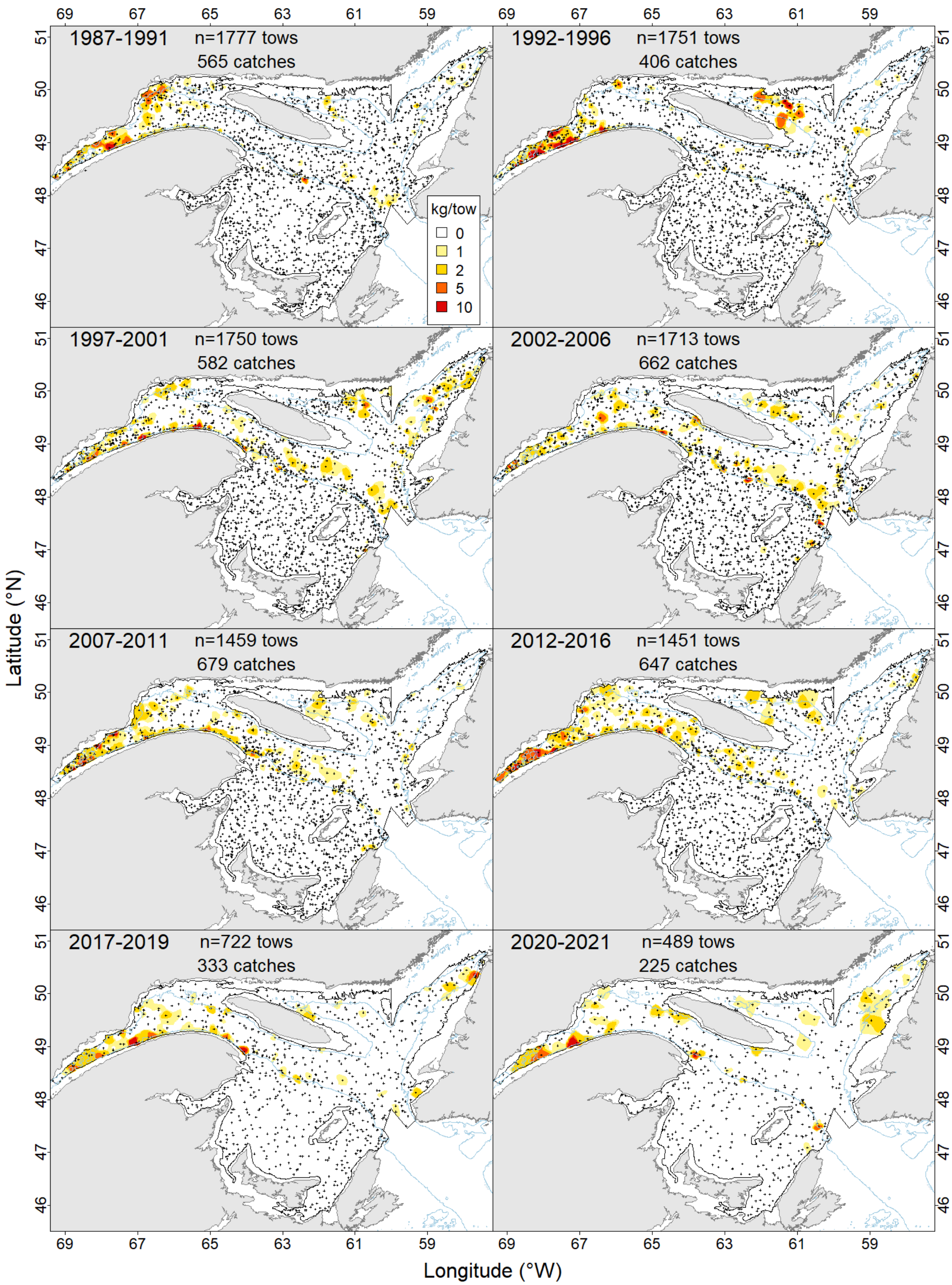

Figure 16. Distribution of biomass of Witch Flounder < 30 cm in length in the August survey of the northern Gulf of St. Lawrence and the September survey of the southern Gulf of St. Lawrence, 1987 to 2021. All catch data are normalised to a 1.75 nautical miles night tow on the Lady Hammond *using a Western IIA trawl (see Appendix A for details). Catches are displayed using Inverse Distance Weighted interpolation (IDW) and all set locations are identified by a small black cross. The 200 m isobath is drawn in light blue.*

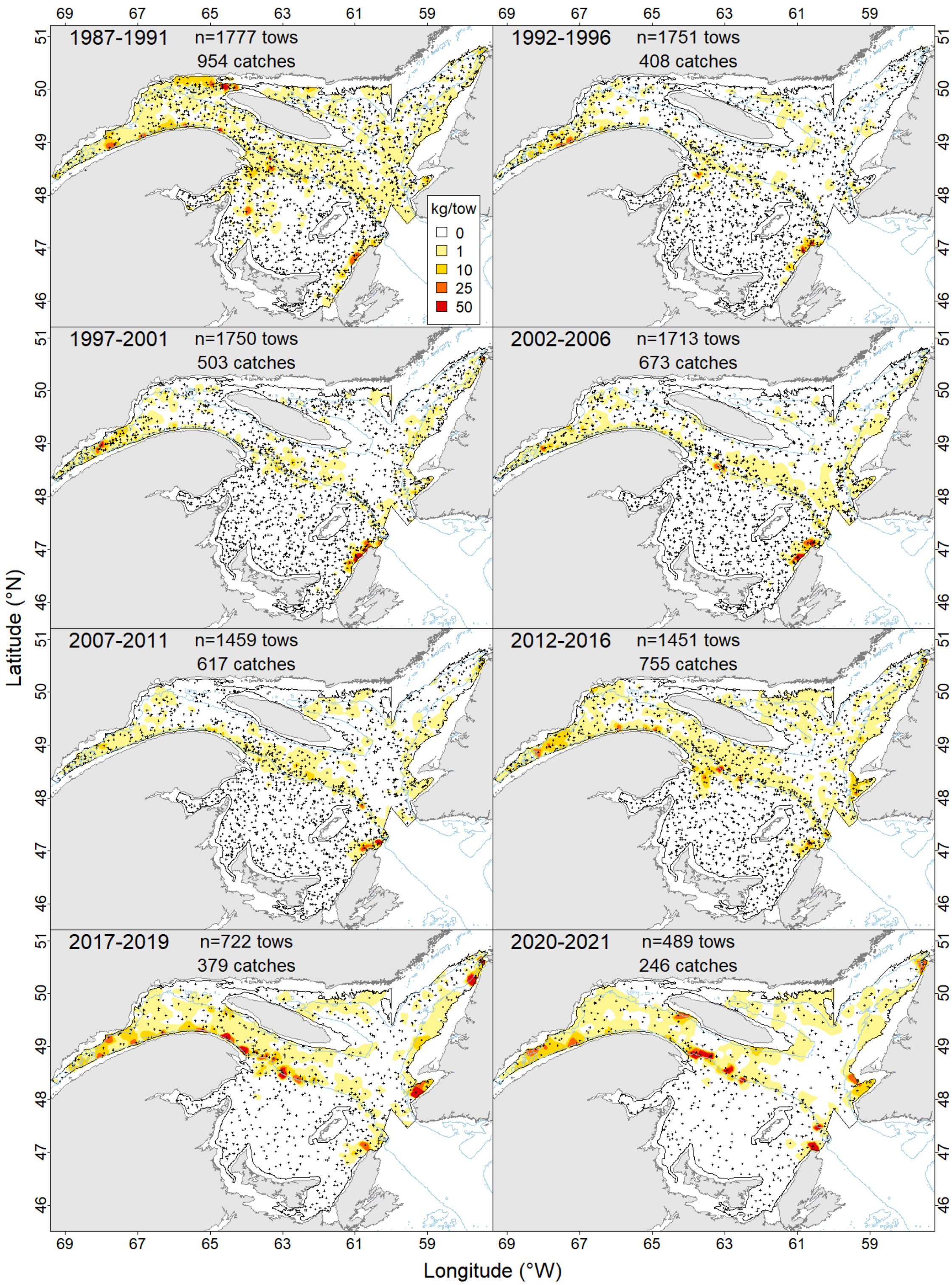

Figure 17. Distribution of biomass of Witch Flounder ≥ 30 cm in length in the August survey of the northern Gulf of St. Lawrence and the September survey of the southern Gulf of St. Lawrence, 1987 to 2021. All catch data are normalised to a 1.75 nautical miles night tow on the Lady Hammond *using a Western IIA trawl (see Appendix A for details). Catches are displayed using Inverse Distance Weighted interpolation (IDW) and all set locations are identified by a small black cross. The 200 m isobath is drawn in light blue.*

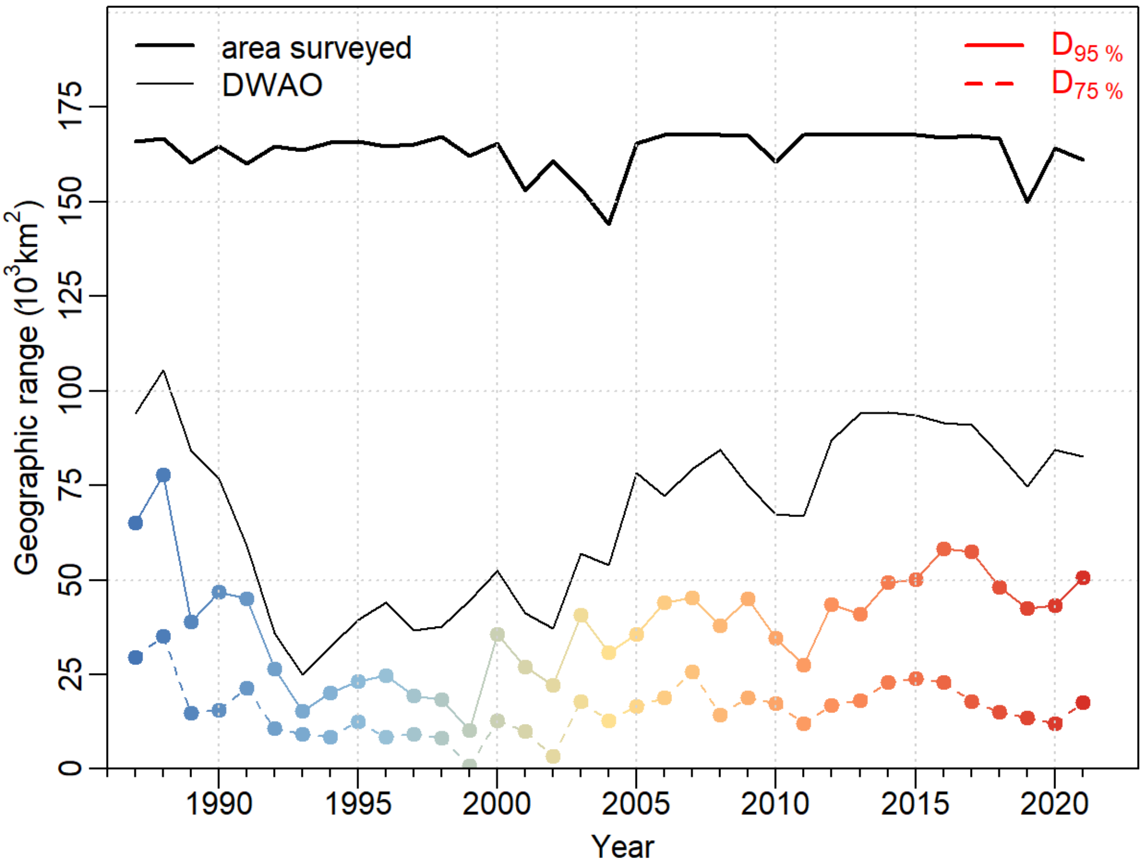

Figure 18. Distribution indices of Witch Flounder ≥ 30 cm in length in the August survey of the northern Gulf of St. Lawrence and the September survey of the southern Gulf of St. Lawrence, 1987 to 2021. All catch data are normalised to a 1.75 nautical miles night tow on the Lady Hammond *using a Western IIA trawl (see Appendix A for details). The area surveyed and the design-weighted area of occupancy (DWAO) are displayed as solid lines. The minimum distribution accounting for 75% ($D_{75\%}$, coloured dots and dashed line) and 95% ($D_{95\%}$, coloured dots and solid line) of the total biomass are also presented and are colour-coded from blue (earliest years) to red (latest years).*

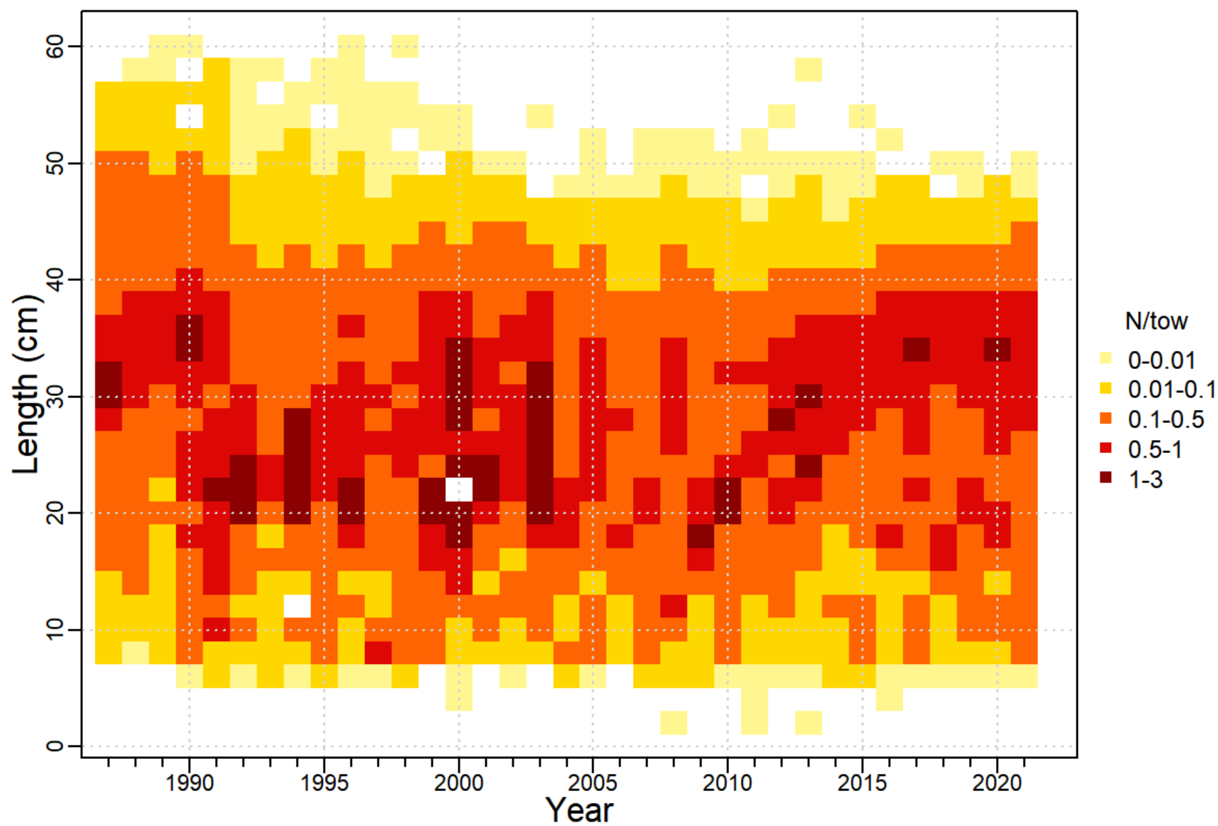

Figure 19. Length distributions (stratified numbers-at-length) of Witch Flounder caught in the August and September surveys of the Gulf of St. Lawrence, 1987 to 2021. Catches were adjusted to a night tow of 1.75 nm by the Lady Hammond *using a Western IIA trawl.*

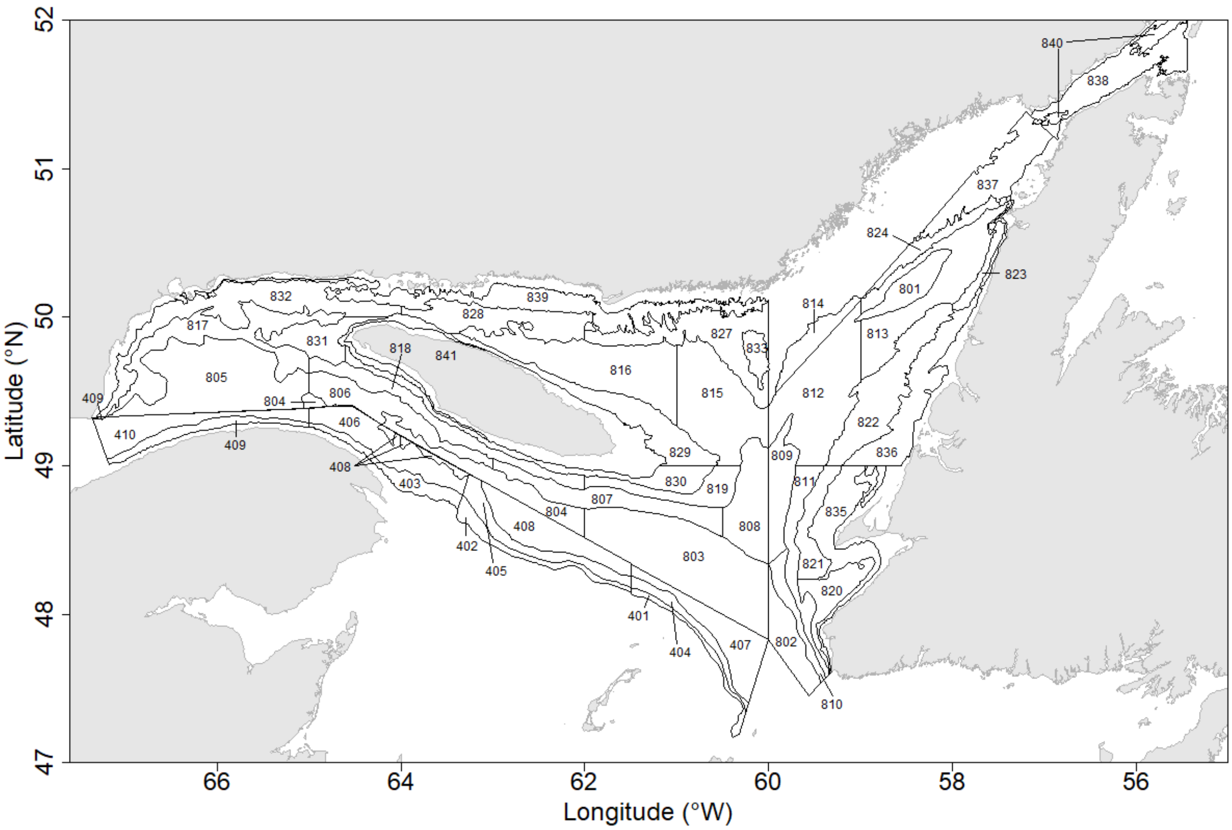

Figure 20. Stratum boundaries for the July mobile sentinel survey of the northern Gulf of St. Lawrence. The strata appearing on the map were those used in the computation of the Gulf-wide Sentinel index (strata 401 to 410, 801 to 824, 827 to 833 and 835 to 841).

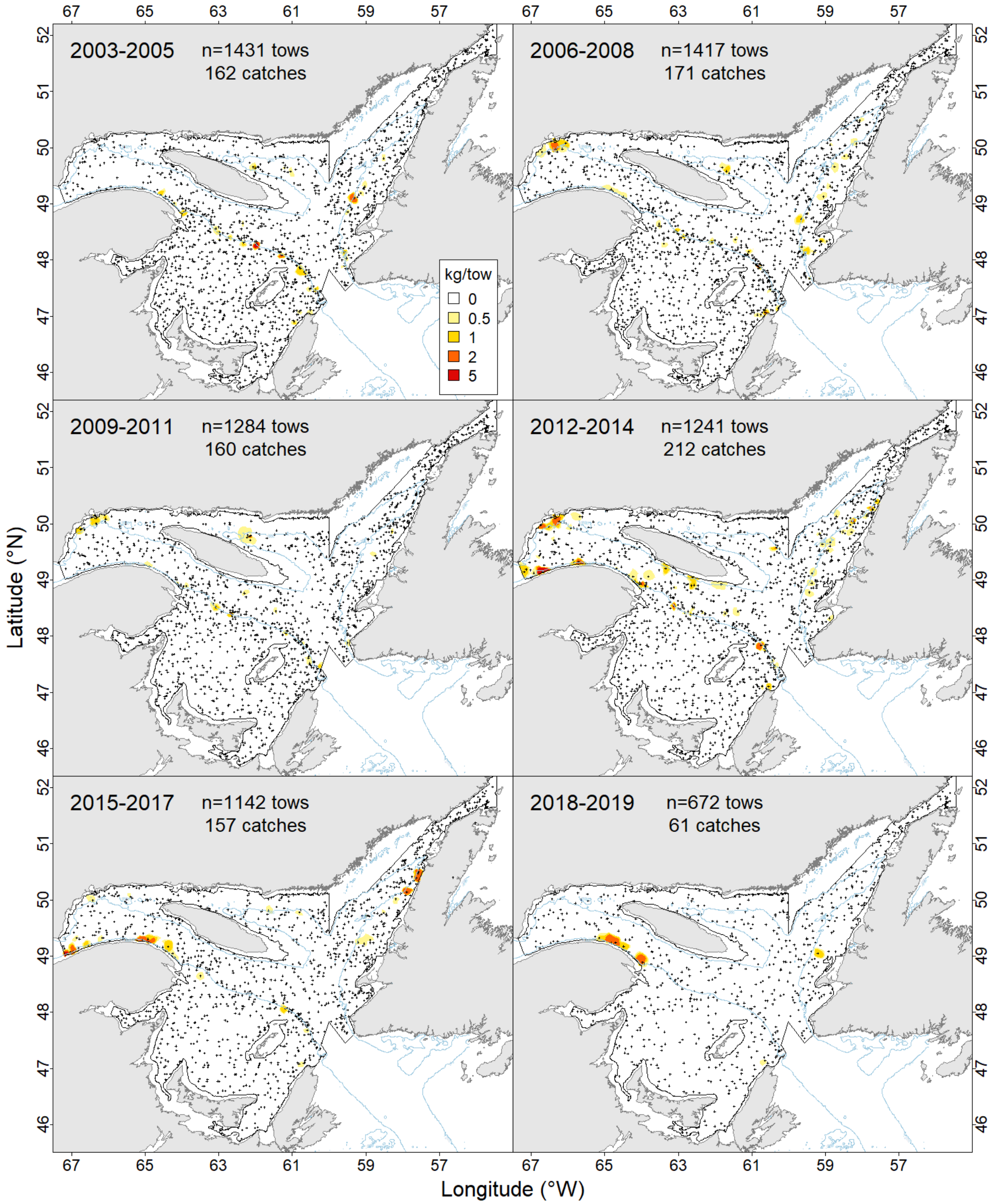

Figure 21. Distribution of biomass of Witch Flounder < 30 cm in length in the July sentinel survey of the northern Gulf of St. Lawrence and the August sentinel survey of the southern Gulf of St. Lawrence, 2003 to 2019. All catch data were normalised to a 1.25 nautical miles tow (see Appendix B for details). Catches are displayed using Inverse Distance Weighted interpolation (IDW) and all set locations are identified by a small black cross. The 200 m isobath is drawn in light blue.

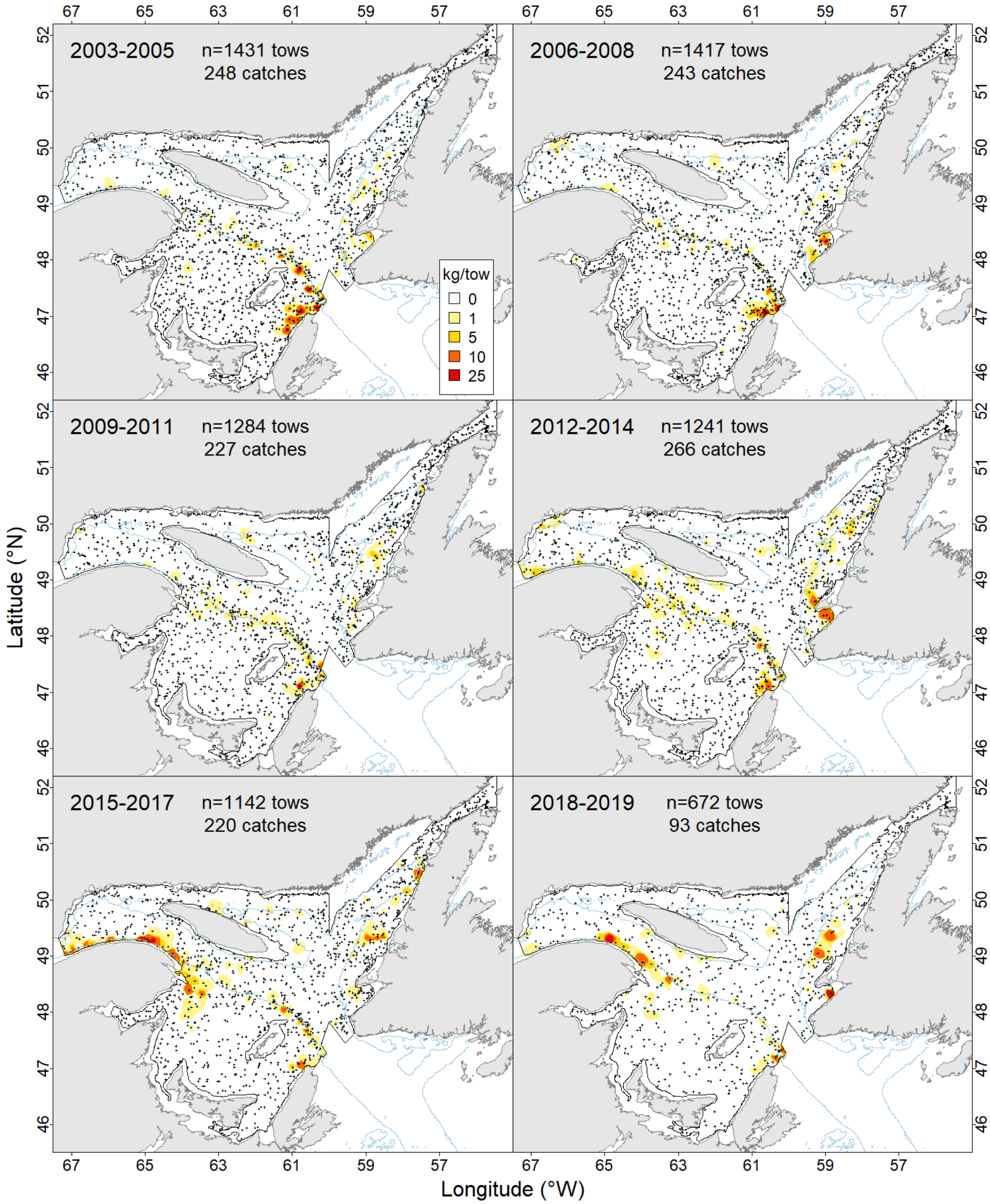

Figure 22. Distribution of biomass of Witch Flounder ≥ 30 cm in length in the July sentinel survey of the northern Gulf of St. Lawrence and the August sentinel survey of the southern Gulf of St. Lawrence, 2003 to 2019. All catch data were normalised to a 1.25 nautical miles tow (see Appendix B for details). Catches are displayed using Inverse Distance Weighted interpolation (IDW) and all set locations are identified by a small black cross. The 200 m isobath is drawn in light blue.

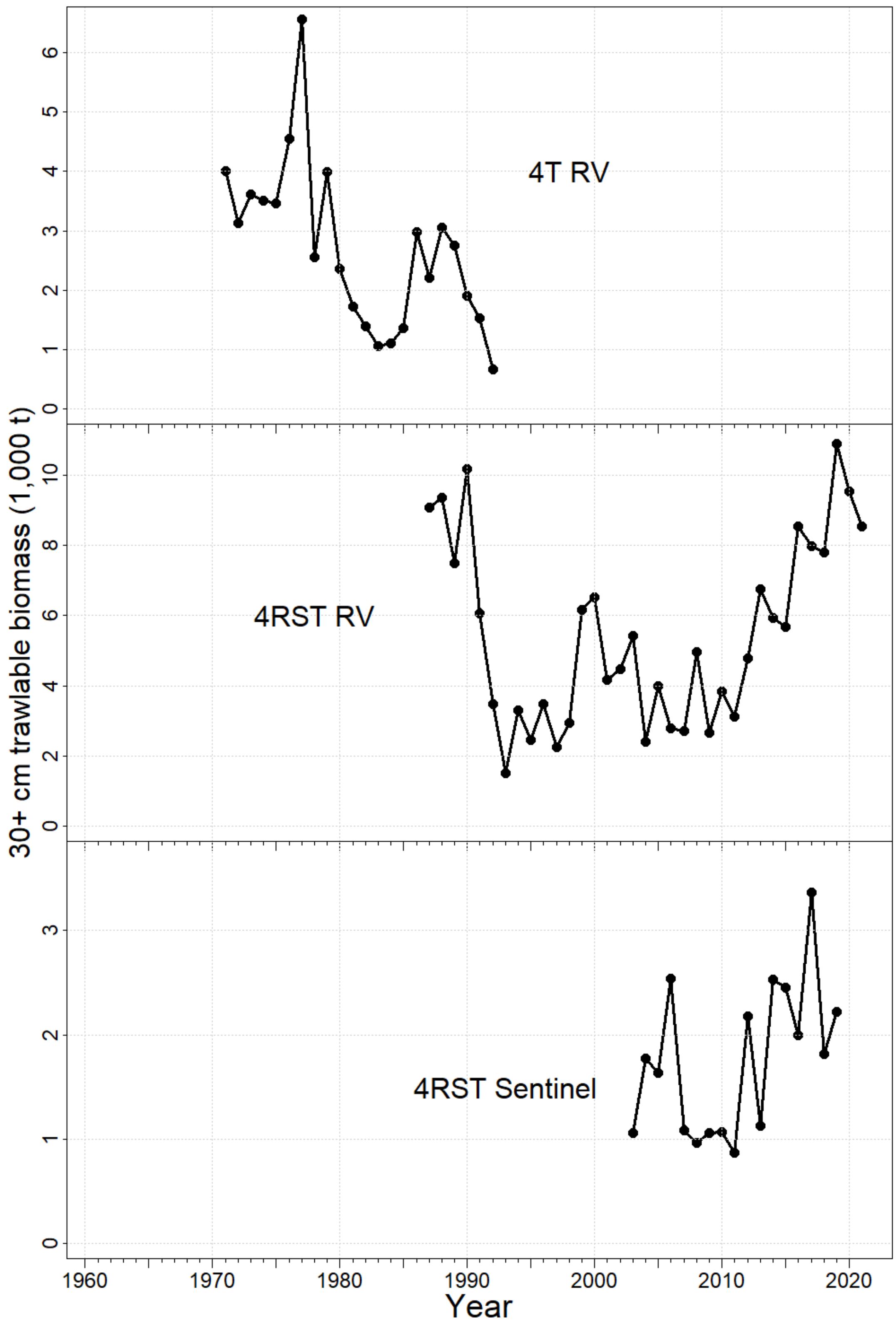

Figure 23. Stock indices used to fit the population model. The three indices are the NAFO 4T RV index (1971-1992, top panel), the NAFO 4RST RV index (1987-2021, middle panel) and the NAFO 4RST Sentinel index (2003-2019, bottom panel).

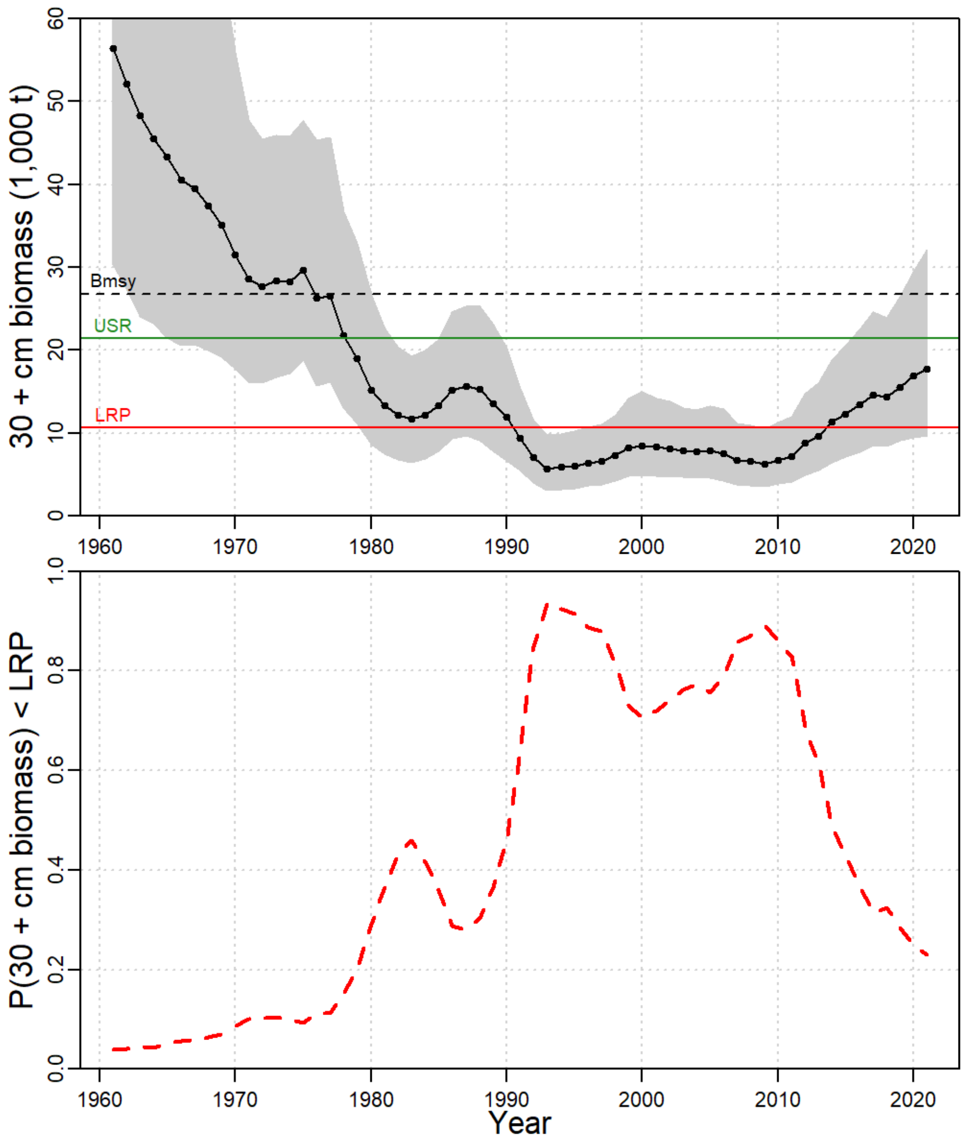

Figure 24. Estimated 30+ cm biomass from the single productivity surplus production model M1 of NAFO Divs. 4RST Witch Flounder (top panel). The solid black line is the posterior median and the grey polygon spans the 2.5th and the 97.5th quantiles. The red horizontal line shows the limit reference point (LRP) which corresponds to 40% of B_{msy} , the green horizontal lines show the Upper Stock Reference (USR) which corresponds to 80% of B_{msy} and the black dashed horizontal line shows B_{msy}. The bottom panel show the probability that the 30+ cm biomass is below the LRP.

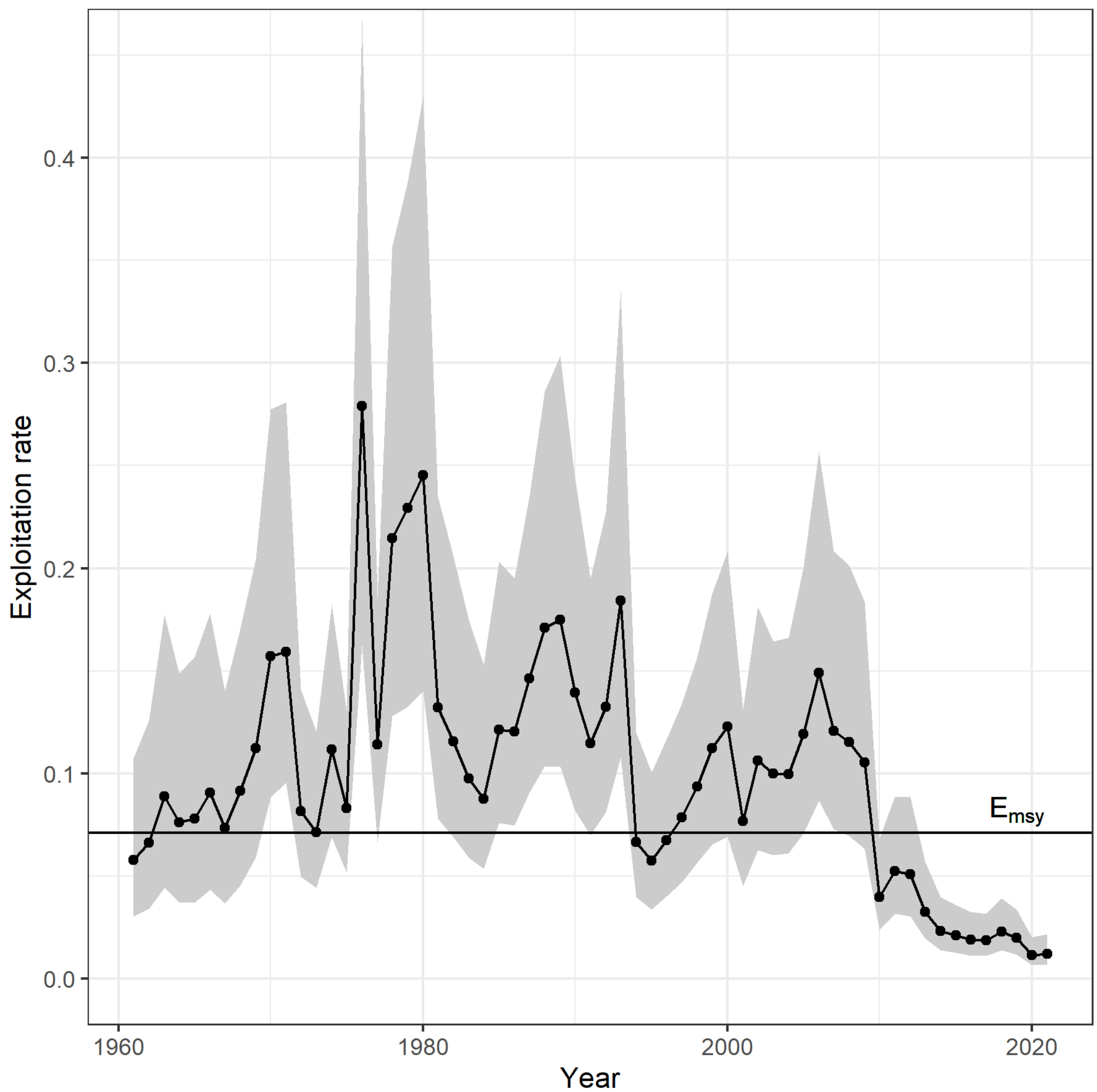

Figure 25. Estimated exploitation rate of 30+ cm biomass from the single productivity surplus production model M1 of NAFO Divs. 4RST Witch Flounder. The solid black line is the posterior median and the grey polygon spans the 2.5th and the 97.5th quantiles. The horizontal line shows the exploitation rate at maximum sustanable yield E_{msy}.

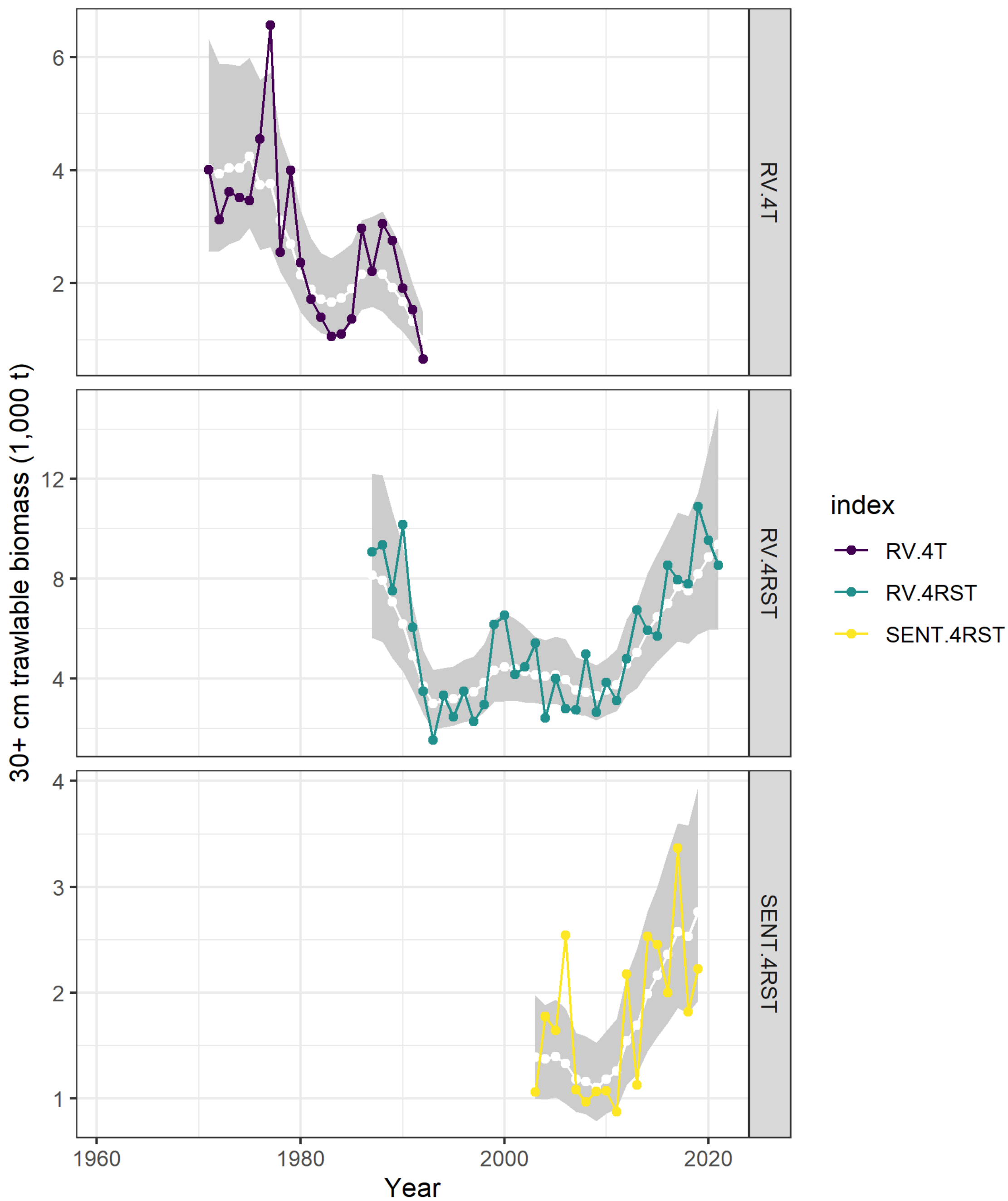

Figure 26. Fit of the single productivity surplus production model M1 of NAFO Divs. 4RST Witch Flounder to the three population indices. The three indices are the NAFO 4T RV index (1971-1992, top panel), the NAFO 4RST RV index (1987-2021, middle panel) and the NAFO 4RST Sentinel index (2003-2019, bottom panel). The fit is shown by plotting each index using a solid coloured line and dots along with the model-derived median estimate of 30+ cm biomass as a solid white line with white dots and a grey polygon around the median denoting the 2.5th and 97.5th percentiles.

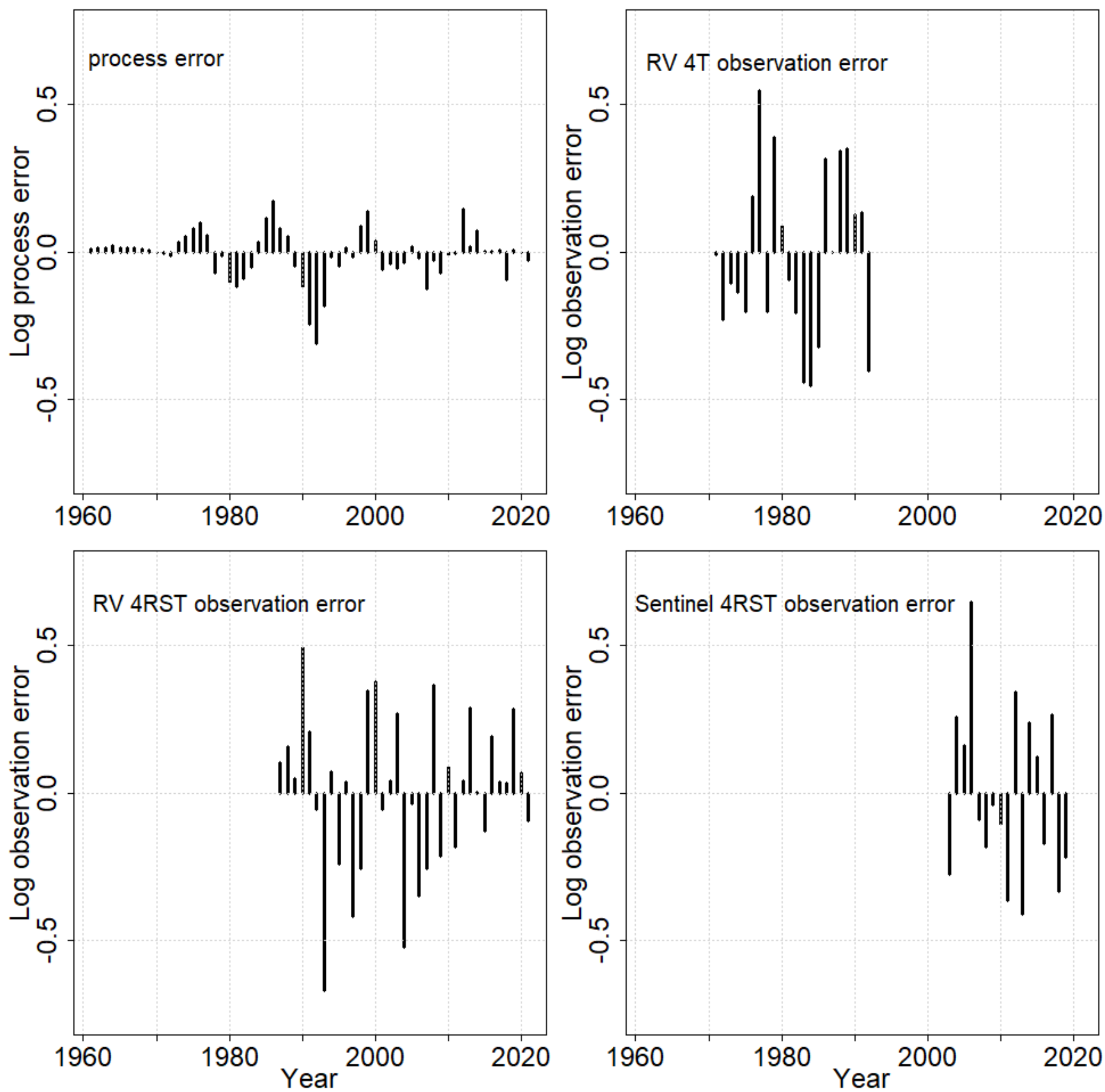

Figure 27. Process and observation errors for the single productivity surplus production model M1 of NAFO Divs. 4RST Witch Flounder.

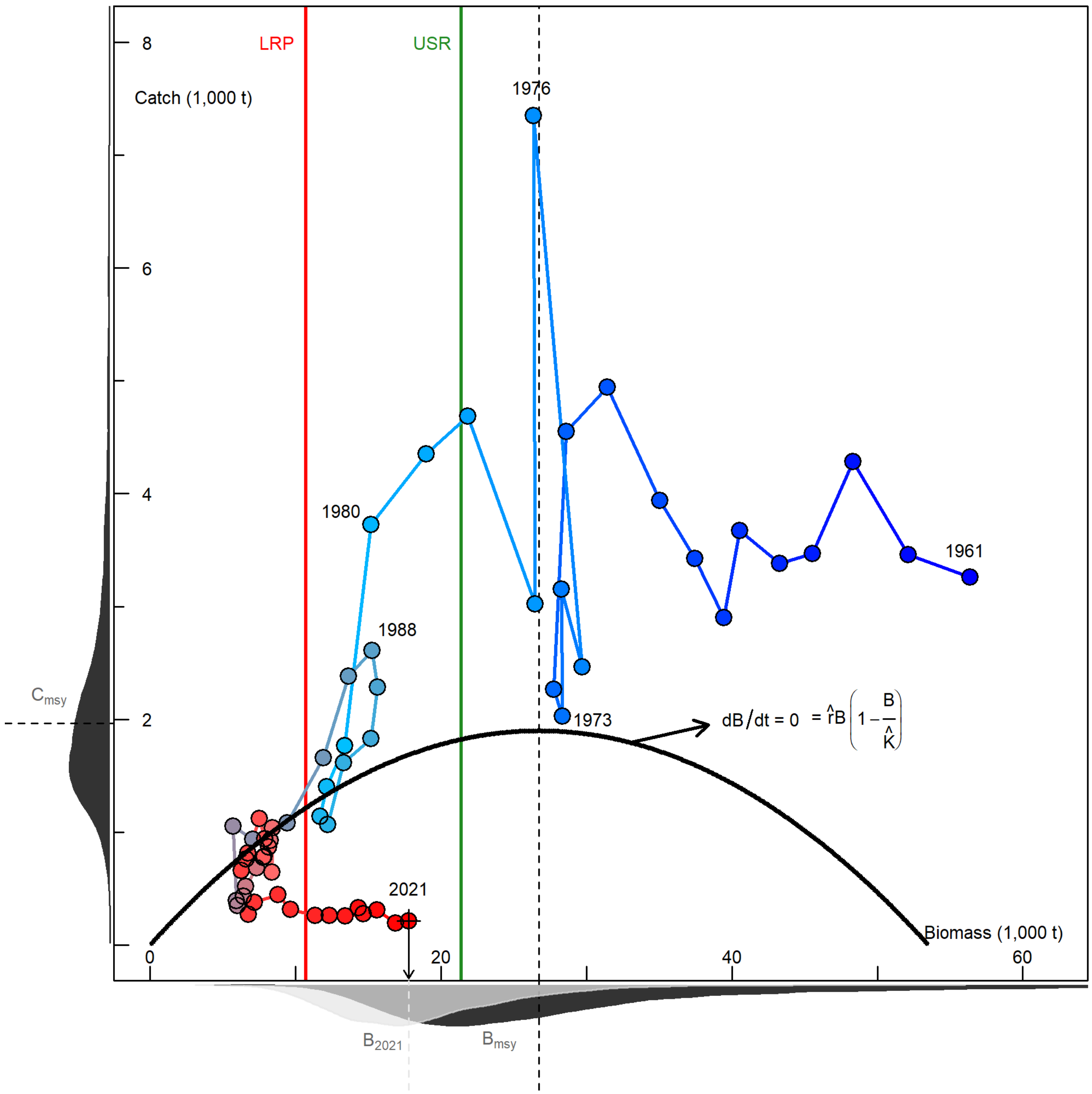

Figure 28. Observed NAFO Divs. 4RST Witch Flounder catch as a function of the 30+ cm biomass estimated from the Schaefer surplus production model for the single productivity regime model M1. The temporal evolution of both the catch and the estimated biomass is colour-coded from blue (earliest years) to red (latest years). The solid black line indicates the model-derived catch levels at different biomass levels that result in no changes in biomass from year to year. Based on the Schaefer model structure, points located above the solid black line will lead to decreasing biomass over time and points located below the line will lead to increasing biomass over time. The solid vertical red line is the median estimate of the Limit Reference Point (LRP) and the solid vertical green line is the median estimate of the Upper Stock Reference (USR). The vertical dashed line is the median estimate of the biomass at maximum sustainable yield (B_{msy}). The posterior probability distribution of the catch at maximum sustainable yield (C_{msy}) is shown on the outer margin of the y-axis and its median value is identified by the horizontal black dashed line. The posterior probability distributions of the biomass that generates the maximum sustainable yield (B_{msy}, in black) and the biomass in 2021 (B_{2021}, in light grey) are shown on the outer margin of the x-axis and their median values are identified by vertical dashed line. Catches for 2021 are preliminary.

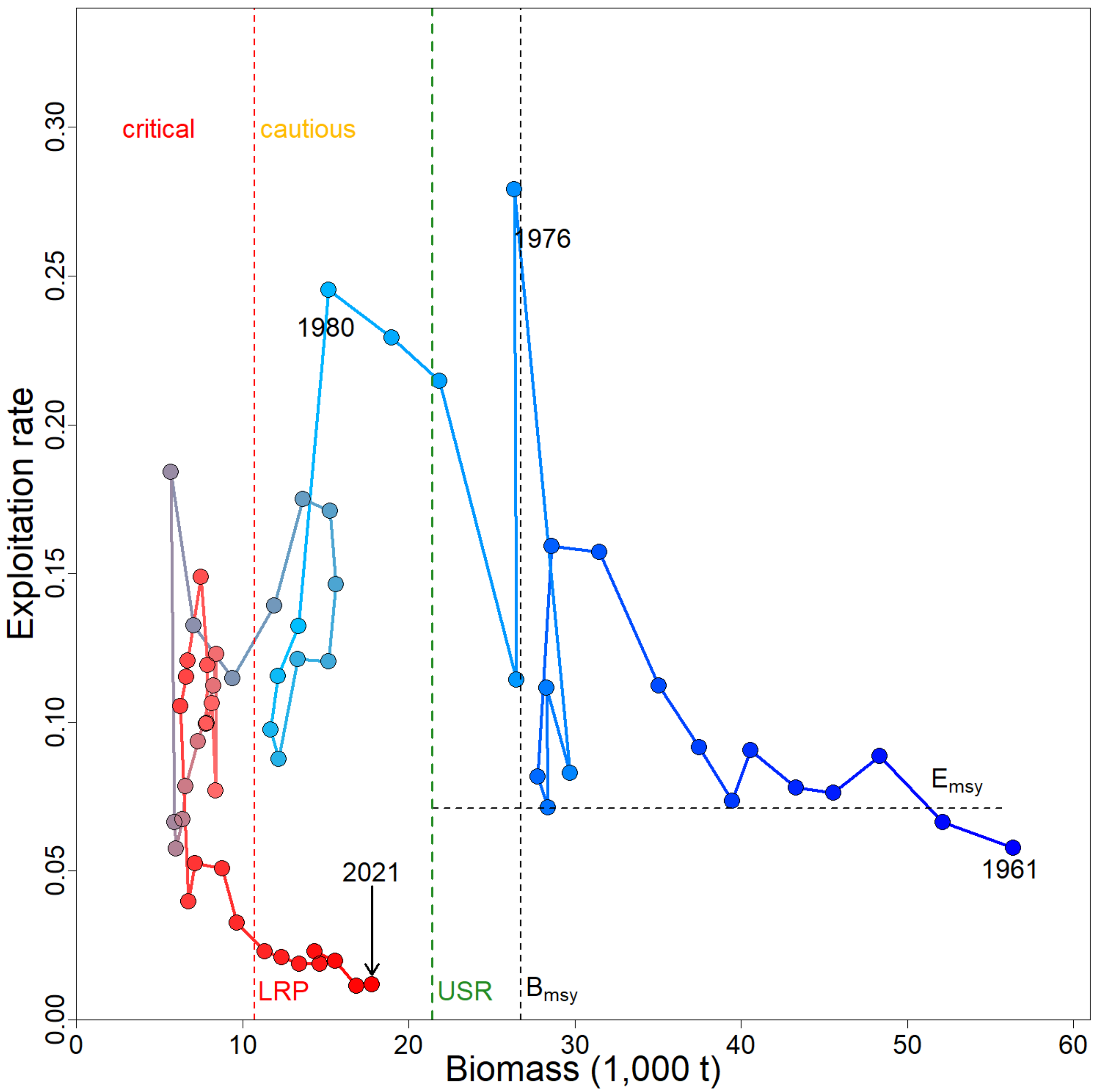

Figure 29. Precautionary approach plot for NAFO Divs. 4RST Witch Flounder. The x axis shows the 30+ cm biomass of Witch Flounder for the period 1961 to 2021 estimated from the Schaefer surplus production model for the single productivity regime model M1. Also shown on the x axis are the Limit Reference Point (LRP, 40% of B_{msy}, in red), the Upper Stock Reference (USR, 80% of B_{msy} , in green) and the biomass at Maximum Sustainable Yield (B_{msy}). The y axis shows the exploitation rate for the period 1961 to 2021 along with the exploitation rate at Maximum Sustainable Yield (E_{msy}). The temporal evolution of both the estimated biomass and the exploitation rate is colour-coded from blue (earliest years) to red (latest years). The exploitation rate for 2021 is based on preliminary landings data.

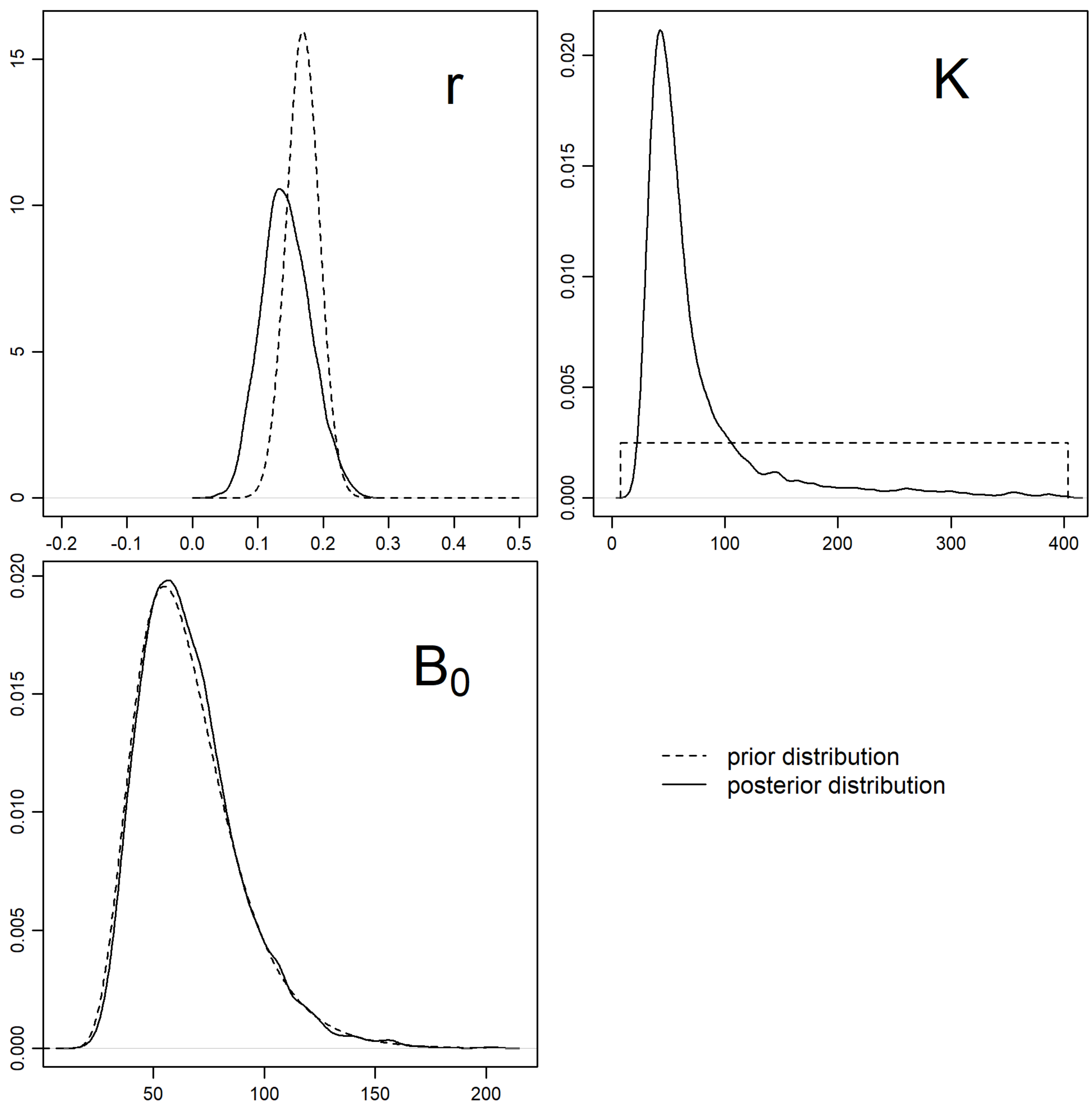

Figure 30. Prior (dashed lines) and posterior (solid lines) probability distributions of the intrinsic rate of increase r , carrying capacity K and starting biomass B_0 for the single productivity regime model M1 of NAFO Divs. 4RST Witch Flounder.

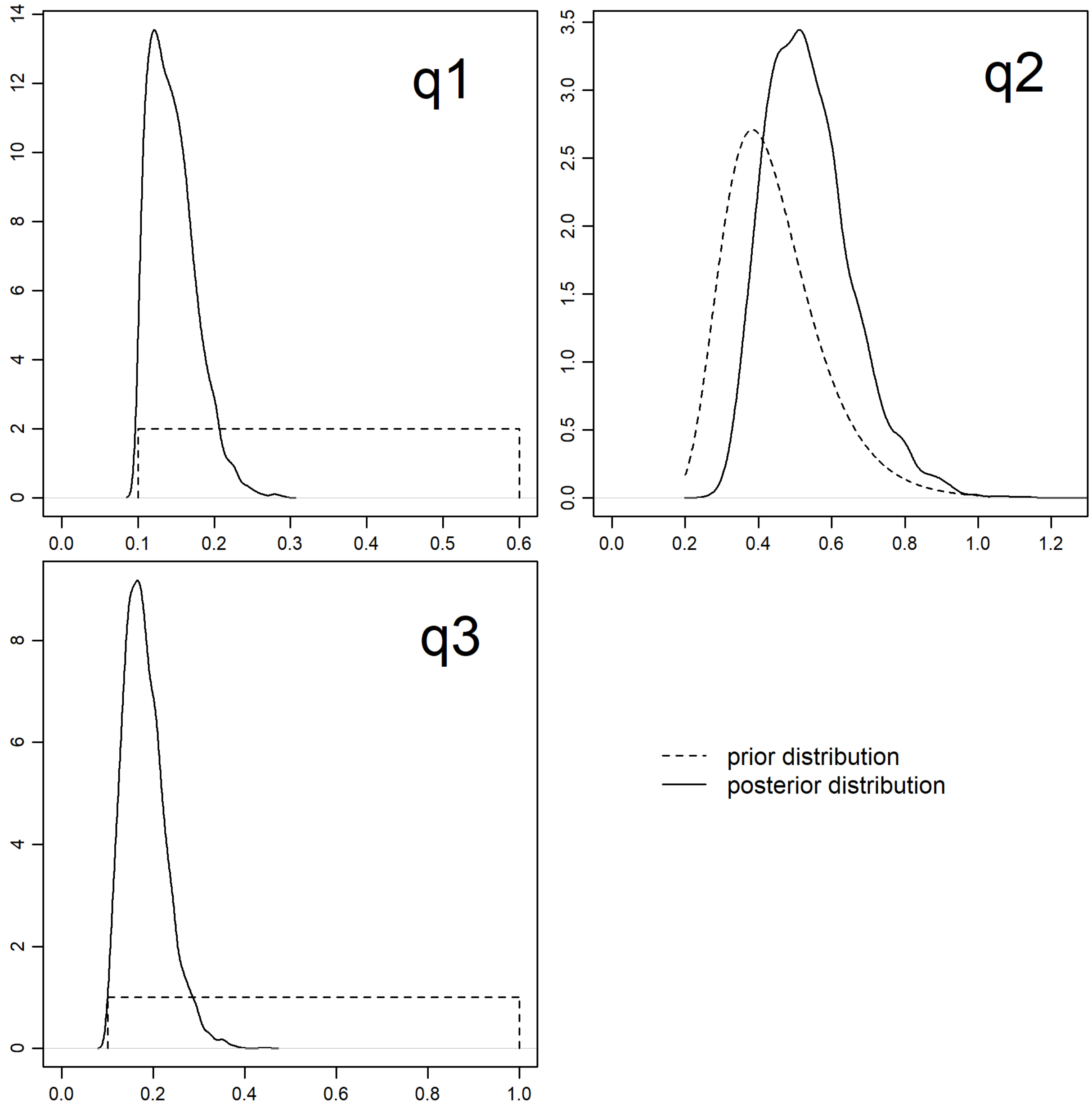

Figure 31. Prior (dashed lines) and posterior (solid lines) probability distributions of the catchability to indices 1 (RV NAFO 4T), 2 (RV NAFO 4RST) and 3 (Sentinel NAFO 4RST) for the single productivity regime model M1 of NAFO Divs. 4RST Witch Flounder.

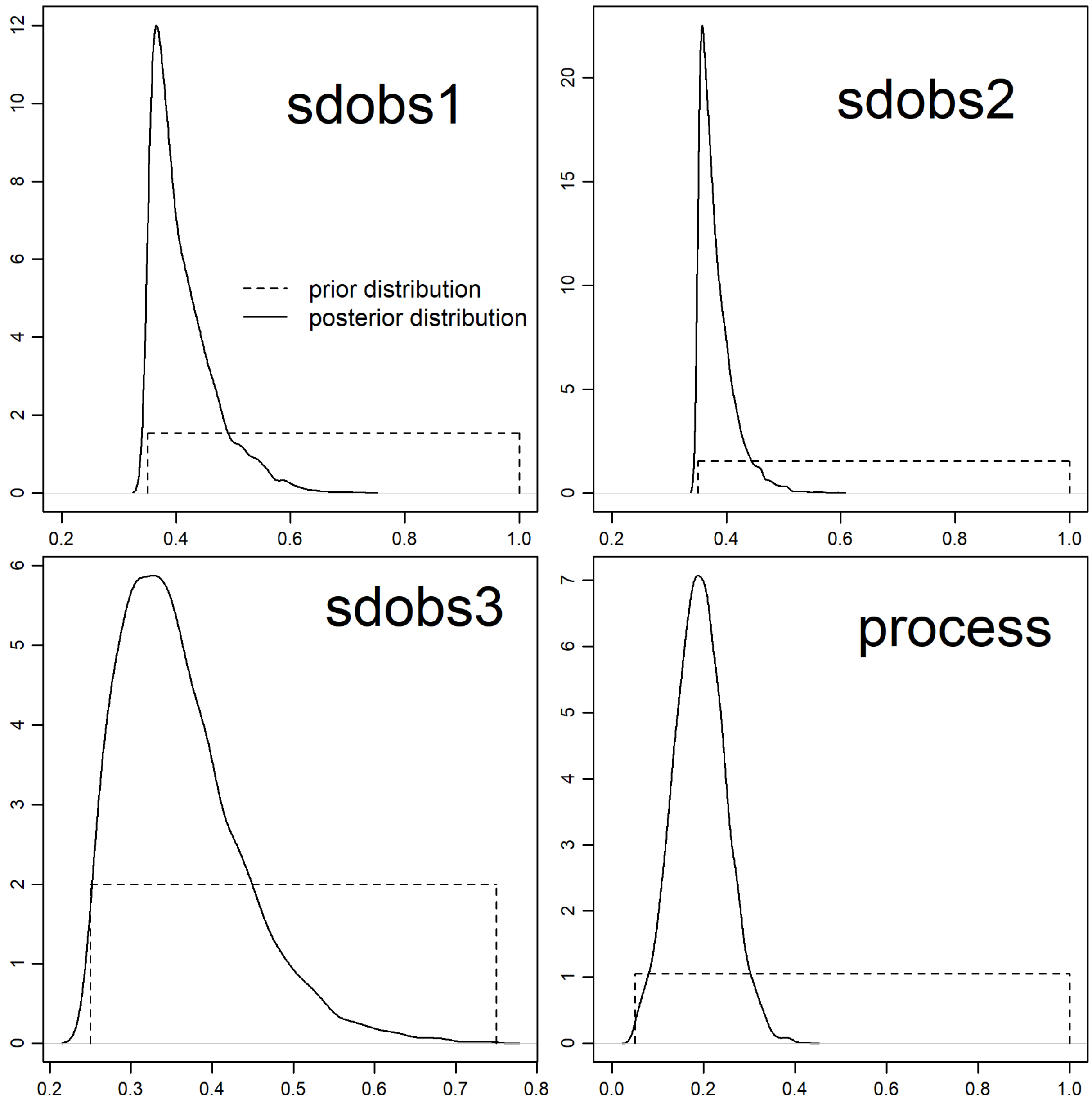

Figure 32. Prior (dashed lines) and posterior (solid lines) probability distributions of the standard deviations of observation and process error for the single productivity regime model M1 of NAFO Divs. 4RST Witch Flounder.

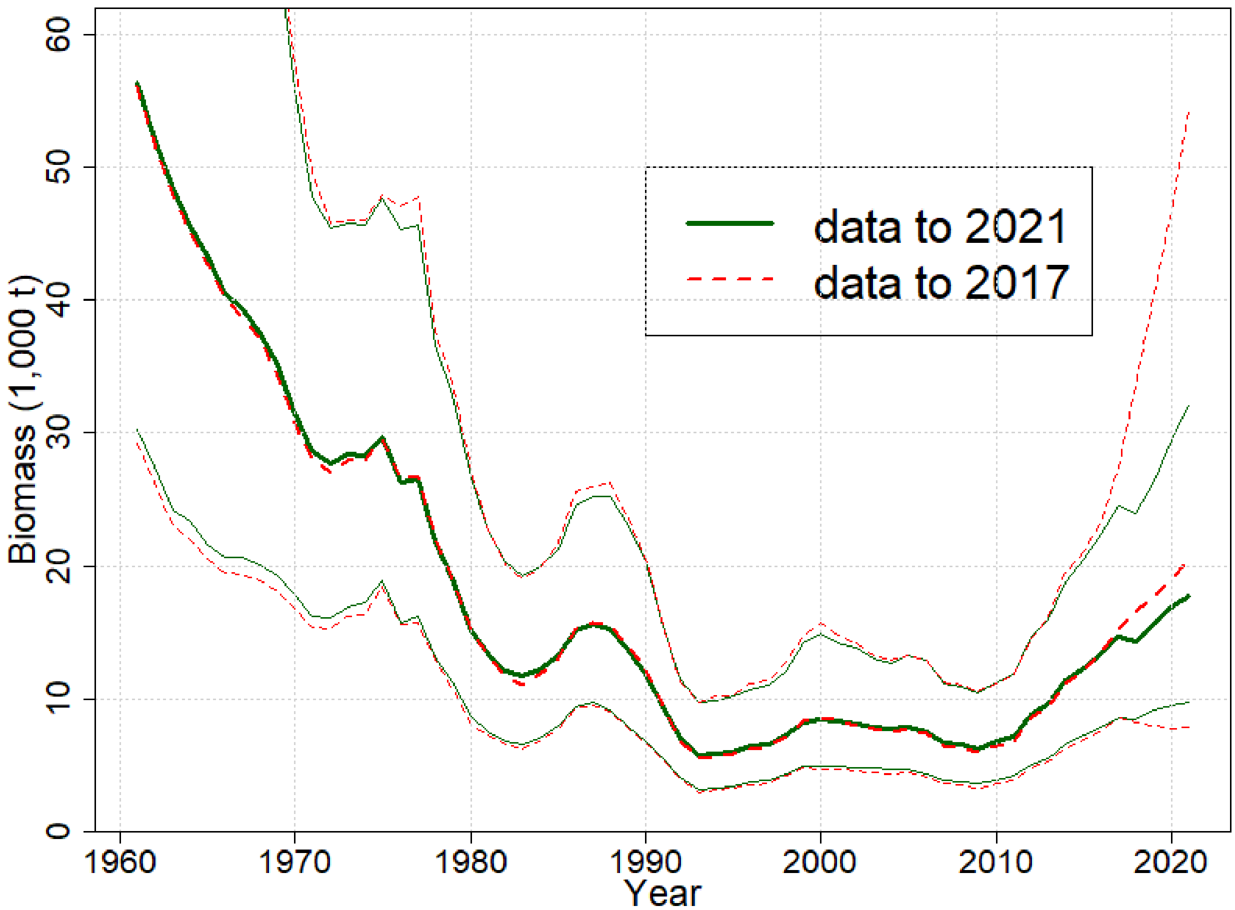

Figure 33. Estimated 30+ cm biomass of Witch Flounder in NAFO Divs. 4RST obtained by fitting the single productivity regime Schaefer model M1 to all the available biomass index data (solid green line) and by omitting the last 4 years of index data (dashed red line). Heavy lines are the median estimates and thin lines show the 2.5th and 97.5th quantiles.

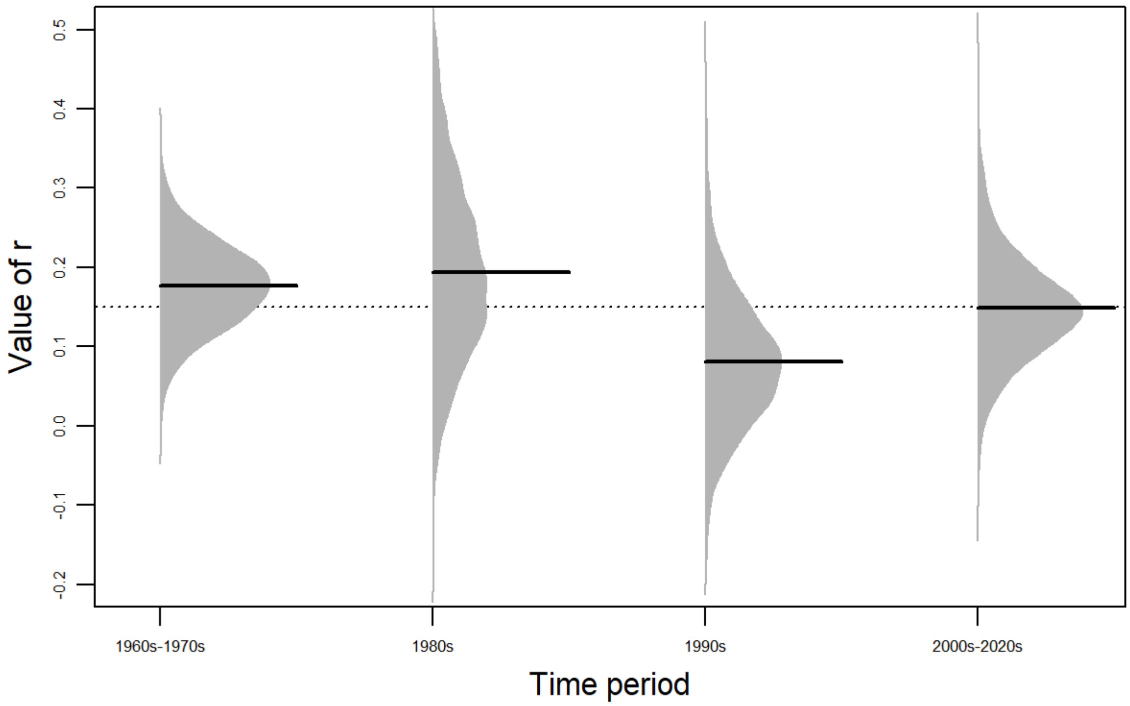

Figure 34. Beanplots showing the posterior distributions for r for the Schaefer surplus production model for NAFO Divs. 4RST Witch Flounder allowing decadal variations in r.

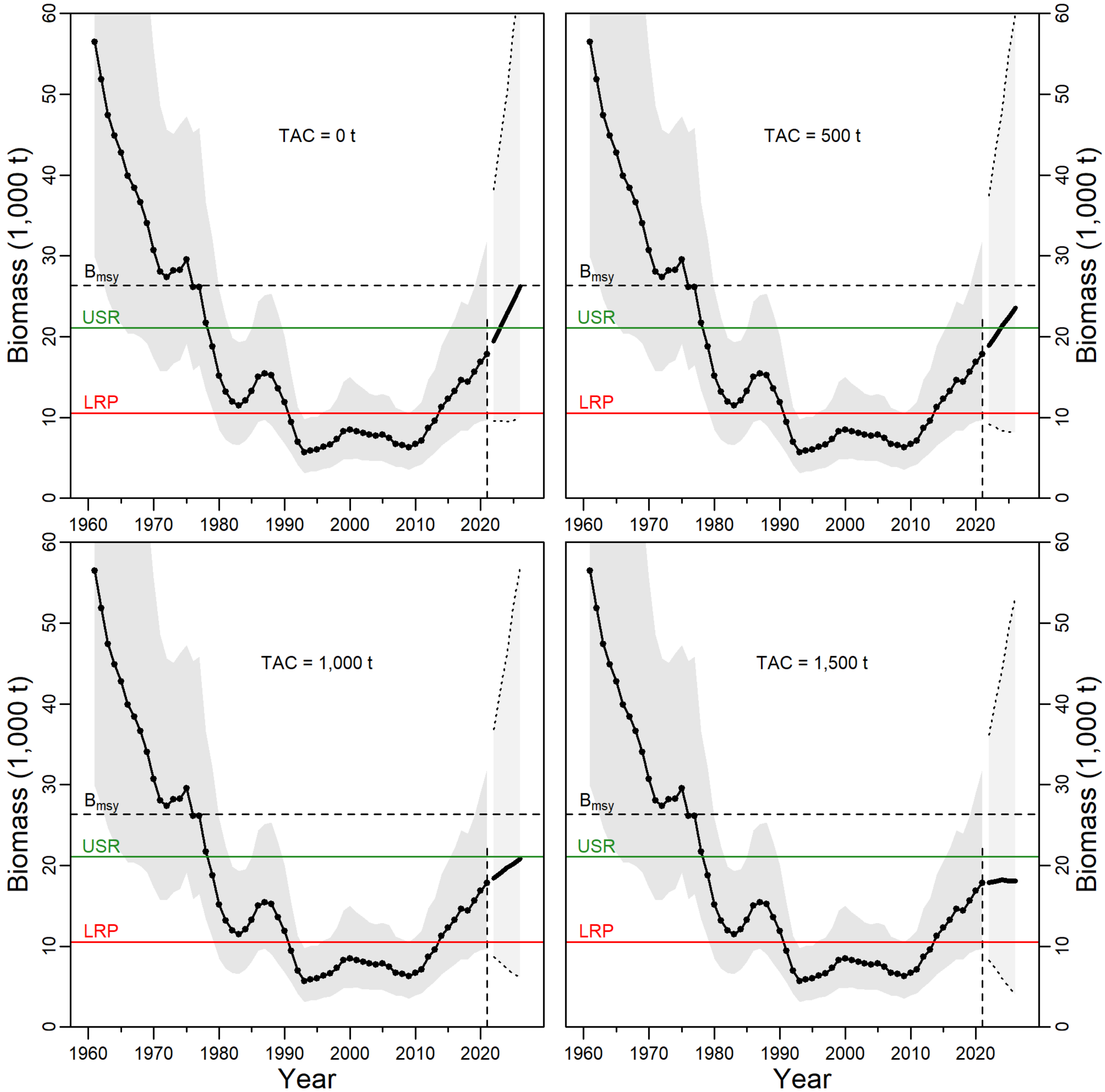

Figure 35. Projected 30+ cm biomass (kt) of NAFO Divs. 4RST Witch Flounder at various annual catch levels in 2022 to 2026 (0 t top-left panel, 500 t top-right panel, 1,000 t bottom-left panel and 1,500 t bottom-right panel) using the single productivity regime model M1. In all four panels, the solid black lines are the posteriors medians and the grey polygon spans the 2.5th and the 97.5th quantiles. Biomasses for years 2022 to 2026 are projected estimates. The red horizontal lines show the limit reference point (LRP) which corresponds to 40% of B_{msy} , the green horizontal lines show the Upper Stock Reference (USR) which corresponds to 80% of B_{msy} , and the horizontal dashed black lines show B_{msy}.

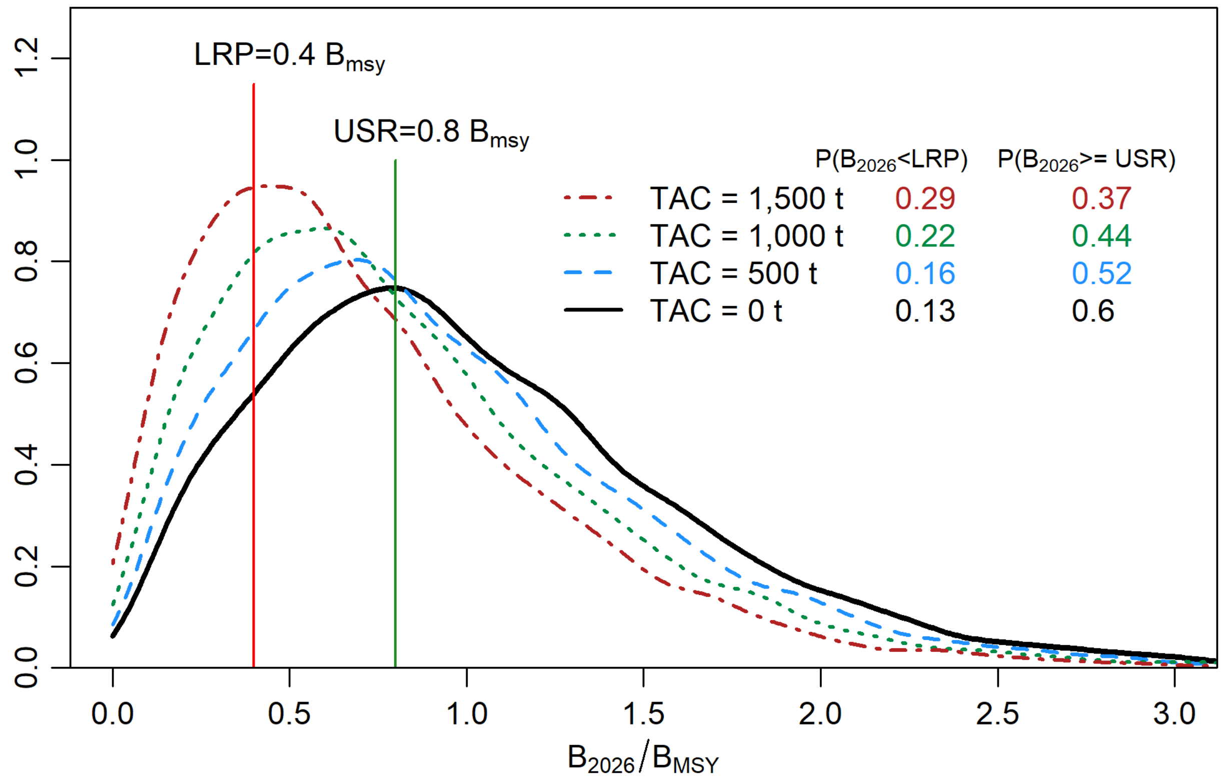

Figure 36. Posterior distribution of the estimated biomass in 2026 of NAFO Divs. 4RST Witch Flounder as a proportion of B_{msy} at various annual catch levels for the period 2022 to 2026. The inset shows the probability of being below the LRP ($P(B_{2026} < LRP)$) and the probability of being above the USR ($P(B_{2026} \geq USR)$) under each catch scenario.

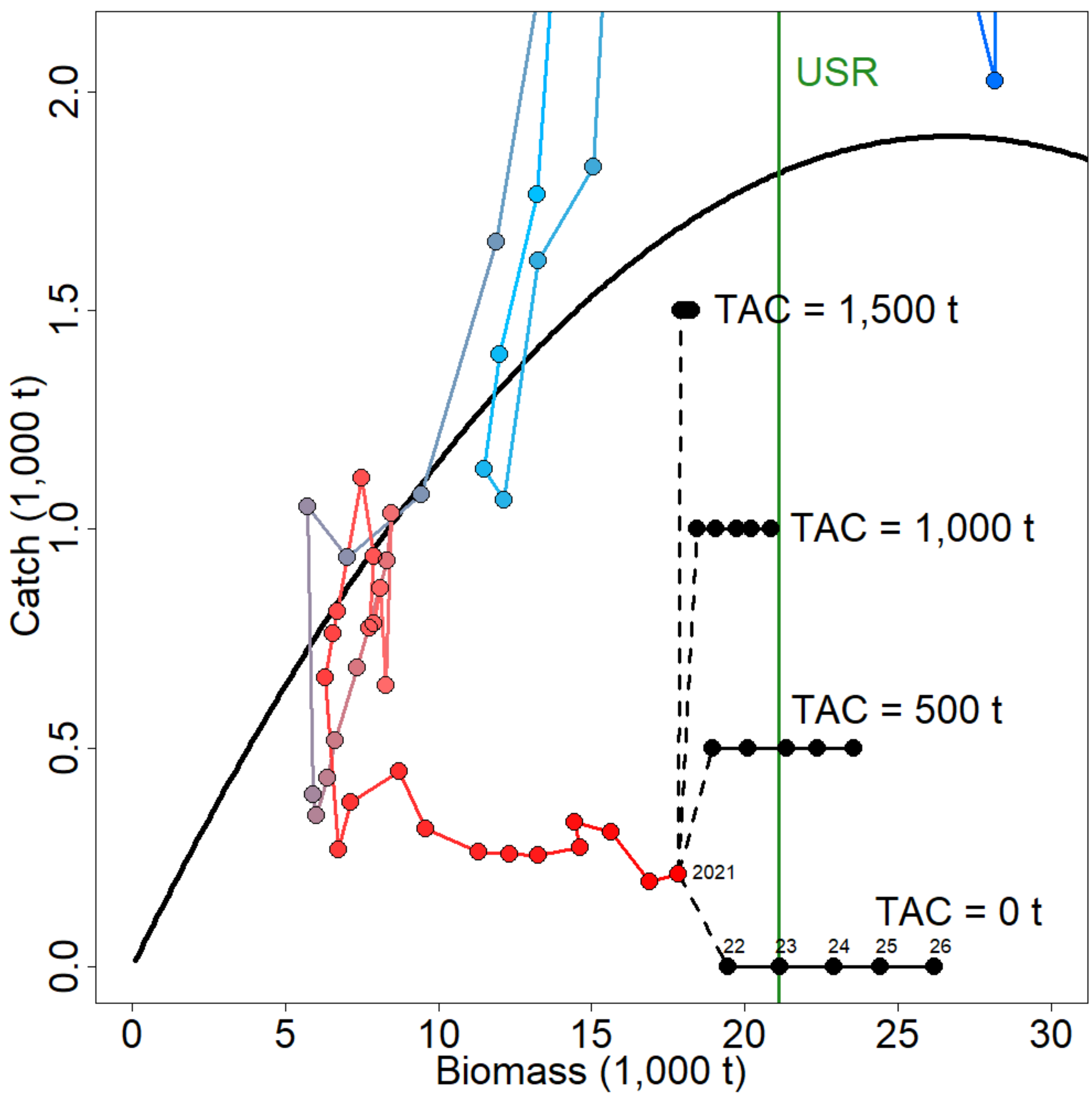

Figure 37. Projected 30+ cm biomass (kt) of NAFO Divs. 4RST Witch Flounder at various annual catch levels in 2022 to 2026. The last red point corresponds to the catch and the estimated 30+ cm biomass in 2021. Each catch scenario is projected for 5 years, indicated by five black dots, and by the last 2 digits of each projection year for the 0 t scenario. Note that this is a zoomed-in version of Figure 28 with the biomass estimates of the projections added, which is why some of the catch and biomass points fall outside the figure.

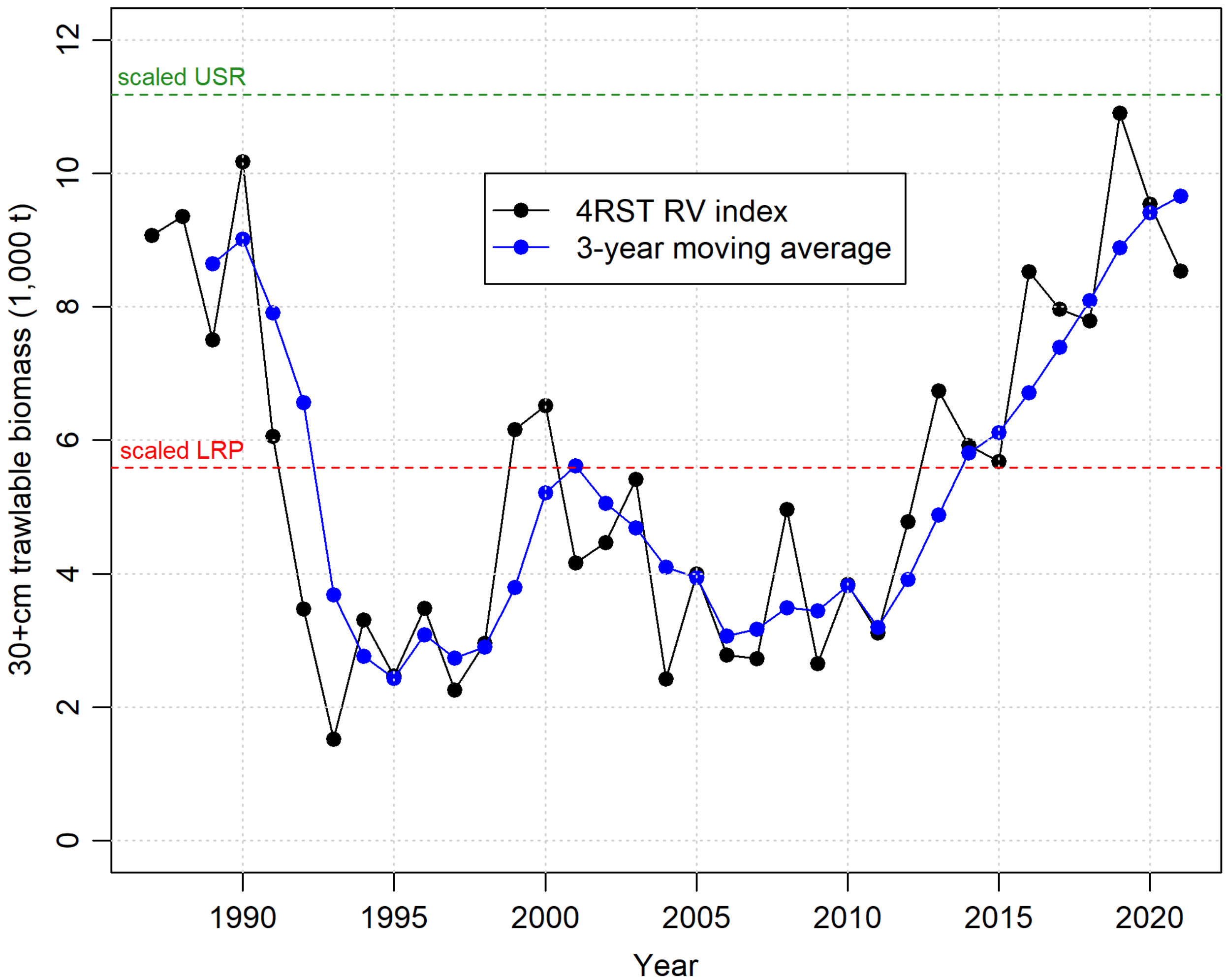

Figure 38. Stock status indicator for NAFO Divs. 4RST Witch Flounder expressed in 30+ cm trawlable biomass. The solid black line and dots are the NAFO Divisions 4RST index and the solid blue line and dots are the 3-year moving average of the index shown in correspondence to the third year of the block of years. The scaled LRP and USR are identified by a red and a green horizontal line, respectively.

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APPENDIX A. METHODOLOGICAL DETAILS OF THE COMPUTATION OF GULF-WIDE INDEX FOR NAFO 4RST WITCH FLOUNDER BASED ON RESEARCH VESSEL SURVEY DATA

Witch Flounder in the Gulf of St. Lawrence (NAFO Divisions 4RST) is managed as a single stock and its assessment relies on the availability of fisheries-independent population indices for the whole stock area. While no single survey covers the entire area encompassing NAFO Divisions 4RST, a number of survey activities are conducted in the stock area and can be drawn upon to provide indices for the whole population.

This Appendix provides the analytical details required to compute a population index for the Gulf of St. Lawrence using two separate bottom trawl surveys. Merging the survey indices coming from a variety of vessel and gear combinations over the time series requires the inclusion of information collected during comparative fishing experiments in order to achieve comparability between the different surveys and continuity in the time-series. The comparative fishing experiments that took place over the years in the Gulf of St. Lawrence are described in more details here. The different conversion factors used and the resulting yearly stratum-level estimates used in the computation of a single population index are documented.

A.1. TRAWL SURVEY DATA ACCESS

The trawl survey data from the Quebec Region is accessed through a DFO shared network drive where data are accessible in a variety of formats. Since the computation of the Witch Flounder indices requires information about the length of individuals captured, both catch and length information were used in the computations. The text files that contain these data were produced by DFO Quebec Region using the contents of the relational database where the survey data are archived. The trawl survey data from the Gulf Region is accessed through the bespoke gulf package in R (R Core Team 2021) which extracts information directly from an Oracle database.

A.2. SUMMARY OF RESEARCH VESSEL (RV) SURVEYS IN NAFO DIVISIONS 4RST

Two separate research vessel surveys are conducted annually in the Gulf of St. Lawrence: 1) the northern Gulf survey conducted in August by the Quebec Region of Fisheries and Oceans Canada and 2) the southern Gulf survey conducted in September by the Gulf Region of Fisheries and Oceans Canada (Figure A1). A description of the timeline for both surveys is provided here, along with a description of the comparative fishing experiments that have taken place to estimate vessel, gear and diurnal effects on survey captures.

Southern Gulf of St. Lawrence RV surveys

The southern Gulf of St. Lawrence stratified random survey has been conducted annually since 1971 (Figure A2). The *E.E. Prince* using a Yankee 36 trawl performed the survey from 1971 to 1984. The *Lady Hammond* using a Western IIA trawl took over in 1985 until 1991. *CCGS Alfred Needler* using a Western IIA trawl became the survey platform starting in 1992 and ending in 2003. Since 2004, the *CCGS Teleost* has been conducting the survey with a Western IIA trawl. Comparative fishing experiments took place in 1985 between the *E.E. Prince* and the *Lady Hammond* (Figure A9), between the *Lady Hammond* and *CCGS Alfred Needler* in 1992 (Figure A11) and between *CCGS Alfred Needler* and *CCGS Teleost* in 2004 and 2005 (Figure A13). In 2003, the usual sampling platform, *CCGS Alfred Needler*, suffered a mechanical failure and its sister vessel, *CCGS Wilfred Templeman* was used for that year's survey. The survey protocol has remained a 30 min tow at 3.5 knots (standard tow = 1.75 nautical miles) since 1971.

There are important diurnal differences in Witch Flounder catchability, the species tends to be more efficiently captured at night than during the day. The extent of this diurnal effect was estimated for the different vessels used in the southern Gulf surveys through the analysis of tows conducted at repeat locations and/or comparison of stratum-level estimates of Witch Flounder catches during the day and at night. In 1988, the *Lady Hammond* conducted 67 paired tows (one day tow and one night tow) at the same locations to obtain information about diurnal differences in catchability (Figure A10). A similar diurnal comparative experiment was conducted in 1998, 1999 and 2000 to estimate the day/night differences in catchability for the *CCGS Alfred Needler* (Figure A12).

The strata used in the analysis of Witch Flounder from the southern Gulf of St. Lawrence survey are those sampled over the entire time-series (strata 415 to 429, and 431 to 439, Figure 11) and do not include the shallow water strata that were added to the surveyed area in 1984. Witch Flounder is a deep water species and only nine individuals were ever captured in the shallow water strata 401, 402 and 403, so omitting these strata from the analyses is inconsequential.

Northern Gulf of St. Lawrence RV surveys

The northern Gulf of St. Lawrence stratified random survey has been taking place in August since 1984 (Figure A2). From 1984 to 1989, the survey platform was the *Lady Hammond* using a Western IIA trawl. From 1990 to 2003, the survey used the *CCGS Alfred Needler* with a URI shrimp trawl. Since 2004, the *CCGS Teleost* is the research vessel used with a Campelen trawl. Comparative fishing experiments took place in 1990 between the *Lady Hammond* and the *CCGS Alfred Needler* and again in 2004 and 2005 between the *CCGS Alfred Needler* and the *CCGS Teleost*. The 1990 comparative fishing experiments consisted in 80 paired tows conducted in the northern Gulf of St. Lawrence (Figure A7) while the 2004 and 2005 comparative fishing experiments had 10 and 159 paired tows, respectively (Figure A8).

The target tow duration has also changed over the history of the northern Gulf survey. The target fishing procedure was a 30 min tow at 3.5 knots in 1984 to 1989 (standard tow= 1.75 nautical miles), a 20 min tow at 2.5 knots in 1990 to 1992 (standard tow= 0.83 nautical miles), a 24 min tow at 2.5 knots in 1993 (standard tow= 1.0 nautical mile), a 24 min tow at 3.0 knots since 1994 using the URI trawl (standard tow= 1.2 nautical miles), and a 15 min tow at 3.0 knots using the Campelen trawl (standard tow= 0.75 nautical miles).

The northern Gulf of St. Lawrence stratified random survey covers the St. Lawrence estuary and the northern Gulf, including around Anticosti Island and along the western Newfoundland coast. Based on the distribution of Witch Flounder in the area and the historical coverage of the survey, the analyses presented here follow the methods of Swain et al. (1998a), concentrated on strata 401 to 414, 801 to 824 and 827 to 832 (Figure 10). In some years, the survey did not sample all the strata (Tables A5 and A6) which requires the estimation of Witch Flounder catch in missing years and strata (see section A3). Because length frequency information was not available prior to 1987, the data from years 1984 to 1986 are not used in the analyses since they rely on length-based information. The combined 4RST indices therefore spans the years 1987 to 2021.

A.3. ANALYTICAL OPTIONS TO PREDICT MISSING YEAR-STRATUM COMBINATIONS

Because of the logistical and time constraints of survey activities, it is common that some strata are not sampled in some years. In order to compute a yearly stratified mean and variance, a minimum number of two tows must be successfully conducted in a stratum in a given year.

A number of options exist to compute yearly indices when observations are missing from some strata. The simplest solution consists in computing the yearly index without the missing strata. However, when indices are combined across years this assumes that the mean index value in the unsampled stratum was the same as the mean index value in all sampled strata. If the missing stratum has a higher or lower mean than the overall mean, this procedure will lead to a potentially biased index.

A temporally-based estimator that uses the catch values in the missed stratum is the first option available. Alternatively, a spatially-based estimator can be computed by using adjacent strata of similar habitat characteristics to estimate the missing value. Another solution consists in fitting a model to the existing survey information and to use the model to predict the mean of the missing stratum-year. A number of approaches have been used to do this, and they vary in how tows with no catch are dealt with. One option consists in using a generalised linear model with year and strata effects to predict the catch in missed strata. This is the type of approach used in the northern Gulf survey when strata are missed in certain years. This is often referred to as a “multiplicative model” since a log link is used in the GLM. A major inconvenience of this approach has to do with the way that catches of zero are accounted for. A workaround to allow for catches of zero in the model is to add a small value to the zero catches so that the logarithm is defined.

Alternatively, a flexible and robust way to predict catch in missed stratum(a) is to use a hurdle model where the zeroes and non-zeroes are treated separately. In the Gulf of St. Lawrence, Witch Flounder are seldom caught in shallower strata while frequently appearing in deeper strata. It is therefore appropriate to first model the probability of observing zero and non-zero catch in each survey stratum s. A binomial model with a stratum effect estimates the proportion of non-zero catches:

$$log\left(\frac{p_s}{1-p_s}\right) = \alpha + \beta_s \qquad \text{(A1)}$$

where p_s is the proportion of tows with non-zero catch in stratum s, α is the overall proportion of non-zero catches and β_s is the stratum-level effect on that proportion. When missing values are present, this model is fitted to the previous three years of available data for the survey with missing values, and is used to predict missing values. The predictions from this model consist of the proportion of tows that will have non-zero catch. The second part of the hurdle model focuses on the non-zero catches and models the 30+ cm catch biomass using a generalised linear model with gamma error and a log link:

$$\mu = log(\alpha + \beta_t + \beta_s) \qquad \text{(A2)}$$

where α is the average 30+ cm biomass in the survey, βt is the year effect and βs is the stratum effect. The two fitted models can then be used to predict the catch in missed each missed stratum. The binomial model is used the predict the proportion of sets with non-zero catches in a given stratum. The gamma model is then used to predict the catch in a given stratum. The overall model prediction is the product of the two models. The hurdle model predictions for missed strata is provided in Table A15.

A.4. DIURNAL DIFFERENCES IN WITCH FLOUNDER CATCHABILITY

The southern Gulf survey switched from day-only operation to 24-hour fishing starting in 1985. In order to account for diurnal changes in fish catchability, diurnal comparative fishing experiments were conducted in 1988 on the *Lady Hammond* (Figure A10) and again in 1998, 1999 and 2000 on the *CCGS Alfred Needler* (Figure A12).

Diurnal differences can be estimated using information made from paired tows conducted at the same location within a 24-hour period, but also by using models that compare day and night catches while accounting for year and strata effects. In all documented cases, the comparison of day catches to the night catches suggests a higher catchability of Witch Flounder at night (Swain and Poirier (1998); Benoît and Swain (2003b)). The diurnal conversion factor used in this assessment for the *Lady Hammond* and the *CCGS Alfred Needler* are from Swain and Poirier (1998). Note that these estimates did not include the diurnal paired tows collected in 1998, 1999 and 2000, and rely on a model that estimates diurnal effects. The diurnal correction factors used are 2.1 for the *Lady Hammond* and 3.2 for the *CCGS Alfred Needler* (Figure A3).

The diurnal correction factors developed by Swain and Poirier (1998) and those presented in Benoît and Swain (2003b) are not fully comparable because of the inclusion of an extra depth-dependent component in the latter analyses. Nonetheless, Witch Flounder was also found to be more catchable at night in the analyses of Benoît and Swain (2003b). The diurnal correction estimate for the *Lady Hammond* was estimated at exp(0.691) = 1.996, which is similar to the value of 2.1 from Swain and Poirier (1998). However, the value of exp(0.513) = 1.670 estimated by Benoît and Swain (2003b) for the *CCGS Alfred Needler* was not significant and is only half of the value of 3.2 derived by Swain and Poirier (1998).

The correction factors used for the northern Gulf of St. Lawrence survey are also those derived by Swain and Poirier (1998). The same correction factor of 2.1 is used for the *Lady Hammond* and a correction factor of 1.6 is used for the *CCGS Alfred Needler* and *CCGS Teleost* (Figure A4).

The diurnal correction factors are used to correct day catches into night catches prior to applying vessel and gear correction factors.

A.5. VESSEL AND GEAR DIFFERENCES IN WITCH FLOUNDER CATCHABILITY

A number of vessel and gear changes took place over duration of both the northern and southern Gulf surveys. To allow the estimation of correction factors used to maintain the continuity of the time-series, comparative fishing experiments took place when such changes took place. The derivation of conversion factors summarised here follows the methods used in previous assessments.

For the southern Gulf, the 1985 comparative fishing between the *E.E. Prince* using a Yankee 36 trawl and the *Lady Hammond* using a Western IIA trawl indicated that the fishing efficiency of both vessel/gear was the same for Witch Flounder. So a conversion factor of 1.0 was used to transform the catch data from the *E.E. Prince*/Yankee 36 into equivalent *Lady Hammond*/Western IIA units. The 1992 comparative fishing indicated a higher fishing efficiency of the *CCGS Alfred Needler* over the *Lady Hammond* and a conversion factor of 0.66 is used to convert between the *CCGS Alfred Needler* and the *Lady Hammond*. The 2004 and 2005 comparative fishing experiments between the *CCGS Alfred Needler* and the *CCGS Teleost* did not detect differences in fishing efficiency between the two vessels, so a conversion of 1.0 is used to convert between the *CCGS Teleost* and the *CCGS Alfred Needler* (bottom panel of Figure A3).

In the northern Gulf survey, the trawls used have different length selectivity. The length distribution of captures obtained during the 1990 comparative fishing experiments shows that the URI trawl captured smaller individuals more than the Western IIA trawl, and that the URI trawl did not capture larger individuals that are captured in the Western IIA trawl (top panel of Figure A5). To account for this difference in the length of captures, the catch of individuals more than 23 cm was multiplied by exp(0.6978) = 2.009327 and those less than 23 cm was corrected using the following length-dependent equation:

$$N_{li}^{LH} = N_{li}^{AN}\left(\alpha_0 + \alpha_1 e^{-\alpha_2 l}\right) \quad \text{(A3)}$$

where N_{li}^{LH} is the number of individuals in *Lady Hammond* equivalent of length *l* in paired tow *i*. α_0, α_1 and α_2 are estimated model parameters to adjust catches from the *CCGS Alfred Needler* (N_{li}^{AN}) to their *Lady Hammond* equivalent (estimated parameter values can be found in Table A1). The application of the correction factors achieves the goal to make catches between the *Lady Hammond* and *CCGS Alfred Needler* comparable (bottom panel of Figure A5).

Similarly, the change to the *CCGS Teleost* using a Campelen trawl requires the analysis of the comparative fishing experiments conducted in 2004 and 2005 to provide comparability between catches. The length distribution of captures obtained during the 2004 and 2005 comparative fishing experiments shows that the Campelen trawl catches more fish of all lengths, and that a length-dependent correction factor is required (top panel of Figure A6) The application of the correction factors achieves the goal to make catches between the *CCGS Teleost* and *CCGS Alfred Needler* comparable (bottom panel of Figure A6). The parameter values used for the conversion can be found in Table A1. The catches from the *CCGS Teleost* are transformed into *Lady Hammond* equivalent by first correcting them to the *CCGS Alfred Needler* equivalent and by then using the above equation to obtain the *Lady Hammond* equivalent.

A.6. INDEX FOR THE SOUTHERN GULF OF ST. LAWRENCE, NAFO 4T, 1971 TO 1992

The index for the southern Gulf of St. Lawrence was computed for years 1971 to 1992. The catch data was standardised to a 1.75 nautical miles (nm) night tow using a Western IIA trawl (Figure A3). The index is the stratified random estimate of 30+ cm catch biomass per tow:

$$\bar{Y}_t = \sum_{i=1}^{s} \bar{y}_{ts} \frac{N_s}{N} \quad \text{(A4)}$$

where *s = 1, 2, 3, ..., S* are the different strata, $\bar{y}_{ts}$ is the catch sample mean for stratum *s* in year *t*, N_s is the number of trawlable units in stratum s and *N* is the total number of trawlable units in the survey area. The fraction $\frac{N_s}{N}$ represents the proportional area of each stratum.

A.7. SINGLE RV INDEX FOR THE WHOLE GULF OF ST. LAWRENCE, NAFO 4RST, 1987 TO 2021

The integration of the catch data requires that all captures be made equivalent to the same sampling platform. This is summarised in Figure A4. Once all set-level data are normalised to a standard tow (a 1.75 nm night tow on the *Lady Hammond* using a Western IIA trawl), the stratified random estimate of 30+ cm catch biomass per tow can be computed using equation A4.

The weighting used in the stratified calculation is defined as the proportion of the survey area in each stratum. For overlapping strata (Figure A1), the weighting of each stratum is set to 0.5, which is equivalent to dividing the surface area of these strata by two. The overall proportion of the survey area in each stratum used in the stratified calculations can be found in Tables A3 and A4.

An additional subtlety in the computation of the stratified random estimate is how to deal with paired tows conducted during comparative fishing experiments. Since the paired tows took place at the same fishing station, and often at the same time, they can not be considered true independent samples. When paired tows are used in the stratified calculations, their catch values are averaged and they are considered as a single tow.

A.8. TABLES

Table A1. Conversion equations and factors used to develop the standardized index of Witch Flounder for the Gulf of St. Lawrence to Lady Hammond *Western IIA Night equivalents for the northern Gulf research vessel survey.*

August Northern Gulf of St. Lawrence Survey by DFO Quebec Region			
Type	**Conversion**	**Equation / conversion factor**	**Reference**
Vessel/gear conversion	*Alfred Needler* URI Night to *Lady Hammond* Western IIA Night	applies to lengths >= 23 cm $\beta_N = 0.6978$ $exp(\beta_N) = 2.009327$	Table 2 in Swain et al. (1998a)
Vessel/gear length-dependent conversion	*Alfred Needler* URI Night (AN) to *Lady Hammond* Western IIA Night (LH)	applies to lengths < 23 cm $N_l^{LH} = N_l^{AN} / e^{\beta_l}$ $\beta_l = 47.184\ exp(-0.3094\ l) - 0.3532$	Appendix B in Ricard and Swain (2018)
Vessel/gear length-dependent conversion	*Teleost* (T) Campelen Night to *Alfred Needler* URI Night	$N_l^{AN} = N_l^{T} e^{\alpha + \beta l}$ $\alpha = 1.4901844$ $\beta = 0.0163411$	pages 4 and 5 in Swain and Morin (2006)
Diurnal conversion	*Lady Hammond* Western IIA Day to *Lady Hammond* Western IIA Night	2.1	page 7 in Swain and Poirier (1998)
Diurnal conversion	*Alfred Needler* URI Day to *Alfred Needler* URI Night	1.6	page 7 in Swain and Poirier (1998)
Diurnal conversion	*Teleost* Campelen Day to *Teleost* Campelen Night	1.6	Swain and Morin (2006)

Table A2. Conversion equations and factors used to develop the standardized index of Witch Flounder for the Gulf of St. Lawrence to Lady Hammond *Western IIA Night equivalents for the southern Gulf research vessel survey.*

September Southern Gulf of St. Lawrence Survey by DFO Gulf Region			
Type	**Conversion**	**Equation / conversion factor**	**Reference**
Vessel/gear conversion	*Alfred Needler* URI Night to *Lady Hammond* Western IIA Night	1.0	Nielsen (1994)
Vessel/gear conversion	*Alfred Needler* Western IIA Night to *Lady Hammond* Western IIA Night	$\beta_N = 0.4101$ $1/exp(\beta_N) = 0.663$	Table 1 in Swain et al. (1998a)
Vessel/gear conversion	*Teleost* Western IIA Night to *Alfred Needler* Western IIA Night	1.0	Benoît (2006)
Diurnal conversion	*Lady Hammond* Western IIA Day to *Lady Hammond* Western IIA Night	2.1	page 7 in Swain and Poirier (1998)
Diurnal conversion	*Alfred Needler* Western IIA Day to *Alfred Needler* Western IIA Night	3.2	page 7 in Swain and Poirier (1998)
Diurnal conversion	*Teleost* Western IIA Day to *Teleost* Western IIA Night	3.2	Swain and Morin (2006)

Table A3. Stratum weights for the northern Gulf of St. Lawrence DFO Quebec Region survey used for the computation of the NAFO 4RST combined index. Shading identifies the strata that overlap between the two surveys and for which the area of each stratum is multiplied by a weighting of 0.5 in the stratified calculations.

Stratum	Area (km^2)	Weight	Proportion
401	545	0.5	0.0016916
402	909	0.5	0.0028214
403	1,190	0.5	0.0036935
404	792	0.5	0.0024582
405	1,478	0.5	0.0045874
406	2,579	0.5	0.0080047
407	2,336	1	0.0145010
408	2,734	1	0.0169717
409	909	1	0.0056427
410	1,818	1	0.0112855
411	1,859	1	0.0115400
412	1,283	1	0.0079644
413	731	1	0.0045378
414	388	1	0.0024086
801	1,214	1	0.0075361
802	1,369	1	0.0084982
803	6,976	1	0.0433044
804	2,490	1	0.0154570
805	5,762	1	0.0357684
806	2,127	1	0.0132036
807	2,370	1	0.0147121
808	2,428	1	0.0150721
809	1,547	1	0.0096032
810	765	1	0.0047488
811	1,506	1	0.0093487
812	4,648	1	0.0288531
813	3,958	1	0.0245698
814	1,029	1	0.0063877
815	4,407	1	0.0273570
816	5,032	1	0.0312368
817	3,646	1	0.0226330
818	2,774	1	0.0172200
819	1,441	1	0.0089452
820	1,358	1	0.0084300
821	1,272	1	0.0078961
822	3,245	1	0.0201438
823	556	1	0.0034514
824	837	1	0.0051958
827	3,231	1	0.0200569
828	2,435	1	0.0151156
829	2,692	1	0.0167109
830	1,917	1	0.0119000
831	1,204	1	0.0074740
832	3,962	1	0.0245946

Table A4. Stratum weights for the southern Gulf of St. Lawrence DFO Gulf Region survey used for the computation of the NAFO 4RST combined index. Shading identifies the strata that overlap between the two surveys and for which the area of each stratum is multiplied by a weighting of 0.5 in the stratified calculations.

Stratum	Area (km^2)	Weight	Proportion
415	2,625	0.5	0.0081475
416	3,666	1	0.0227572
417	1,804	1	0.0111986
418	1,354	1	0.0084051
419	1,522	1	0.0094480
420	2,656	1	0.0164875
421	1,130	1	0.0070146
422	4,274	1	0.0265314
423	11,033	1	0.0684888
424	3,608	1	0.0223971
425	2,165	0.5	0.0067198
426	1,333	1	0.0082748
427	3,268	1	0.0202865
428	694	1	0.0043081
429	5,827	1	0.0361719
431	4,876	1	0.0302684
432	1,034	1	0.0064187
433	4,082	1	0.0253396
434	4,161	1	0.0258300
435	2,196	1	0.0136320
436	3,292	1	0.0204355
437	1,701	1	0.0105592
438	577	1	0.0035818
439	1,213	0.5	0.0037649

Table A5. Number of valid tows by stratum for all years and strata sampled in the northern Gulf of St. Lawrence August survey, 1987 to 2003. Shaded cells show stratum and year combinations with zero valid tow.

survey	stratum	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
August	401	2	3	3	6	4	4	4	3	3	3	3	3	3	3	3	3	3
August	402	2	3	3	6	5	5	3	3	1	3	2	3	5	3	3	3	2
August	403	2	3	3	4	3	3	3	3	3	10	10	3	5	3	3	3	3
August	404	2	3	3	6	3	3	3	3	3	3	3	3	3	3	3	3	3
August	405	2	3	3	6	3	3	3	3	3	3	2	4	4	4	3	3	3
August	406	4	6	5	5	3	3	3	3	3	5	5	3	5	3	4	5	3
August	407	3	5	5	10	3	3	3	3	3	3	3	2	3	3	3	3	5
August	408	5	5	5	7	5	5	3	2	3	3	2	5	5	4	3	3	3
August	409	2	3	3	3	3	3	3	0	3	4	3	3	4	4	4	3	3
August	410	0	3	3	2	3	3	3	4	6	10	6	5	4	4	4	5	3
August	411	2	3	0	3	3	3	3	4	7	9	7	6	9	5	9	4	3
August	412	2	3	0	3	3	3	3	4	5	3	3	3	4	4	4	3	3
August	413	2	3	0	3	4	3	3	0	3	3	4	3	4	4	4	3	3
August	414	2	3	0	3	2	3	3	1	3	3	3	3	4	4	4	3	3
August	801	2	3	3	6	3	3	4	3	3	3	3	4	5	5	5	2	3
August	802	2	3	3	6	3	3	3	3	3	3	3	3	3	3	3	2	8
August	803	12	13	10	23	3	2	4	3	3	3	3	4	5	3	4	6	2
August	804	3	4	4	5	4	3	3	4	3	3	3	3	3	3	6	3	2
August	805	10	12	8	14	7	4	4	6	4	11	8	4	5	5	5	12	8
August	806	5	4	3	4	4	3	3	3	3	3	3	3	3	3	3	3	3
August	807	4	4	4	3	12	11	10	5	5	4	4	3	3	4	3	2	1
August	808	4	4	3	8	7	6	4	5	4	3	3	2	4	3	3	3	3
August	809	2	3	3	6	9	7	6	4	3	3	3	3	3	3	3	3	3
August	810	2	3	3	6	4	5	4	3	3	3	3	4	4	4	4	6	5
August	811	2	3	3	6	4	4	4	5	3	8	6	3	3	3	3	3	3
August	812	10	7	6	14	9	8	11	4	3	3	3	3	3	3	3	3	3
August	813	8	6	5	12	6	5	9	3	4	6	5	7	4	6	8	2	5
August	814	2	3	3	6	4	4	4	3	0	3	3	3	3	3	3	3	3
August	815	9	8	6	9	15	11	8	5	4	3	3	8	9	9	2	6	3
August	816	10	9	7	9	11	9	9	6	6	17	17	20	21	21	1	6	4
August	817	6	8	6	7	18	11	7	9	10	9	5	11	17	13	14	8	5
August	818	4	4	5	4	7	5	4	3	3	3	4	4	4	4	5	7	5
August	819	4	3	3	5	7	9	5	4	5	3	2	3	3	4	1	1	3
August	820	2	3	3	6	3	3	3	3	3	7	5	6	5	5	3	2	3
August	821	2	3	3	6	3	3	3	2	3	3	2	3	3	3	3	3	3
August	822	6	6	5	12	4	3	2	3	3	6	4	10	8	10	9	3	3
August	823	2	3	3	6	3	3	3	2	3	2	3	1	3	2	3	2	5
August	824	2	3	3	6	1	3	1	3	3	3	3	3	3	2	3	2	2
August	827	5	4	0	0	1	1	1	3	3	0	2	3	1	3	0	2	2
August	828	2	4	3	4	1	2	2	3	3	3	3	3	1	0	1	0	3

survey	stratum	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
August	829	6	5	3	3	2	3	3	3	3	3	0	3	3	2	0	2	1
August	830	4	4	4	3	3	4	3	3	3	2	2	3	3	3	2	1	1
August	831	2	3	3	3	0	2	3	3	3	3	2	3	4	3	3	1	3
August	832	7	7	6	4	12	11	7	7	9	8	5	3	3	3	3	2	3
	all	173	198	160	273	217	198	180	152	160	199	171	185	204	189	163	148	144

Table A6. Number of valid tows by stratum for all years and strata sampled in the northern Gulf of St. Lawrence August survey, 2004 to 2021. Shaded cells show stratum and year combinations with zero valid tow.

survey	stratum	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
August	401	3	6	3	3	3	3	0	3	3	2	2	3	2	2	2	2	1	2
August	402	0	3	3	3	3	3	3	3	3	3	2	3	2	2	2	2	2	2
August	403	6	4	3	3	3	3	3	3	3	2	2	3	2	2	1	2	2	1
August	404	3	6	3	3	3	3	0	3	3	3	2	3	2	2	2	2	2	2
August	405	2	9	3	3	3	3	3	3	3	3	2	3	2	2	2	2	2	2
August	406	5	6	4	4	4	3	3	3	4	3	3	4	4	4	3	3	4	4
August	407	3	5	3	3	3	3	0	3	3	2	4	4	2	3	4	3	3	3
August	408	2	11	4	4	4	4	3	3	4	3	4	4	2	4	3	2	2	2
August	409	3	4	3	3	3	3	3	3	2	3	2	2	2	2	2	2	2	2
August	410	3	6	3	3	3	3	3	3	3	3	3	3	3	3	2	2	3	3
August	411	5	8	3	3	3	3	3	3	3	3	3	2	3	3	3	2	3	3
August	412	2	5	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2
August	413	1	5	3	3	3	3	3	3	3	2	2	2	2	2	2	2	1	2
August	414	3	6	3	3	2	1	3	3	2	3	2	2	2	0	2	1	0	2
August	801	3	4	3	3	3	3	2	3	3	3	3	3	2	3	3	3	2	2
August	802	3	8	2	3	3	3	0	3	3	3	3	3	2	3	3	3	2	2
August	803	1	14	6	8	8	7	3	6	7	3	10	8	5	8	8	4	4	5
August	804	3	10	3	3	3	3	3	3	3	3	4	4	4	4	3	3	3	3
August	805	4	10	8	7	7	6	4	5	7	5	7	7	9	7	5	6	6	8
August	806	5	4	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3
August	807	0	7	3	3	3	3	3	2	3	3	4	4	4	4	3	2	3	2
August	808	0	3	3	3	3	3	2	3	3	2	4	4	4	4	4	0	2	3
August	809	1	5	3	3	3	3	3	3	2	3	3	3	4	3	3	0	3	2
August	810	3	8	3	3	4	3	0	3	3	2	3	2	2	2	2	1	1	2
August	811	3	7	3	3	3	2	2	2	3	2	2	2	2	2	2	0	2	2
August	812	4	5	5	4	5	4	5	3	5	3	8	7	6	6	5	6	5	5
August	813	3	9	5	3	5	3	4	4	6	3	6	6	4	3	5	5	6	4
August	814	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2
August	815	3	14	5	5	6	5	5	3	6	4	6	7	6	6	5	6	4	7
August	816	4	11	7	7	7	6	4	4	3	6	6	8	7	7	5	6	4	6
August	817	2	7	5	5	4	5	3	3	4	4	5	4	6	6	5	5	6	5
August	818	1	6	4	4	2	4	3	4	3	3	4	5	4	5	4	4	5	1
August	819	0	8	2	3	3	2	3	3	3	3	2	2	2	2	2	1	2	0
August	820	3	14	3	3	3	3	0	2	3	3	3	3	2	3	3	0	2	3
August	821	3	7	3	3	3	3	2	4	3	3	3	2	2	3	3	0	2	1
August	822	3	8	4	4	4	3	4	2	4	2	5	3	4	2	3	4	5	4
August	823	2	10	3	3	3	3	2	3	3	3	3	3	2	2	3	3	2	2
August	824	3	6	3	3	3	3	2	3	3	2	2	2	1	2	2	2	2	2
August	827	3	6	4	4	3	3	3	2	3	2	2	3	3	3	4	0	2	3
August	828	3	1	3	3	3	3	3	2	2	2	2	2	2	4	4	3	2	3
August	829	0	8	4	4	3	2	3	2	2	3	2	4	3	2	3	1	2	3

survey	stratum	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
August	830	0	6	3	3	3	3	3	3	2	3	2	4	4	3	3	3	2	2
August	831	3	4	3	3	3	3	3	3	3	2	2	2	2	2	2	1	2	2
August	832	4	8	4	5	5	3	4	3	6	4	4	4	3	5	5	4	5	4
	all	114	305	157	158	156	144	117	134	149	128	150	156	138	144	139	110	122	125

Table A7. Number of valid tows by stratum for all years and strata sampled in the southern Gulf of St. Lawrence September survey, 1987 to 2003. Shaded cells show stratum and year combinations with zero valid tow.

survey	stratum	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
September	415	6	8	6	5	7	5	5	5	5	7	7	6	6	6	5	6	3
September	416	9	13	7	8	9	9	9	8	8	9	8	8	8	8	7	9	3
September	417	7	10	6	4	5	5	5	4	5	5	5	5	4	4	4	4	2
September	418	6	10	6	3	4	4	4	3	4	4	5	4	3	4	3	4	2
September	419	4	6	6	3	4	4	3	3	4	4	4	4	3	4	3	4	2
September	420	6	5	5	5	7	7	7	6	7	9	12	6	6	6	5	6	3
September	421	3	0	3	2	3	4	4	3	4	3	5	3	3	4	3	3	2
September	422	11	10	11	9	10	11	12	10	12	12	14	11	10	10	7	11	4
September	423	17	6	19	20	22	23	25	22	22	23	26	22	22	22	14	22	10
September	424	6	4	7	7	9	8	10	8	8	9	8	8	8	8	8	8	3
September	425	3	6	4	3	5	4	5	4	5	6	5	5	5	5	4	5	1
September	426	3	6	4	3	3	3	4	3	3	5	4	3	3	3	2	4	2
September	427	5	2	8	6	7	7	8	7	7	8	7	7	7	7	6	7	3
September	428	3	4	4	2	3	3	4	2	3	4	4	3	3	3	3	3	2
September	429	7	7	13	11	17	14	16	13	14	13	14	13	13	13	11	14	7
September	431	5	6	11	10	14	10	12	10	13	12	12	11	12	11	11	12	6
September	432	2	6	3	3	4	3	3	3	4	6	5	3	4	4	3	4	2
September	433	18	8	11	9	11	9	9	9	11	13	16	27	18	18	10	10	7
September	434	9	7	8	7	14	8	10	8	10	12	13	9	9	9	9	9	7
September	435	5	4	4	4	6	4	6	6	6	6	6	5	5	5	5	6	3
September	436	6	5	8	7	10	7	9	7	8	8	7	7	7	7	7	9	1
September	437	5	6	5	4	6	4	4	4	4	6	6	11	10	10	4	6	3
September	438	3	4	3	3	4	3	4	3	4	5	5	3	3	3	3	3	0
September	439	3	4	4	3	4	3	5	3	4	5	4	8	8	8	4	4	0
	all	152	147	166	141	188	162	183	154	175	194	202	192	180	182	141	173	78

Table A8. Number of valid tows by stratum for all years and strata sampled in the southern Gulf of St. Lawrence September survey, 2004 to 2021. Shaded cells show stratum and year combinations with zero valid tow.

survey	**stratum**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
September	415	9	6	6	6	7	6	5	4	5	4	6	6	6	6	5	4	5	8
September	416	12	16	8	8	8	8	8	6	5	6	8	8	8	6	8	5	4	9
September	417	7	7	4	4	5	4	4	3	4	3	4	4	4	3	4	3	3	4
September	418	7	5	4	3	4	4	3	3	3	3	3	3	3	3	3	3	3	4
September	419	7	6	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	5
September	420	6	10	6	7	6	6	5	4	5	5	6	5	6	4	3	4	5	7
September	421	3	3	3	2	3	3	3	3	3	3	3	3	4	3	3	3	0	2
September	422	11	18	10	11	9	9	9	8	9	9	10	10	8	7	3	6	4	9
September	423	37	34	23	21	23	18	16	14	16	13	17	17	17	14	4	12	5	13
September	424	9	12	8	8	9	7	7	7	8	5	8	8	8	6	7	5	4	9
September	425	5	8	5	5	6	4	3	4	5	3	5	5	5	4	3	5	4	7
September	426	3	3	3	3	4	3	3	3	3	3	4	5	4	2	3	3	3	4
September	427	7	8	7	7	8	6	6	6	7	3	7	7	7	5	3	5	3	7
September	428	2	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
September	429	14	16	12	13	13	11	11	9	12	10	13	13	11	4	4	6	3	7
September	431	15	11	10	11	11	9	8	9	9	9	11	11	9	4	4	6	4	8
September	432	8	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	4
September	433	16	13	10	10	11	9	6	7	8	9	9	9	8	9	8	7	5	9
September	434	10	15	10	10	10	7	9	7	8	9	9	9	9	6	4	6	4	9
September	435	5	4	5	5	6	4	4	4	5	2	5	6	5	3	4	5	5	5
September	436	7	7	7	6	8	6	7	6	7	3	7	8	7	8	5	6	4	8
September	437	5	10	6	5	6	5	4	4	5	5	5	6	6	4	5	4	3	6
September	438	3	5	3	3	4	4	3	3	3	3	4	4	3	3	3	3	3	4
September	439	4	6	4	4	5	4	3	3	3	3	3	5	3	3	4	4	3	5
	all	212	231	165	163	177	148	137	126	142	122	156	161	150	116	99	114	86	156

Table A9. Mean numbers per tow (in Lady Hammond *night tow with a Western IIA trawl equivalent) for all strata sampled in the northern and southern Gulf of St. Lawrence RV surveys, 1987 to 1998.*

survey	stratum	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
August	401	2.10	5.33	2.35	4.60	1.13	2.23	0.00	2.37	3.98	1.48	5.35	7.64
August	402	14.70	7.27	5.32	63.29	59.97	3.33	0.00	1.61	0.00	7.64	0.00	16.64
August	403	7.35	71.03	6.00	16.59	19.00	2.14	8.44	20.50	16.17	10.22	7.10	38.76
August	404	14.05	5.60	3.17	4.86	0.00	0.98	1.00	0.00	4.26	1.00	0.00	0.00
August	405	12.60	7.00	1.45	3.00	1.34	0.00	0.00	0.00	1.61	1.61	2.41	0.75
August	406	2.75	5.24	1.45	4.33	0.98	1.40	0.00	5.18	0.00	0.00	0.00	4.68
August	407	9.70	13.01	13.01	11.71	6.36	1.61	0.00	0.00	6.60	1.61	20.58	1.51
August	408	6.57	5.54	2.43	7.80	9.86	2.59	0.61	0.00	13.15	1.95	7.51	19.40
August	409	53.25	44.47	27.74	113.73	105.97	97.80	5.82	NA	104.07	30.13	17.46	35.68
August	410	NA	15.60	11.83	4.52	22.40	2.63	3.21	27.12	22.35	8.28	6.55	14.03
August	411	64.20	19.95	NA	71.17	99.48	227.06	35.13	94.24	73.64	32.09	35.12	27.38
August	412	64.50	36.56	NA	59.22	152.39	283.87	113.94	464.58	34.41	32.15	63.39	38.95
August	413	72.95	20.54	NA	51.22	82.57	122.52	5.47	NA	34.51	26.67	23.40	15.63
August	414	8.40	35.73	NA	53.27	99.22	26.23	4.28	508.47	14.66	5.02	1.61	1.85
August	801	12.60	9.80	7.11	26.68	14.99	7.73	0.00	13.57	9.10	6.66	12.19	19.74
August	802	12.40	24.33	9.93	11.52	6.32	0.00	0.00	0.00	1.61	9.86	12.23	1.54
August	803	8.62	9.63	9.78	10.82	15.32	0.00	0.00	5.40	8.41	2.61	8.86	4.82
August	804	8.17	8.62	5.64	0.00	2.01	2.41	1.26	1.21	4.26	22.19	0.00	5.85
August	805	15.54	8.25	2.28	16.86	15.53	18.75	15.41	15.74	16.94	6.17	0.38	5.12
August	806	6.04	9.69	0.70	7.29	3.21	0.00	1.10	5.04	2.37	6.02	0.00	12.36
August	807	3.62	5.91	2.60	3.86	6.39	0.58	0.52	0.00	2.12	8.38	3.69	0.00
August	808	8.40	10.72	2.91	6.07	2.76	0.67	1.94	0.96	3.38	0.00	1.00	0.00
August	809	14.70	8.43	1.98	4.43	6.02	0.00	0.00	0.00	1.61	1.00	10.28	4.20
August	810	24.15	13.67	5.57	8.85	1.51	3.66	0.95	0.00	2.19	1.00	1.66	4.68
August	811	7.75	1.67	1.67	2.61	6.83	7.77	0.00	3.70	11.55	5.68	3.03	26.75
August	812	4.90	4.64	2.12	6.30	0.85	8.58	0.29	0.75	3.21	0.00	6.55	1.05
August	813	13.60	3.71	3.62	2.80	4.85	0.00	0.00	0.00	5.69	1.43	16.94	6.09
August	814	4.00	5.12	1.58	3.79	8.75	2.03	0.00	1.00	NA	1.00	2.05	0.00
August	815	7.00	3.69	2.31	1.59	1.86	1.97	0.58	1.31	6.84	95.15	4.76	2.48
August	816	6.44	9.08	4.21	25.98	10.19	3.56	2.49	0.49	4.88	62.25	5.37	4.26
August	817	16.03	10.38	7.56	16.29	59.10	11.13	2.15	8.02	4.39	13.69	2.53	10.14
August	818	20.85	9.52	9.44	8.54	8.45	0.80	2.03	3.85	3.12	8.48	3.78	3.62
August	819	5.08	4.78	1.40	2.76	4.37	5.70	0.43	0.00	5.26	41.77	1.39	3.36
August	820	9.50	18.04	0.70	6.13	10.55	27.10	0.00	0.00	0.00	2.31	0.96	9.02
August	821	1.00	1.96	4.00	3.30	2.68	1.34	0.00	0.00	3.01	4.02	18.08	0.00
August	822	6.30	5.60	5.46	12.23	4.82	2.41	4.93	0.00	11.65	2.01	1.51	9.63
August	823	54.00	38.28	25.33	7.00	2.68	2.41	0.00	0.00	0.00	2.05	7.76	0.00
August	824	48.50	5.46	4.83	5.36	0.00	0.00	0.00	3.01	1.37	0.00	0.00	0.86
August	827	3.64	4.99	NA	NA	0.00	0.00	0.00	1.00	4.02	NA	18.08	18.62
August	828	0.50	13.76	12.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00

survey	stratum	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
August	829	0.00	6.21	6.79	10.72	6.03	1.21	0.00	0.00	0.73	0.00	NA	1.61
August	830	0.00	3.34	1.89	13.70	0.00	5.02	0.00	0.00	0.00	0.00	0.00	3.01
August	831	10.00	18.53	8.11	3.03	NA	6.03	0.00	1.00	1.21	1.10	0.00	0.00
August	832	41.53	40.60	45.09	137.88	36.94	0.00	15.41	20.33	1.16	1.50	0.60	0.00
September	415	17.25	29.12	1.41	4.41	3.46	5.20	10.30	10.24	8.47	9.11	3.68	63.19
September	416	12.04	20.22	11.99	12.44	5.72	5.08	8.14	17.49	11.70	7.37	3.91	7.49
September	417	1.58	13.32	3.37	5.61	0.87	2.89	1.67	0.00	0.41	0.46	0.00	0.00
September	418	2.04	0.58	2.28	0.00	0.00	0.00	0.15	0.73	0.00	0.00	0.00	0.00
September	419	3.12	0.38	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00
September	420	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	421	0.64	NA	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	422	0.74	0.00	0.19	5.19	1.67	0.38	0.39	0.75	0.22	0.06	0.04	0.09
September	423	0.27	0.00	0.95	0.41	0.77	0.12	0.03	0.25	0.03	0.03	0.00	0.24
September	424	0.68	1.80	0.88	2.50	1.28	0.08	0.56	0.40	0.34	0.44	0.00	0.00
September	425	10.37	11.31	1.26	2.37	7.08	7.30	5.60	5.76	4.05	33.56	6.63	14.13
September	426	1.63	0.90	7.00	0.00	7.79	6.18	14.20	2.96	20.45	20.05	16.38	1.09
September	427	0.00	0.00	0.00	1.02	0.62	0.76	0.00	0.13	0.09	0.45	0.30	0.00
September	428	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00
September	429	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	431	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	432	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	433	0.49	0.00	2.81	0.00	2.85	0.00	0.00	0.43	0.07	0.00	0.33	0.10
September	434	0.00	0.34	7.25	0.62	0.75	0.34	0.13	6.44	0.06	3.26	1.20	5.17
September	435	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00
September	436	0.00	0.00	0.00	0.29	0.22	0.00	0.00	0.55	0.24	0.00	0.00	0.31
September	437	13.44	20.34	38.16	25.76	6.28	1.99	19.37	37.60	25.94	93.37	30.62	42.67
September	438	2.45	0.00	0.99	2.11	4.69	3.59	9.85	2.84	1.94	9.31	7.65	30.92
September	439	1.45	4.41	3.80	10.23	1.34	1.18	0.55	5.09	3.92	1.08	2.52	4.71

Table A10. Mean numbers per tow (in Lady Hammond *night tow with a Western IIA trawl equivalent) for all strata sampled in the northern and southern Gulf of St. Lawrence RV surveys, 1999 to 2010.*

survey	stratum	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
August	401	9.56	4.74	14.63	129.17	6.16	19.74	10.40	6.80	9.54	2.55	14.63	NA
August	402	30.12	21.52	4.04	5.56	7.59	NA	25.81	19.33	28.38	37.92	2.86	12.23
August	403	24.63	79.60	43.00	8.81	75.25	18.42	26.50	12.55	51.24	22.83	26.30	60.29
August	404	2.01	1.00	1.00	14.25	9.64	10.24	4.88	8.41	1.62	12.94	7.26	NA
August	405	0.00	8.15	2.01	0.93	1.00	3.97	6.83	6.83	13.06	17.68	16.96	17.48
August	406	6.30	25.78	10.82	3.24	16.32	3.18	7.52	2.80	23.83	5.64	12.12	5.87
August	407	10.66	27.37	20.34	17.46	22.56	19.65	27.79	27.91	8.91	10.71	7.81	NA
August	408	16.14	26.39	27.10	9.32	48.81	15.38	21.68	13.27	26.35	36.61	8.31	26.07
August	409	9.99	108.46	165.88	13.75	45.68	23.21	27.91	48.71	22.26	74.16	46.13	119.91
August	410	3.54	20.64	16.98	3.17	64.83	11.11	11.02	14.52	10.39	6.81	12.19	36.73
August	411	23.08	128.45	66.39	12.61	96.11	32.17	33.77	39.51	35.94	43.50	34.57	78.94
August	412	42.99	88.66	63.80	10.39	62.73	13.59	52.18	31.99	30.75	73.04	81.01	67.69
August	413	18.71	44.37	60.19	6.48	138.04	98.39	28.72	46.55	70.95	64.59	70.31	92.74
August	414	1.45	38.90	77.72	3.52	0.00	1.63	1.34	0.99	21.13	1.71	0.37	88.58
August	801	10.42	34.19	17.00	2.31	7.89	5.97	3.75	3.66	2.63	5.63	18.10	18.14
August	802	4.07	7.67	4.15	1.51	15.49	10.77	2.95	2.24	6.95	5.18	0.76	NA
August	803	23.35	52.61	16.28	30.18	15.09	9.54	15.26	15.75	11.88	10.87	4.49	21.08
August	804	26.24	16.17	15.86	2.52	33.74	29.98	12.41	6.77	18.57	15.23	14.05	10.23
August	805	2.91	18.15	9.19	2.93	46.56	10.06	8.59	10.34	11.53	11.99	14.58	18.48
August	806	19.97	10.74	9.67	12.96	15.59	19.97	15.12	8.46	29.58	4.79	4.72	7.35
August	807	10.30	13.59	6.68	0.00	9.64	NA	5.95	2.80	17.49	15.45	10.59	6.38
August	808	0.75	1.00	0.00	0.00	8.94	NA	3.21	4.23	1.21	1.18	3.82	0.87
August	809	1.61	8.62	2.61	9.42	11.67	20.10	7.88	3.84	8.16	1.55	1.49	3.76
August	810	2.41	22.38	2.69	1.00	14.72	4.32	10.74	8.55	10.77	3.56	10.77	NA
August	811	7.46	28.04	3.93	3.38	39.30	16.47	9.17	4.28	7.11	29.19	7.74	21.22
August	812	4.80	37.99	10.01	1.54	12.83	7.58	12.36	7.94	6.55	5.81	3.58	6.69
August	813	16.55	61.81	18.74	2.41	12.08	6.15	5.52	4.55	10.51	2.70	8.87	5.03
August	814	4.94	18.76	6.00	0.00	5.96	4.61	18.62	5.14	13.72	1.61	1.49	1.93
August	815	30.32	10.54	4.52	5.42	6.40	5.09	6.31	11.71	7.80	15.43	5.83	10.27
August	816	16.67	6.99	0.00	0.57	16.54	25.11	19.07	15.07	18.81	5.63	22.08	25.30
August	817	4.72	37.14	22.60	3.57	26.14	29.31	15.58	5.98	19.82	20.48	23.66	33.86
August	818	18.29	14.61	7.04	4.04	36.80	6.07	8.44	4.00	13.21	4.53	4.71	10.18
August	819	6.18	5.57	9.04	2.00	10.01	NA	3.02	5.47	2.59	3.33	2.48	4.07
August	820	7.23	22.73	7.36	1.51	16.07	1.62	15.71	5.18	8.04	15.74	16.41	NA
August	821	15.07	13.06	3.21	1.10	1.00	6.07	2.48	5.85	4.99	5.97	4.68	29.53
August	822	14.83	15.08	11.12	0.00	17.02	6.63	3.92	14.88	8.35	11.99	3.84	14.67
August	823	103.72	24.11	13.42	1.51	40.76	0.84	13.66	8.85	16.05	10.57	33.89	58.00
August	824	11.15	12.46	0.00	0.00	0.00	0.30	2.03	1.24	3.89	4.24	1.84	3.18
August	827	23.89	4.38	NA	4.52	5.07	0.84	0.63	4.58	4.28	8.93	20.34	2.89
August	828	0.00	NA	0.00	NA	0.00	1.07	0.91	0.00	0.00	0.00	4.84	1.75

survey	stratum	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
August	829	5.83	1.51	NA	0.00	0.00	NA	0.00	0.00	3.51	0.00	0.00	0.50
August	830	0.00	1.61	0.00	0.00	9.04	NA	3.75	0.00	0.68	5.30	1.90	1.61
August	831	0.75	1.98	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.22	4.28	0.00
August	832	0.00	30.30	0.00	0.00	5.10	3.35	0.55	1.18	0.71	2.16	0.00	28.75
September	415	15.96	23.85	11.80	39.56	12.62	8.80	10.06	11.58	10.41	16.91	20.93	37.19
September	416	1.45	1.23	1.61	1.13	0.32	0.26	0.00	3.67	8.50	9.24	9.10	8.29
September	417	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	418	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	419	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	420	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	421	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	422	0.00	0.06	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.07	0.00	0.00
September	423	0.03	0.00	0.00	0.06	0.00	0.00	0.08	0.03	0.08	0.03	0.00	0.00
September	424	0.16	0.27	0.00	0.49	0.22	0.07	0.75	0.16	0.00	0.29	0.47	0.00
September	425	4.07	10.21	63.42	48.03	17.05	4.64	17.03	52.70	18.41	8.44	25.16	20.31
September	426	0.90	23.67	0.64	2.81	1.00	6.31	3.26	0.00	5.09	23.07	15.58	8.95
September	427	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.27	0.08	0.00	0.00
September	428	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	429	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	431	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.90	0.00	0.00	0.00	0.00
September	432	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	433	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00
September	434	0.23	0.23	1.91	1.52	0.18	1.44	3.93	3.24	1.54	0.85	2.60	0.00
September	435	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	436	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.60	0.00	1.65	0.00	0.38
September	437	410.87	164.43	68.73	208.53	42.84	44.23	110.33	25.43	8.24	130.83	20.75	15.52
September	438	1.36	3.60	7.08	14.71	NA	13.74	7.75	2.07	1.12	3.05	5.25	13.15
September	439	0.16	7.95	3.26	9.48	NA	1.90	8.70	4.59	1.88	7.78	4.40	7.20

Table A11. Mean numbers per tow (in Lady Hammond *night tow with a Western IIA trawl equivalent) for all strata sampled in the northern and southern Gulf of St. Lawrence RV surveys, 2011 to 2021.*

survey	stratum	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
August	401	9.08	8.45	15.12	5.92	4.85	2.67	4.60	4.32	37.04	31.32	70.42
August	402	10.84	19.34	13.49	5.71	6.18	6.11	5.00	26.27	133.45	45.18	16.29
August	403	34.17	114.78	40.07	48.66	49.22	7.85	8.45	143.74	265.07	44.64	93.18
August	404	11.94	8.33	23.67	9.39	11.59	12.43	5.75	8.77	8.02	10.82	10.13
August	405	10.43	13.66	14.05	2.86	12.63	11.11	7.92	12.22	21.02	4.84	4.73
August	406	6.90	13.87	41.25	7.96	24.44	14.42	16.21	28.94	17.65	4.74	12.84
August	407	9.75	9.85	5.23	4.57	10.40	12.45	9.76	5.20	6.09	5.91	6.31
August	408	14.65	28.12	27.11	32.15	9.14	7.80	11.82	7.19	8.08	13.87	14.84
August	409	59.15	51.10	95.10	41.09	86.29	69.27	181.03	96.25	106.49	193.27	45.00
August	410	33.17	49.04	39.03	27.04	23.14	28.75	31.44	18.72	36.28	10.10	50.04
August	411	120.57	99.00	141.37	79.63	48.74	66.45	53.18	60.89	64.64	54.62	73.97
August	412	70.90	85.73	172.07	46.81	29.68	73.08	100.53	90.10	98.52	91.15	82.21
August	413	95.38	64.76	113.95	81.69	60.62	162.86	94.48	81.05	50.50	20.47	57.33
August	414	124.84	237.28	57.59	56.59	5.07	73.48	NA	2.36	0.00	NA	0.00
August	801	4.75	11.19	8.25	11.04	4.68	8.67	8.14	50.12	13.33	14.70	10.26
August	802	1.96	13.59	7.49	9.74	4.67	11.16	21.21	1.75	8.83	8.40	3.76
August	803	8.66	17.44	12.58	9.84	2.91	5.62	5.58	7.91	17.39	4.32	3.79
August	804	10.17	34.07	15.84	13.55	23.52	20.18	8.52	5.97	9.32	3.42	11.60
August	805	11.43	19.90	16.88	11.61	16.34	13.39	11.72	6.93	34.11	15.05	13.69
August	806	26.26	31.23	5.30	28.74	21.38	7.54	11.64	10.93	20.63	13.02	46.27
August	807	8.46	23.05	5.04	7.74	5.50	0.67	10.31	1.78	0.00	3.39	5.78
August	808	0.60	1.93	1.79	2.15	0.90	2.98	1.85	1.84	NA	1.63	2.78
August	809	0.38	4.49	1.12	3.00	2.16	1.40	3.08	2.31	NA	1.78	1.36
August	810	4.41	2.64	4.70	6.56	6.40	1.73	2.06	1.23	1.42	0.00	3.50
August	811	3.30	9.77	18.61	1.25	2.35	1.52	1.86	0.58	NA	0.59	11.21
August	812	4.16	2.10	3.86	7.68	2.20	6.65	2.45	3.69	6.22	16.51	13.09
August	813	3.55	3.59	8.48	5.88	9.62	11.27	12.97	16.55	23.09	19.62	13.11
August	814	2.88	5.39	2.90	1.64	2.64	4.36	0.63	2.64	6.91	5.82	5.11
August	815	12.32	7.29	39.77	4.80	20.36	9.04	5.67	5.23	14.70	13.46	10.28
August	816	19.03	8.64	12.32	16.04	11.18	12.01	14.89	7.92	13.19	18.53	9.10
August	817	7.66	42.96	25.67	10.59	5.36	7.21	20.02	4.18	10.33	25.36	23.43
August	818	8.89	12.62	10.77	7.96	6.97	14.26	38.82	7.37	47.73	52.68	55.86
August	819	0.57	1.60	2.41	1.16	2.07	1.85	3.83	3.03	0.00	0.00	NA
August	820	18.57	32.80	47.42	52.28	27.20	17.16	58.87	165.39	NA	19.38	32.16
August	821	5.94	5.81	17.59	2.82	26.38	31.54	2.34	3.97	NA	55.69	3.75
August	822	1.99	11.69	1.74	8.43	17.24	24.64	8.43	14.92	32.31	30.50	14.15
August	823	13.13	32.00	27.87	43.22	23.90	69.77	165.48	153.75	81.55	122.51	12.20
August	824	1.85	0.41	0.66	0.52	10.06	6.56	2.38	10.60	12.55	10.70	5.29
August	827	3.10	0.50	22.77	12.27	11.76	9.20	2.88	3.77	NA	14.90	10.38
August	828	11.47	0.47	0.00	19.50	0.00	0.00	5.63	0.43	6.50	0.42	4.84

survey	stratum	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
August	829	0.00	0.00	1.10	0.00	5.82	6.72	0.00	0.59	0.00	5.94	15.99
August	830	0.00	0.00	8.13	8.41	2.95	6.41	14.45	5.11	0.52	50.72	4.37
August	831	0.00	4.12	0.71	0.73	7.33	3.19	12.78	0.00	4.58	0.62	0.30
August	832	1.15	2.88	12.73	25.55	5.81	18.58	15.18	17.00	0.56	0.93	1.63
September	415	48.05	34.80	15.66	14.02	11.10	16.19	103.76	57.93	52.83	190.12	49.56
September	416	3.21	16.36	6.99	18.00	22.28	41.12	9.14	4.50	8.37	2.10	0.76
September	417	0.00	0.00	0.00	0.00	2.08	0.52	0.69	0.00	0.00	0.00	0.00
September	418	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	419	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	420	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	421	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	0.00
September	422	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	423	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
September	424	0.00	0.18	0.19	0.89	0.76	0.20	0.33	0.00	0.13	0.00	0.07
September	425	24.81	31.69	82.56	9.85	11.19	43.54	58.55	28.46	112.21	78.62	46.47
September	426	0.91	3.63	75.28	1.22	1.33	1.12	0.33	0.21	0.00	0.00	0.00
September	427	0.00	0.13	0.00	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	428	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	429	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	431	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	432	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	433	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	434	0.10	0.45	1.26	0.29	1.38	0.59	1.32	1.15	0.33	0.00	0.50
September	435	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	436	0.00	0.67	0.47	1.70	0.26	0.40	0.08	0.00	0.00	0.00	0.36
September	437	48.47	20.57	22.68	39.90	17.08	52.22	42.81	10.61	11.97	11.23	55.86
September	438	49.46	5.36	19.47	8.09	26.75	6.23	24.04	0.66	0.59	9.76	1.93
September	439	16.34	55.10	36.80	23.03	11.37	37.11	7.51	6.54	3.13	4.02	66.45

Table A12. Mean kg per tow of individuals greater than 30 cm (in Lady Hammond *night tow with a Western IIA trawl equivalent) for all strata sampled in the northern and southern Gulf of St. Lawrence RV surveys, 1987 to 1998.*

survey	stratum	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
August	401	0.22	1.50	0.68	0.48	0.00	0.00	0.00	0.00	0.79	0.47	0.54	2.82
August	402	5.26	2.04	1.52	7.38	19.17	0.65	0.00	0.34	0.00	0.77	0.00	3.07
August	403	1.77	28.43	2.81	5.68	2.96	0.56	0.63	0.96	3.35	0.40	0.61	6.24
August	404	7.23	2.42	1.77	2.50	0.00	0.00	0.16	0.00	1.02	0.00	0.00	0.00
August	405	6.33	3.31	0.57	1.03	0.51	0.00	0.00	0.00	0.87	0.51	0.00	0.00
August	406	1.14	2.43	0.34	2.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	407	2.35	1.59	2.92	1.35	0.00	0.00	0.00	0.00	0.39	0.51	1.64	0.26
August	408	1.75	0.83	0.58	3.04	1.08	0.00	0.00	0.00	2.03	0.00	0.56	2.57
August	409	21.39	10.75	7.74	31.51	23.77	6.75	1.11	NA	9.81	1.43	2.29	4.32
August	410	NA	6.49	5.30	3.43	3.71	0.00	2.30	1.72	2.12	0.93	1.32	1.63
August	411	13.45	3.81	NA	4.06	14.09	16.47	0.30	5.23	4.93	4.26	6.10	5.05
August	412	14.77	9.07	NA	3.38	12.92	30.58	0.30	16.59	2.11	6.19	7.29	4.17
August	413	16.26	3.85	NA	2.61	8.03	5.07	0.00	NA	1.96	2.27	1.73	2.80
August	414	1.96	7.87	NA	7.90	11.77	0.55	0.00	0.00	2.74	0.54	0.28	0.00
August	801	0.18	1.11	1.01	1.31	0.00	0.00	0.00	1.80	1.72	0.28	0.00	0.24
August	802	3.05	4.43	1.99	1.10	0.79	0.00	0.00	0.00	0.00	1.25	0.55	0.00
August	803	1.33	1.78	1.72	1.50	0.67	0.00	0.00	0.87	0.00	0.83	0.59	0.26
August	804	1.80	1.73	1.07	0.00	0.39	0.00	0.00	0.00	1.02	0.50	0.00	0.34
August	805	2.17	1.75	0.33	1.36	1.02	1.97	1.13	1.69	1.12	0.59	0.06	0.00
August	806	1.59	3.06	0.51	5.29	1.80	0.00	0.00	0.17	0.17	0.51	0.00	0.29
August	807	1.02	2.35	0.74	1.46	2.30	0.43	0.08	0.00	0.31	0.48	0.13	0.00
August	808	1.90	2.79	1.48	2.63	1.31	0.42	0.14	0.00	0.13	0.00	0.26	0.00
August	809	4.38	1.70	0.77	1.05	1.41	0.00	0.00	0.00	0.00	0.00	0.34	0.00
August	810	4.94	2.72	1.13	0.97	0.81	1.20	0.00	0.00	0.23	0.21	0.00	0.27
August	811	2.55	0.21	0.20	0.59	1.32	0.69	0.00	0.00	1.01	0.10	0.23	1.60
August	812	0.72	1.29	0.71	0.59	0.20	0.54	0.00	0.24	0.00	0.00	0.00	0.00
August	813	1.49	0.81	0.45	0.14	0.00	0.00	0.00	0.00	0.00	0.00	1.39	0.18
August	814	1.03	1.04	0.05	0.87	0.00	0.77	0.00	0.00	NA	0.17	0.00	0.00
August	815	2.04	1.42	0.59	0.39	0.34	0.09	0.00	0.00	0.00	1.10	0.00	0.00
August	816	1.01	1.59	0.42	1.81	0.51	0.00	0.69	0.00	0.13	1.40	0.35	0.11
August	817	3.01	1.65	1.29	1.63	3.45	1.21	0.23	1.21	0.67	1.08	0.31	1.17
August	818	5.59	3.12	1.89	1.62	0.53	0.17	0.26	0.00	0.00	0.00	0.65	0.00
August	819	1.49	1.51	0.50	0.94	1.00	1.26	0.00	0.00	0.57	2.14	0.00	0.28
August	820	3.53	7.29	0.18	2.23	3.16	6.21	0.00	0.00	0.00	0.60	0.21	3.60
August	821	0.67	1.24	1.38	1.17	0.77	0.42	0.00	0.00	0.67	1.97	2.69	0.00
August	822	2.39	2.27	1.91	3.91	2.05	0.00	1.34	0.00	1.64	0.40	0.00	1.84
August	823	10.88	7.31	3.06	1.12	0.85	0.41	0.00	0.00	0.00	0.00	0.77	0.00
August	824	10.29	1.58	1.44	1.89	0.00	0.00	0.00	0.61	0.00	0.00	0.00	0.00
August	827	1.04	1.28	NA	NA	0.00	0.00	0.00	0.00	0.98	NA	1.39	1.39
August	828	0.16	5.37	4.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	829	0.00	1.96	1.80	1.76	2.02	0.54	0.00	0.00	0.00	0.00	NA	0.50

survey	stratum	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
August	830	0.00	1.15	0.56	2.82	0.00	1.30	0.00	0.00	0.00	0.00	0.00	0.26
August	831	2.15	5.57	2.51	0.28	NA	1.28	0.00	0.00	0.38	0.00	0.00	0.00
August	832	11.67	12.62	17.47	43.48	6.72	0.00	1.20	1.30	0.00	0.12	0.13	0.00
September	415	7.39	10.25	0.68	1.24	0.92	1.03	2.37	1.06	1.67	2.64	0.52	5.06
September	416	7.20	11.58	4.44	4.82	3.10	1.83	2.16	5.45	2.99	1.84	0.81	1.62
September	417	1.14	9.28	2.33	3.16	0.50	2.21	0.79	0.00	0.17	0.13	0.00	0.00
September	418	1.33	2.12	2.01	0.00	0.00	0.00	0.05	0.66	0.00	0.00	0.00	0.00
September	419	3.46	0.39	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00
September	420	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	421	0.55	NA	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	422	0.70	0.05	0.10	3.91	1.20	0.28	0.34	0.39	0.16	0.01	0.01	0.08
September	423	0.23	0.45	0.75	0.31	0.59	0.09	0.02	0.14	0.02	0.01	0.00	0.10
September	424	0.39	0.55	0.67	1.37	0.76	0.01	0.35	0.11	0.14	0.11	0.00	0.00
September	425	5.00	4.10	0.90	0.78	3.10	2.29	1.63	1.03	0.87	4.52	1.69	2.49
September	426	1.02	0.80	3.45	0.00	2.51	1.42	3.32	1.06	4.38	3.66	3.83	0.39
September	427	0.00	0.00	0.00	0.44	0.34	0.28	0.00	0.03	0.03	0.26	0.05	0.00
September	428	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
September	429	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	431	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	432	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	433	0.57	0.17	1.70	0.00	2.22	0.00	0.00	0.25	0.05	0.00	0.18	0.14
September	434	0.00	0.13	4.65	0.39	0.69	0.09	0.05	3.00	0.06	1.14	0.47	2.26
September	435	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00
September	436	0.00	0.00	0.00	0.41	0.25	0.00	0.00	0.17	0.14	0.00	0.00	0.08
September	437	6.20	7.67	20.87	7.63	2.52	0.43	6.80	12.49	7.79	31.05	11.40	13.79
September	438	1.73	0.08	0.56	0.65	2.55	1.66	2.57	0.77	0.57	2.52	1.85	7.64
September	439	0.72	1.73	1.54	2.98	1.10	1.15	0.28	0.65	1.38	0.18	0.62	0.43

Table A13. Mean kg per tow of individuals greater than 30 cm (in Lady Hammond *night tow with a Western IIA trawl equivalent) for all strata sampled in the northern and southern Gulf of St. Lawrence RV surveys, 1999 to 2010.*

survey	stratum	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
August	401	0.96	0.26	2.26	13.49	1.33	2.93	1.51	1.45	1.33	0.21	1.85	NA
August	402	3.94	1.52	0.00	1.23	0.64	NA	1.68	0.84	1.76	1.80	0.30	1.34
August	403	3.71	1.25	1.44	0.81	4.74	1.36	4.79	0.41	2.09	0.70	4.25	2.34
August	404	0.17	0.74	0.00	1.52	2.24	1.74	1.06	1.75	0.25	2.34	1.06	NA
August	405	0.00	0.83	0.93	0.16	0.63	0.83	1.24	0.87	2.90	2.19	3.35	3.38
August	406	0.41	1.69	0.21	1.31	1.80	0.57	0.56	0.03	1.09	0.40	1.43	0.43
August	407	0.71	2.51	1.50	0.92	1.76	1.23	1.50	2.32	0.18	1.30	0.86	NA
August	408	1.16	2.27	3.10	0.51	3.53	1.03	1.64	2.19	1.88	3.93	0.63	3.38
August	409	1.13	7.26	6.28	1.48	2.54	2.98	3.16	3.90	2.57	5.00	1.42	6.90
August	410	0.62	2.82	3.33	0.33	14.81	2.05	0.95	2.48	1.61	1.06	1.31	2.06
August	411	5.68	26.95	11.56	1.01	21.05	6.31	6.19	5.82	4.47	7.97	3.11	3.43
August	412	5.67	10.87	10.75	0.90	11.20	0.87	4.40	1.85	2.99	8.33	1.01	2.45
August	413	3.43	10.06	10.08	2.19	9.23	3.16	2.60	3.99	4.83	6.39	5.09	7.98
August	414	0.99	2.27	2.74	0.00	0.00	0.00	0.17	0.18	0.04	0.00	0.00	1.73
August	801	0.00	0.25	0.31	0.00	0.00	0.11	0.00	0.17	0.00	0.64	0.68	0.00
August	802	1.37	0.39	0.49	0.00	3.45	1.65	0.86	0.42	1.95	0.58	0.00	NA
August	803	0.15	0.49	0.94	1.71	2.27	0.55	0.99	1.40	0.53	0.83	0.16	1.33
August	804	1.31	0.00	1.24	0.00	1.76	0.43	1.72	0.28	1.38	0.81	2.14	1.29
August	805	0.31	1.54	0.32	0.05	2.45	0.37	1.04	0.36	0.66	1.01	0.59	0.19
August	806	0.28	0.00	0.42	0.39	0.69	0.78	0.51	0.22	1.21	0.38	0.14	0.50
August	807	0.45	1.27	0.81	0.00	0.83	NA	0.61	0.00	1.21	1.89	2.04	1.06
August	808	0.29	0.00	0.00	0.00	0.82	NA	0.00	0.55	0.00	0.12	0.23	0.06
August	809	0.62	0.00	0.17	0.82	0.39	1.22	0.40	0.16	0.77	0.27	0.33	0.49
August	810	0.00	2.68	0.18	0.00	0.70	0.29	0.88	0.40	0.73	0.32	0.34	NA
August	811	0.21	3.18	0.00	0.00	2.17	0.57	1.55	0.42	0.62	2.31	0.50	3.10
August	812	0.00	1.59	0.42	0.00	1.85	0.37	0.67	0.30	0.71	0.52	0.53	0.94
August	813	0.00	2.22	0.67	0.00	0.31	0.00	0.17	0.20	0.14	0.52	0.53	0.07
August	814	0.00	0.28	0.66	0.00	0.00	0.11	1.11	0.00	0.00	0.11	0.00	0.00
August	815	0.00	0.09	0.32	0.11	0.00	0.13	0.26	0.47	0.29	0.44	0.74	0.47
August	816	0.37	0.02	0.00	0.00	0.00	0.22	0.55	0.96	1.69	0.60	0.62	2.55
August	817	0.75	4.12	1.18	0.47	2.05	1.60	1.39	0.59	1.43	1.57	0.24	0.40
August	818	0.46	0.16	0.77	0.21	2.11	0.00	0.39	0.33	0.38	0.15	0.16	1.09
August	819	0.17	0.41	0.64	0.00	0.46	NA	0.46	0.24	0.00	0.14	0.09	0.99
August	820	1.87	4.36	2.00	0.81	2.25	0.36	5.05	1.96	2.41	2.33	3.77	NA
August	821	3.34	1.93	0.51	0.35	0.74	2.31	0.61	2.80	1.49	1.96	1.62	4.35
August	822	2.63	2.98	1.39	0.00	0.93	2.34	1.64	2.30	1.72	2.33	0.56	3.71
August	823	15.98	4.76	2.61	0.48	7.22	0.30	3.15	3.09	5.18	2.91	8.98	15.95
August	824	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.24	0.26	0.58	0.47	0.87
August	827	2.09	0.00	NA	1.70	0.32	0.00	0.08	0.82	0.63	1.73	0.93	0.06
August	828	0.00	NA	0.00	NA	0.00	0.29	0.49	0.00	0.00	0.00	0.00	0.00
August	829	1.16	0.00	NA	0.00	0.00	NA	0.00	0.00	0.83	0.00	0.00	0.16

survey	stratum	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
August	830	0.00	0.28	0.00	0.00	0.64	NA	0.11	0.00	0.00	0.91	0.07	0.12
August	831	0.13	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	832	0.00	0.00	0.00	0.00	0.00	0.14	0.11	0.05	0.05	0.09	0.00	0.10
September	415	2.55	1.53	1.14	6.24	1.43	0.79	1.21	1.07	1.49	2.42	2.41	3.72
September	416	0.40	0.26	0.14	0.36	0.21	0.03	0.00	0.56	1.92	2.01	2.15	1.79
September	417	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	418	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	419	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	420	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	421	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	422	0.00	0.03	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
September	423	0.01	0.00	0.00	0.02	0.00	0.00	0.03	0.01	0.01	0.01	0.00	0.00
September	424	0.03	0.05	0.00	0.15	0.07	0.03	0.17	0.03	0.00	0.06	0.16	0.00
September	425	0.84	0.92	11.34	2.61	4.87	1.25	3.07	8.77	2.61	2.37	6.63	4.64
September	426	0.24	3.50	0.16	0.84	0.32	1.78	1.04	0.00	1.02	3.70	2.20	2.02
September	427	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.08	0.01	0.00	0.00
September	428	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	429	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	431	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	432	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	433	0.06	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
September	434	0.06	0.12	0.90	0.59	0.06	0.58	1.26	0.95	0.40	0.23	0.75	0.00
September	435	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	436	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.17	0.00	0.67	0.00	0.14
September	437	95.87	46.58	24.22	71.15	10.35	13.02	31.58	6.45	2.61	36.87	5.42	4.77
September	438	0.39	1.41	2.20	3.18	NA	2.80	2.51	0.65	0.19	0.58	1.46	2.86
September	439	0.28	1.70	0.64	2.95	NA	0.65	3.04	1.21	0.56	2.79	1.28	2.01

Table A14. Mean kg per tow of individuals greater than 30 cm (in Lady Hammond *night tow with a Western IIA trawl equivalent) for all strata sampled in the northern and southern Gulf of St. Lawrence RV surveys, 2011 to 2021.*

survey	stratum	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
August	401	1.51	1.88	3.62	1.61	1.47	0.63	0.93	1.86	10.97	4.42	10.44
August	402	0.53	0.97	1.56	0.64	1.35	1.24	0.71	9.16	39.80	14.44	4.94
August	403	4.89	6.48	3.49	6.34	9.50	1.48	1.55	46.97	72.03	11.96	27.19
August	404	1.98	1.90	4.31	1.95	3.36	2.16	1.47	1.72	2.52	2.30	1.91
August	405	2.61	2.20	3.59	0.72	2.50	2.86	1.71	2.38	6.93	1.80	1.29
August	406	0.79	1.83	2.11	0.84	4.68	2.34	3.13	5.93	4.02	0.90	2.74
August	407	0.36	0.94	0.62	0.31	1.57	1.68	0.81	0.53	0.91	0.63	1.15
August	408	1.57	3.35	3.82	4.00	1.22	1.41	2.12	0.99	1.31	1.22	1.79
August	409	1.83	5.37	10.61	4.61	15.27	17.90	20.90	12.55	29.93	20.83	9.84
August	410	2.91	4.80	4.68	4.36	4.97	4.98	7.51	3.23	9.67	1.82	10.24
August	411	5.16	6.48	13.62	12.95	9.82	14.13	9.15	7.27	9.85	8.72	15.88
August	412	4.04	7.34	10.87	8.83	5.53	17.45	16.85	19.61	19.61	24.02	14.44
August	413	1.49	2.71	10.54	8.41	4.74	11.67	8.30	10.59	8.40	1.74	7.19
August	414	0.35	14.14	3.60	2.53	0.37	3.84	NA	0.63	0.00	NA	0.00
August	801	0.18	0.34	0.79	1.92	0.34	0.57	0.96	0.35	0.37	1.18	0.23
August	802	0.55	0.76	2.05	2.21	0.91	1.24	1.48	0.32	1.39	0.56	0.56
August	803	0.23	0.90	0.57	1.21	0.28	0.62	0.28	0.73	1.12	0.37	0.24
August	804	0.65	3.40	2.15	2.54	3.46	2.36	1.05	0.91	1.98	0.48	1.62
August	805	0.03	0.97	0.46	1.01	1.88	0.78	1.27	0.53	5.31	1.69	2.57
August	806	2.12	1.35	0.96	3.59	1.93	0.93	2.43	2.30	3.41	2.46	10.06
August	807	1.56	2.84	1.12	1.79	1.28	0.07	1.96	0.68	0.00	1.10	1.74
August	808	0.00	0.24	0.00	0.81	0.24	0.23	0.18	0.23	NA	0.13	0.35
August	809	0.00	1.21	0.32	0.37	0.56	0.46	0.84	0.40	NA	0.07	0.16
August	810	0.65	0.17	0.83	0.45	1.48	0.31	0.00	0.52	0.00	0.00	0.80
August	811	0.73	1.77	3.30	0.31	0.26	0.28	0.24	0.19	NA	0.00	3.13
August	812	0.43	0.32	0.76	1.34	0.34	1.49	0.55	0.75	0.52	1.13	1.06
August	813	0.07	0.24	0.36	0.57	1.24	2.28	1.61	1.61	0.35	1.18	0.86
August	814	0.13	0.27	0.07	0.30	0.41	0.71	0.00	0.00	0.42	0.57	0.54
August	815	0.90	0.25	2.90	0.97	2.61	1.63	0.69	0.35	1.10	1.30	1.29
August	816	0.72	1.00	0.64	0.95	1.66	2.27	1.49	0.57	1.21	1.33	1.10
August	817	0.31	1.40	1.48	0.96	0.36	0.94	2.14	0.88	1.33	3.81	3.59
August	818	0.26	0.62	1.08	0.83	1.33	3.04	6.30	1.55	10.21	9.95	9.05
August	819	0.00	0.46	0.33	0.16	0.60	0.16	1.07	0.80	0.00	0.00	NA
August	820	5.29	8.73	13.54	11.74	5.40	5.53	16.15	46.98	NA	7.13	11.63
August	821	1.98	1.01	5.22	0.80	4.48	10.15	1.11	1.83	NA	23.58	2.49
August	822	0.57	3.17	0.67	2.14	3.41	5.52	1.90	3.88	6.72	3.97	1.74
August	823	3.73	8.13	7.86	7.55	5.00	19.88	49.38	49.67	8.23	31.75	3.45
August	824	0.19	0.09	0.21	0.27	2.11	2.34	0.44	2.94	1.51	1.46	0.74
August	827	0.27	0.16	2.73	1.39	1.87	1.48	1.04	0.73	NA	4.03	2.13
August	828	0.56	0.00	0.00	0.34	0.00	0.00	1.11	0.07	1.39	0.16	1.09
August	829	0.00	0.00	0.24	0.00	1.16	1.86	0.00	0.11	0.00	0.72	2.85
August	830	0.00	0.00	0.70	1.19	0.57	0.91	2.58	1.54	0.20	8.64	1.34
August	831	0.00	0.28	0.00	0.06	1.13	0.88	2.05	0.00	0.26	0.13	0.00
August	832	0.00	0.02	0.57	3.98	0.81	2.45	0.64	3.23	0.00	0.13	0.22
September	415	7.59	3.99	2.42	2.77	2.72	4.69	24.27	16.55	15.54	52.97	16.48
September	416	0.84	4.78	2.00	5.26	7.40	14.28	2.36	1.68	2.19	0.43	0.29
September	417	0.00	0.00	0.00	0.00	0.41	0.20	0.16	0.00	0.00	0.00	0.00
September	418	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	419	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	420	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	421	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	0.00
September	422	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	423	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
September	424	0.00	0.05	0.06	0.27	0.20	0.06	0.15	0.00	0.06	0.00	0.03
September	425	6.01	6.83	21.84	1.96	1.97	9.87	16.16	5.71	34.36	28.88	12.78
September	426	0.19	0.95	21.92	0.40	0.30	0.31	0.08	0.11	0.00	0.00	0.00

survey	stratum	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
September	427	0.00	0.03	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	428	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	429	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	431	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	432	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	433	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	434	0.03	0.13	0.36	0.16	0.43	0.19	0.42	0.37	0.12	0.00	0.14
September	435	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	436	0.00	0.24	0.17	0.51	0.06	0.11	0.02	0.00	0.00	0.00	0.11
September	437	12.15	5.67	7.45	12.02	5.02	19.54	13.84	2.70	3.60	2.07	18.61
September	438	12.40	1.59	4.92	2.22	6.32	1.76	6.64	0.28	0.25	1.77	0.50
September	439	5.68	14.06	11.26	5.75	3.04	8.78	1.61	1.85	1.07	1.63	13.31

Table A15. Hurdle model predictions in kg per tow of individuals greater than 30 cm (in Lady Hammond *night tow with a Western IIA trawl equivalent) for all missed strata in the northern and southern Gulf of St. Lawrence RV surveys, 1987 to 2021. The northern Gulf strata numbers are preceded by a 'Q' and the southern Gulf strata numbers are preceded by a 'G'.*

year	stratum	hurdle model prediction (kg/tow)
1987	Q410	7.236
1989	Q411	5.122
1989	Q412	7.590
1989	Q413	5.886
1989	Q414	3.693
1989	Q827	0.766
1991	Q831	4.161
1994	Q409	6.268
1994	Q413	2.802
1995	Q814	0.160
1996	Q827	0.307
1997	Q829	0.000
2000	Q828	0.335
2001	Q827	0.613
2001	Q829	0.000
2002	Q828	0.161
2004	Q402	0.460
2004	Q807	0.336
2004	Q808	0.077
2004	Q819	0.159
2004	Q830	0.078
2004	Q829	0.000
2010	Q401	1.678
2010	Q404	1.643
2010	Q407	1.075
2010	Q802	1.170
2010	Q810	0.628
2010	Q820	4.068
2017	Q414	2.335
2019	Q808	0.323
2019	Q809	0.830
2019	Q811	0.349
2019	Q820	40.191
2019	Q821	5.271
2019	Q827	1.565
2020	Q414	0.506
2021	Q819	0.397
1998	G421	0.000
2003	G438	1.072
2003	G439	0.809
2020	G421	0.000

A.9. FIGURES

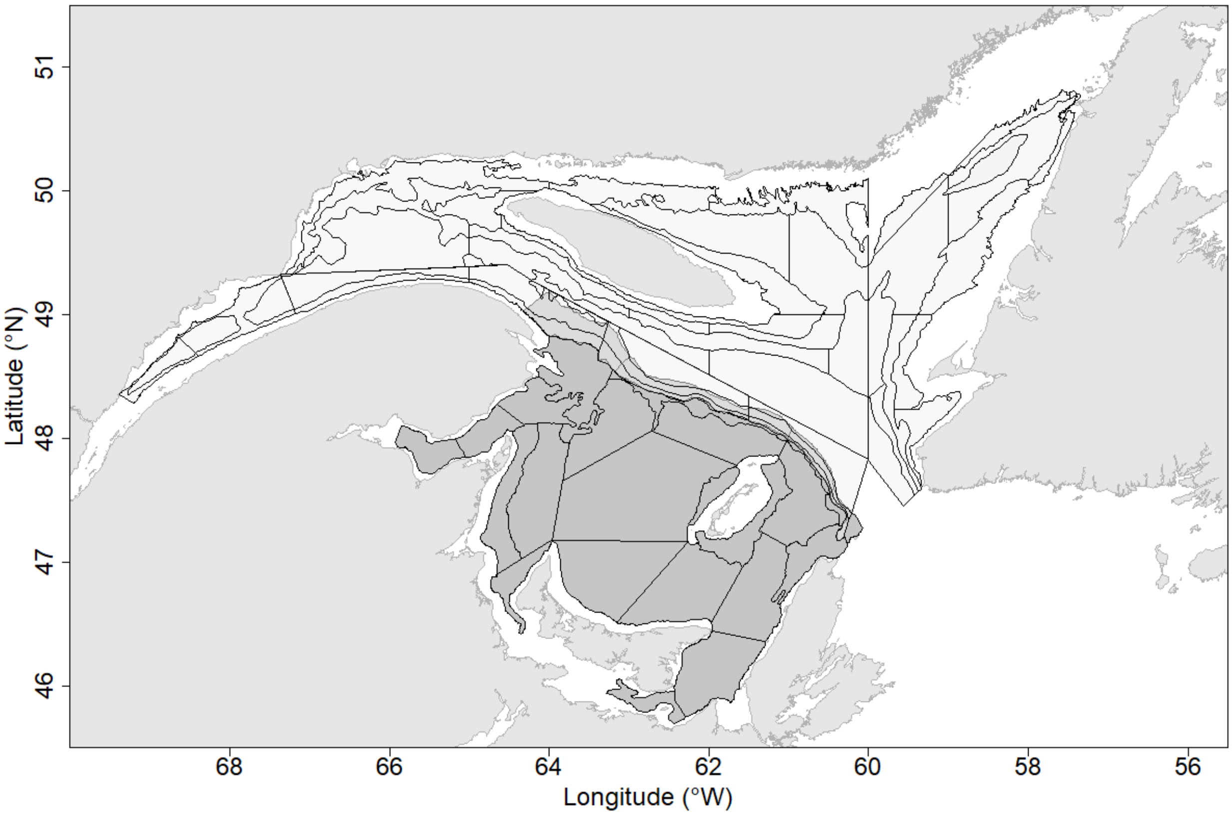

Figure A1. Strata boundaries for the Quebec Region's August bottom trawl survey of the northern Gulf of St. Lawrence (light grey polygon) and the Gulf Region's September bottom trawl survey of the southern Gulf of St. Lawrence (dark grey polygons), showing the overlapping strata located on the southern edge of the Laurentian channel. The strata shown are only those used in the computation of the single index for NAFO Divisions 4RST.

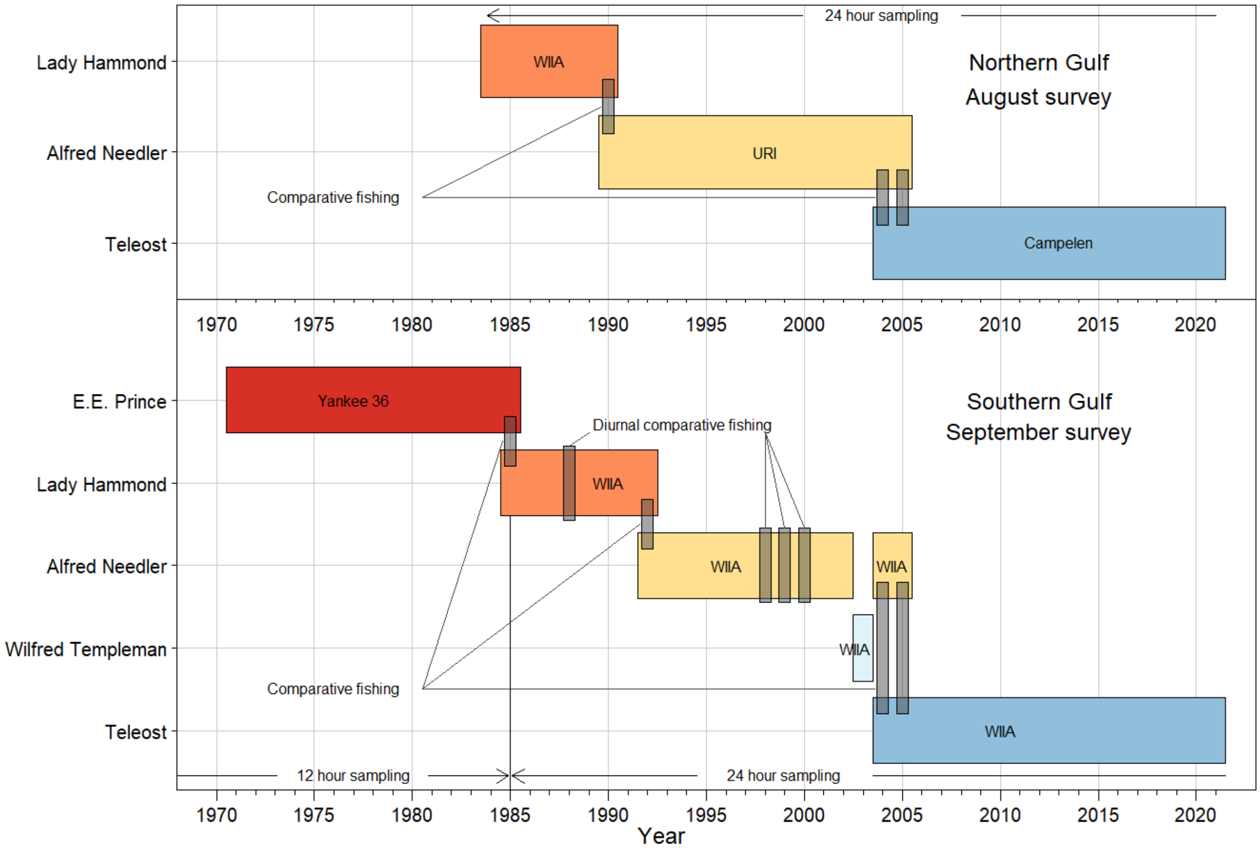

Figure A2. Timelines of the research vessel surveys in the Gulf of St. Lawrence. The x axis show years and the y axis shows the vessel and gear used for the northern Gulf of St. Lawrence survey (top panel) and the southern Gulf of St. Lawrence (bottom panel). Comparative fishing experiments are identified by grey polygons overlapping the survey platforms under comparison.

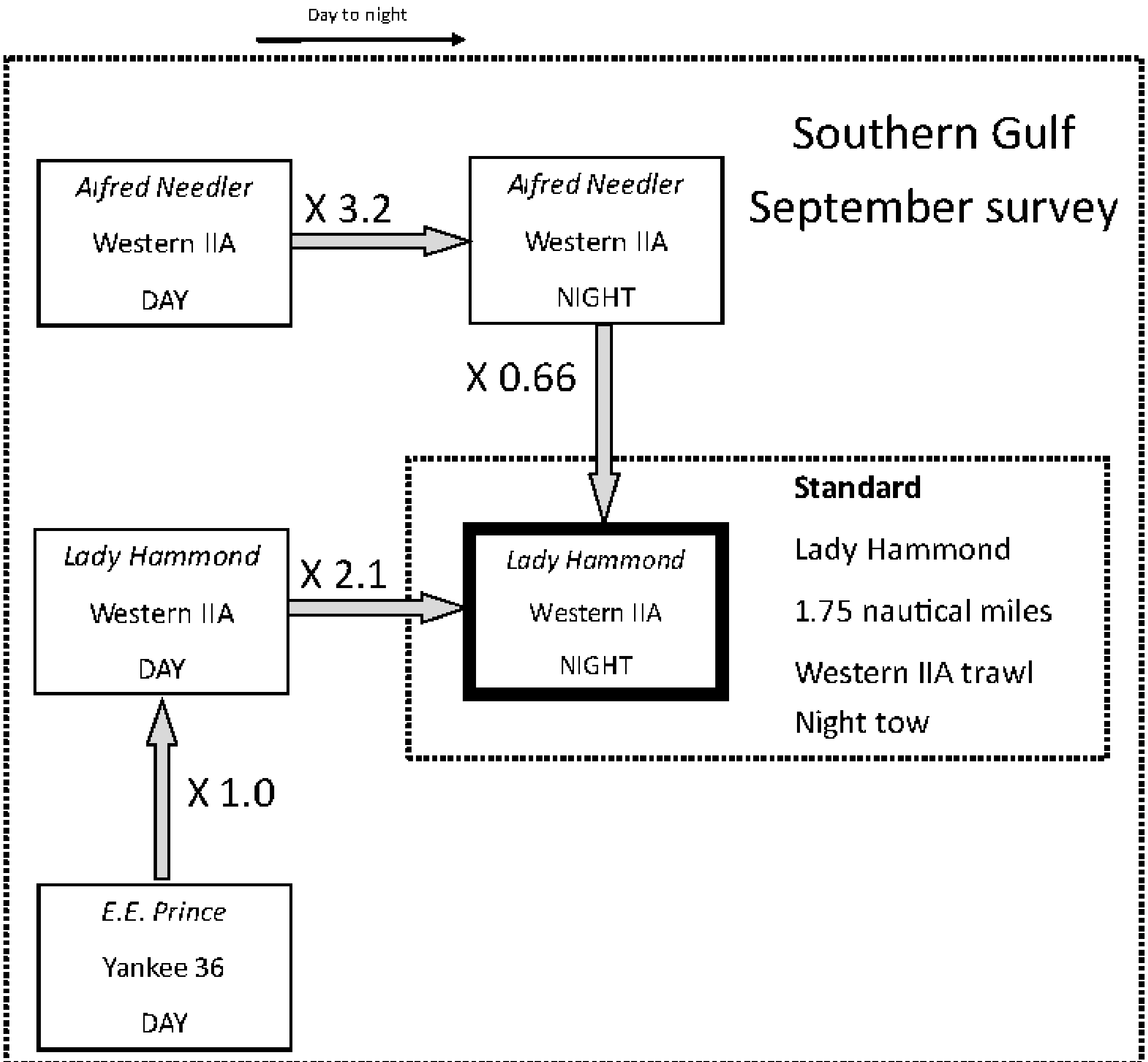

Figure A3. Summary of conversion factors between the different vessels and gears used during the September survey of the Gulf of St. Lawrence to derive the NAFO 4T index for Witch Flounder.

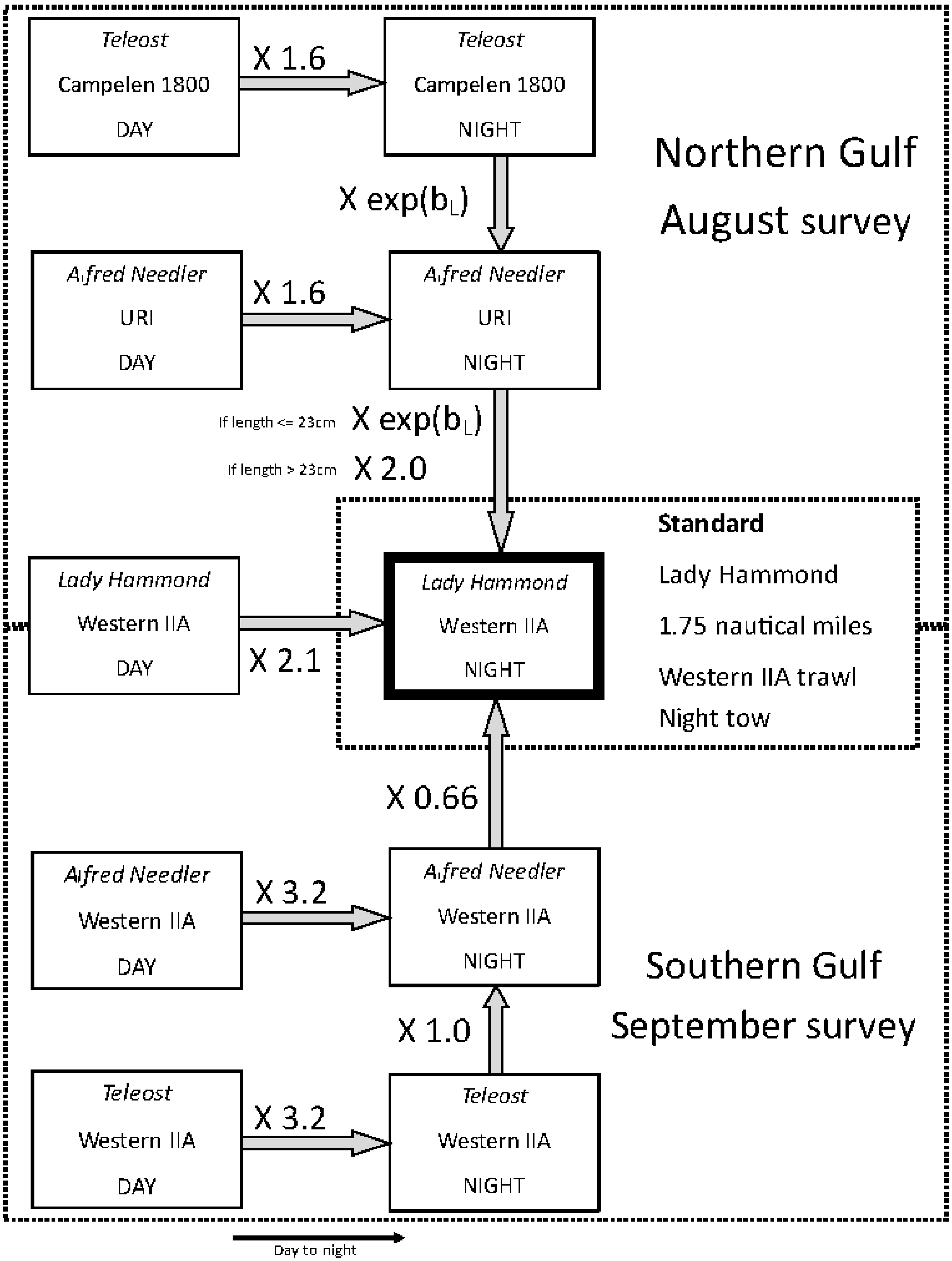

Figure A4. Summary of conversion factors between the different vessels and gears used during the August and September survey of the Gulf of St. Lawrence to derive the Gulf of St. Lawrence standard index for Witch Flounder. The conversion equations and references are summarized in Tables A1 and A2.

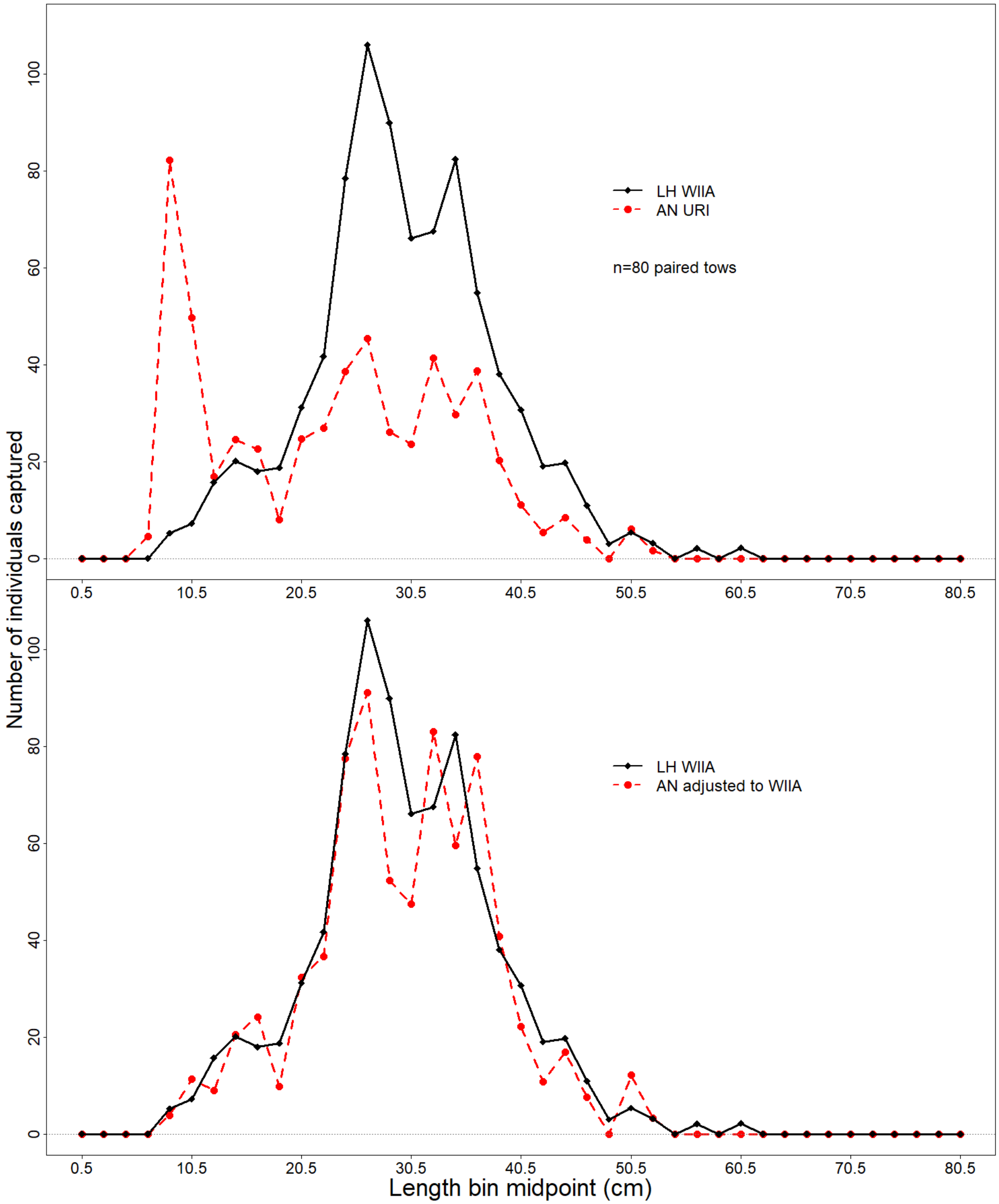

Figure A5. Number of Witch Flounder caught by length in paired tows in the northern Gulf of St. Lawrence in August 1990. Catches from the Lady Hammond *using a Western IIA trawl appear as black dots connected by a solid black line and catches from the* CCGS Alfred Needler *using a URI trawl appear as red dots connected by a dashed red line. Diurnal adjustments were applied to the cumulative catches-at-length and the results presented here are for a night tow. The top panel shows the unadjusted catches and the bottom panel shows the adjusted catches.*

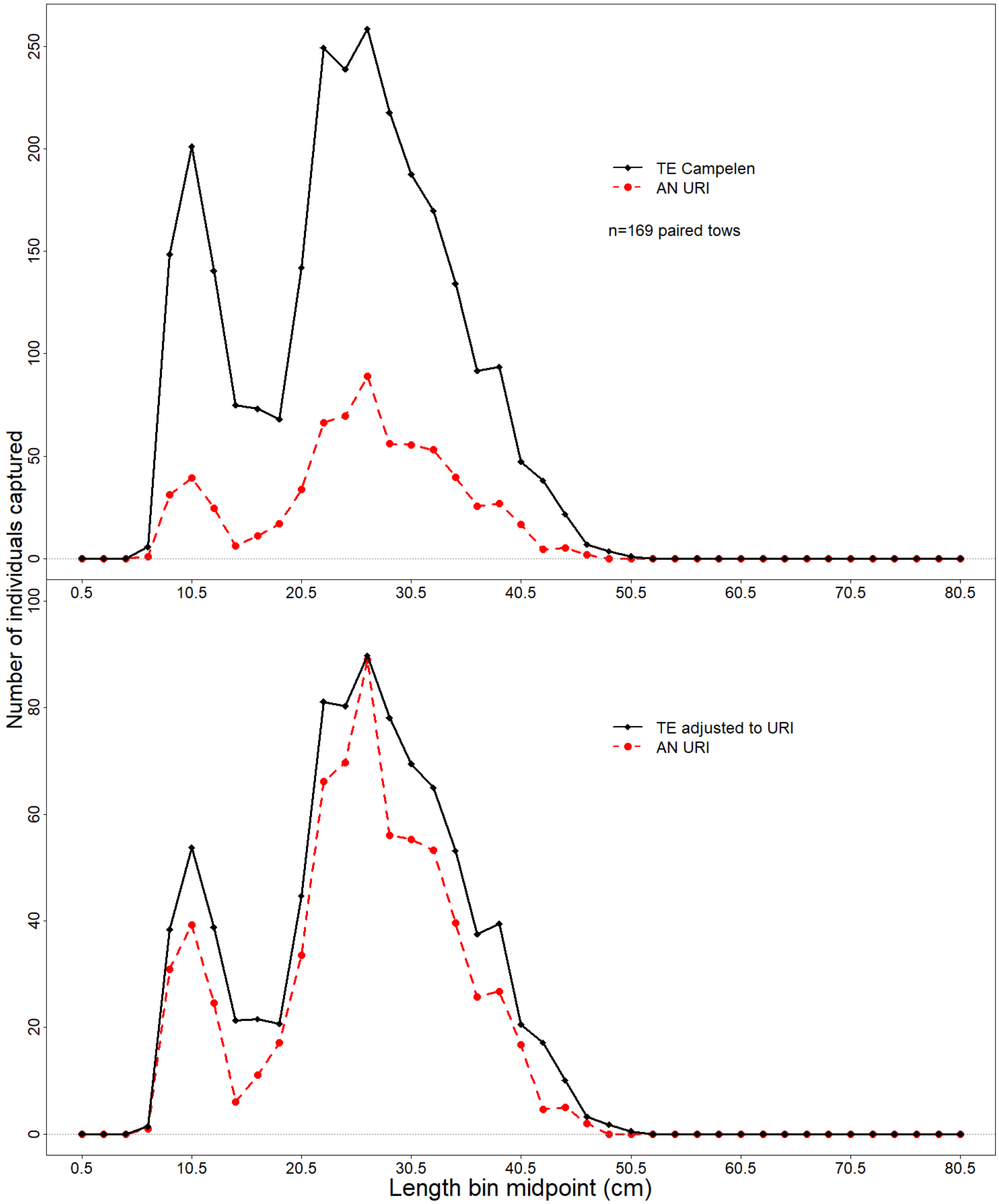

Figure A6. Number of Witch Flounder caught by length in paired tows in the northern Gulf of St. Lawrence in August 2004 and 2005. Catches from the CCGS Teleost using a Campelen trawl appear as black dots connected by a solid black line and catches from the CCGS Alfred Needler *using a URI trawl appear as red dots connected by a dashed red line. Diurnal adjustments were applied to the cumulative catches-at-length and the results presented here are for a night tow. The top panel shows the unadjusted catches and the bottom panel shows the adjusted catches.*

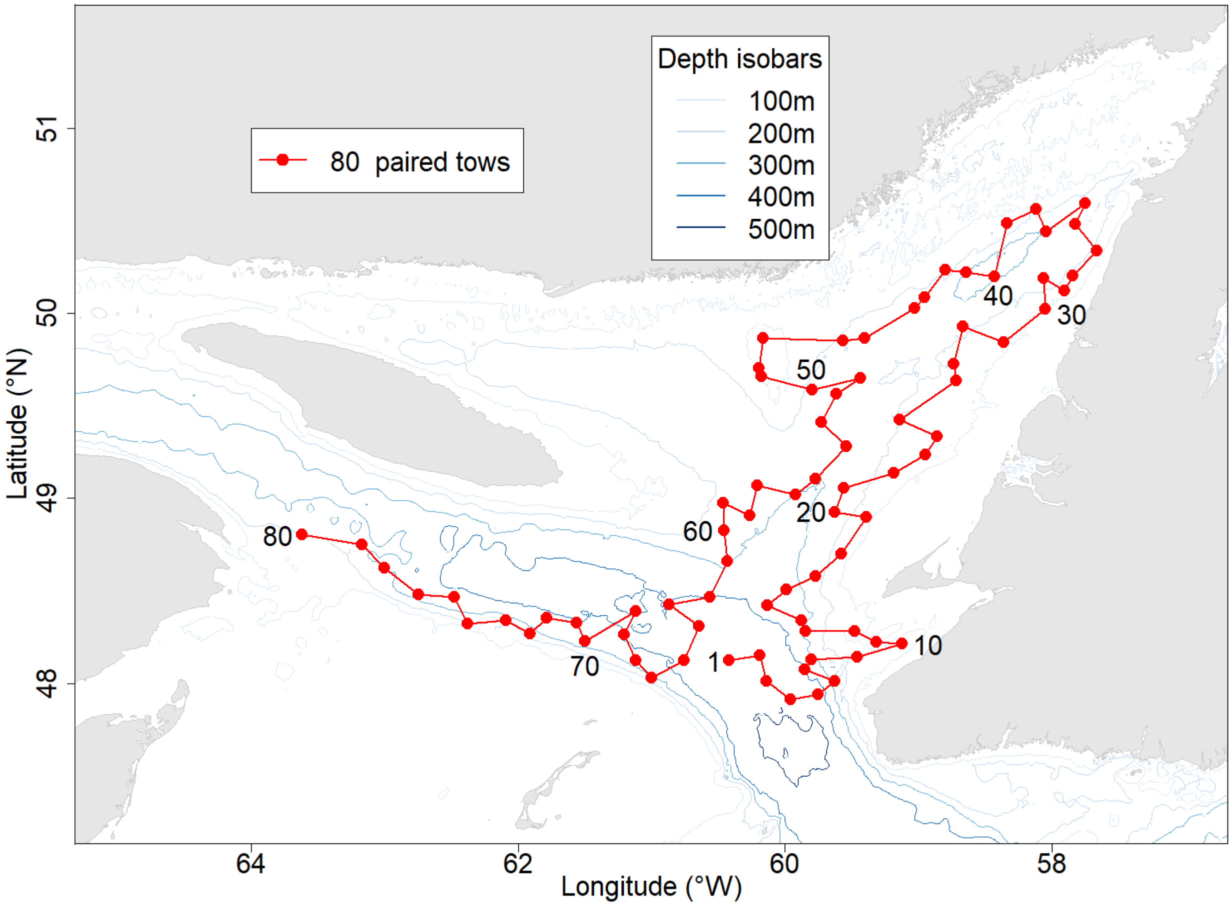

Figure A7. Location and sequence of the 80 comparative paired tows conducted in the northern Gulf of St. Lawrence during the 1990 comparative fishing experiment between the Lady Hammond *using a Western IIA and the* CCGS Alfred Needler *using a URI trawl.*

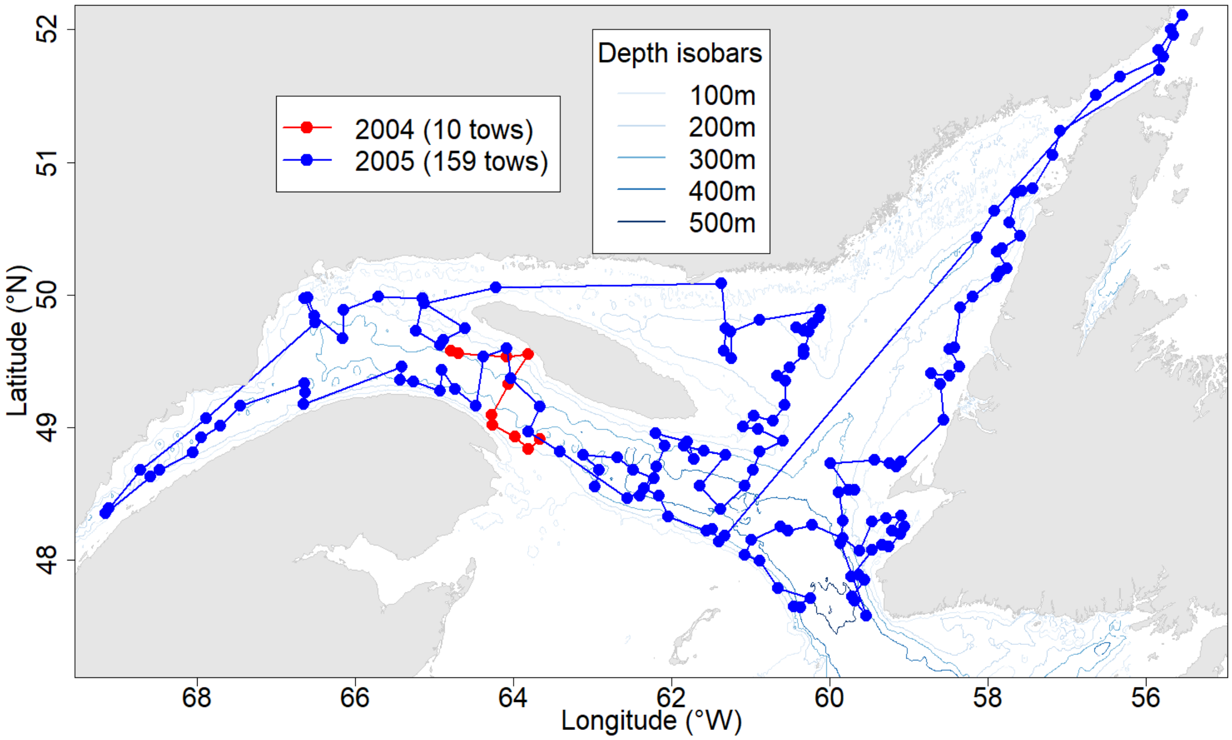

Figure A8. Location and sequence of the comparative paired tows conducted in the northern Gulf of St. Lawrence during the 2004 (10 tows) and 2005 (159 tows) comparative fishing experiments between the CCGS Alfred Needler *using a URI trawl and the CCGS Teleost using a Campelen trawl.*

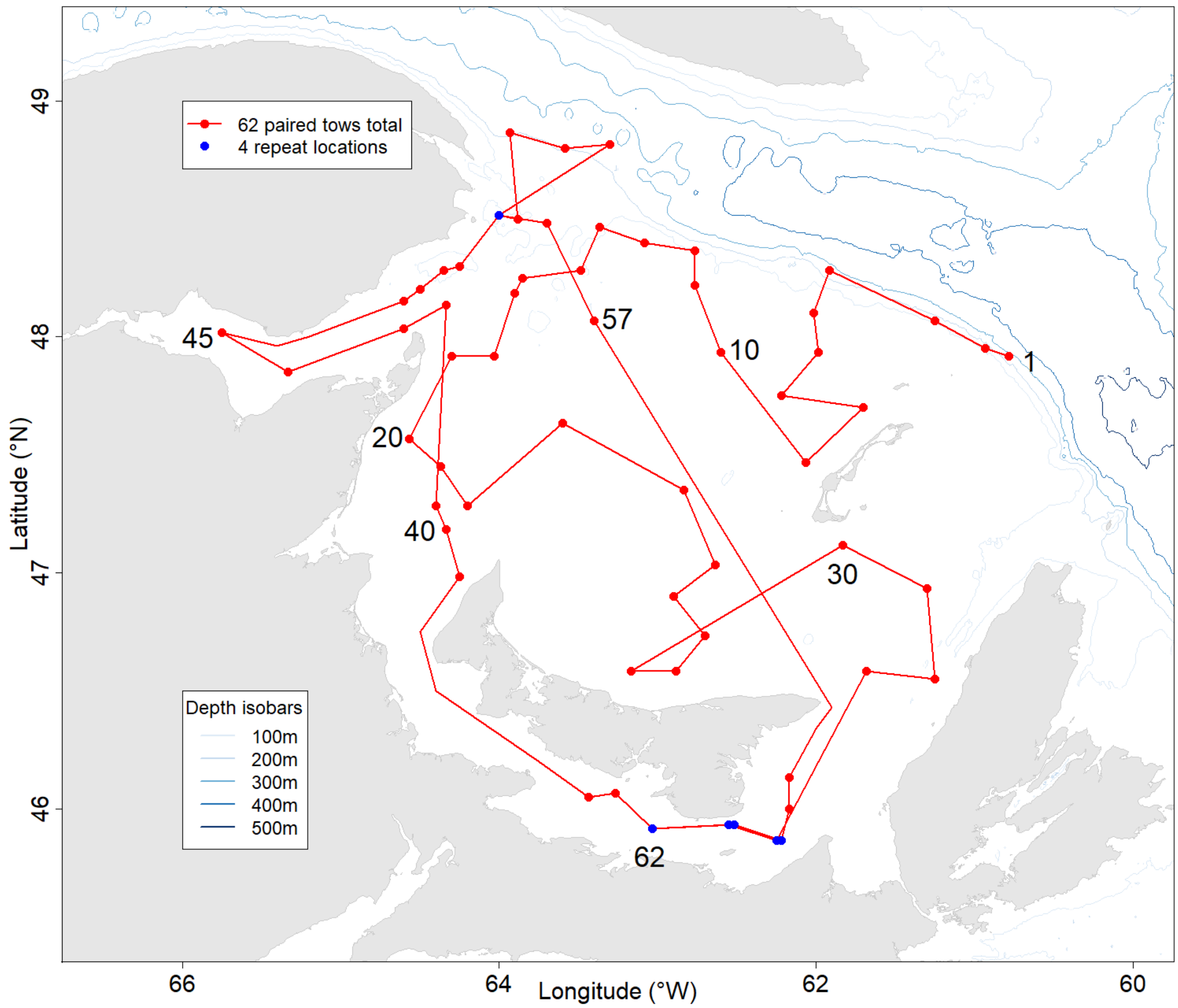

Figure A9. Location and sequence of the 62 comparative paired tows conducted in the southern Gulf of St. Lawrence during the 1985 comparative fishing experiment between the E.E. Prince using a Yankee 36 trawl and the Lady Hammond *using a Western IIA trawl.*

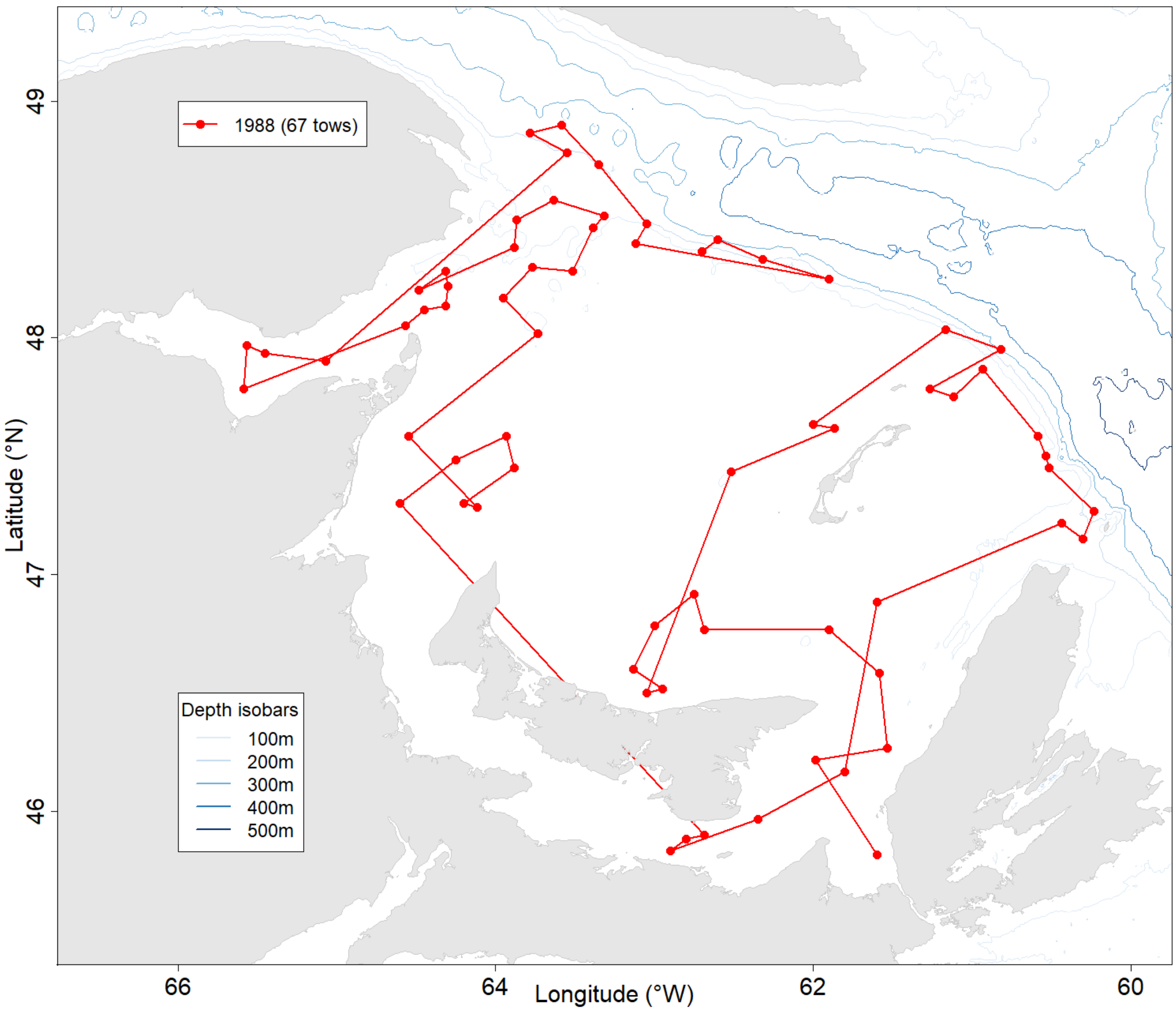

Figure A10. Location and sequence of the 67 diurnal comparative tows conducted by the Lady Hammond *using a Yankee 36 trawl in the southern Gulf of St. Lawrence during the 1988 comparative fishing experiments. Each tow location was sampled twice within a 24 hour period, once during the day (between 0700 and 1900) and once during the night (between 1900 and 0700).*

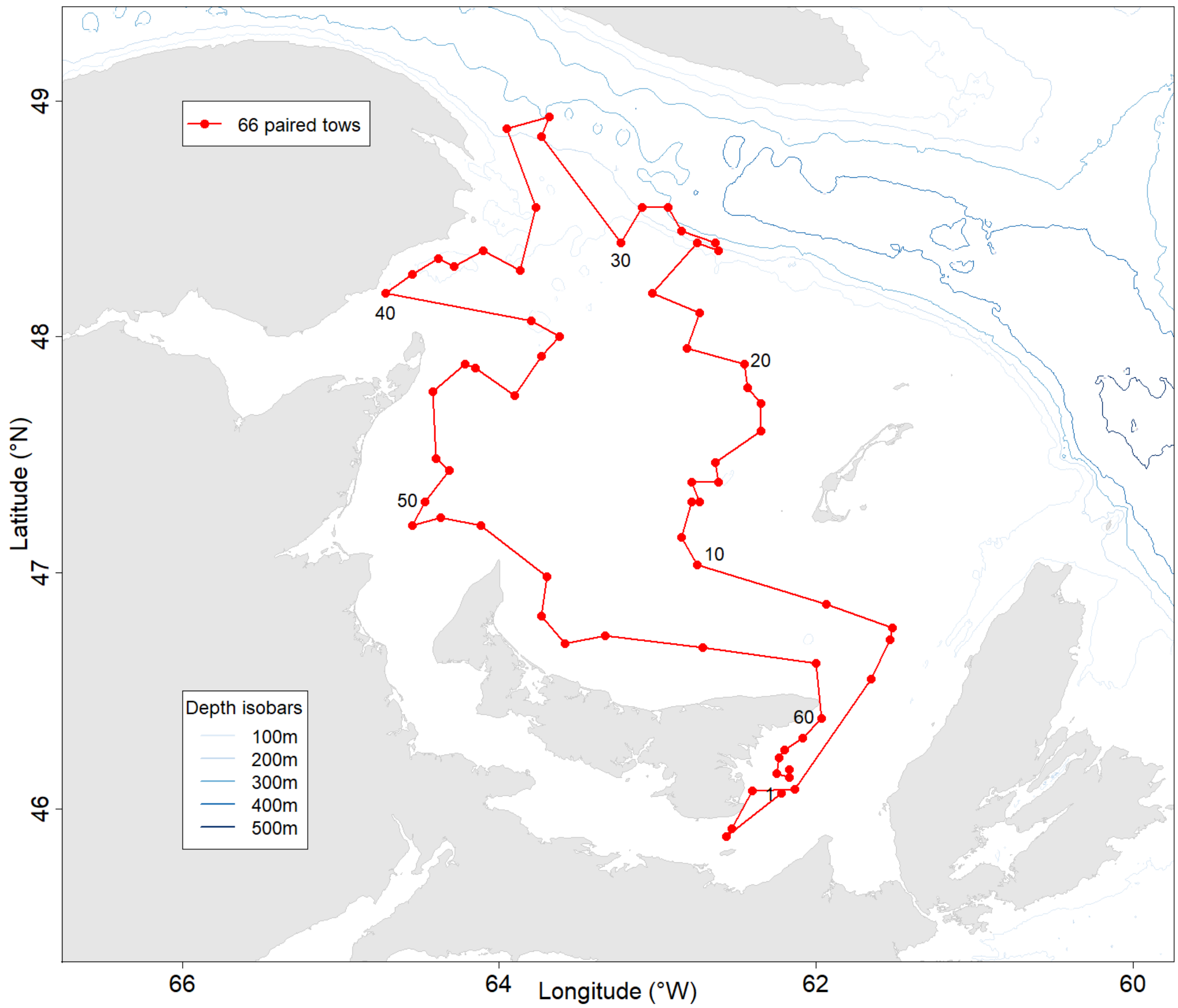

Figure A11. Location and sequence of the 66 comparative paired tows conducted by the Lady Hammond *and the* CCGS Alfred Needler*, both using a Western IIA trawl, during the 1992 comparative fishing experiments.*

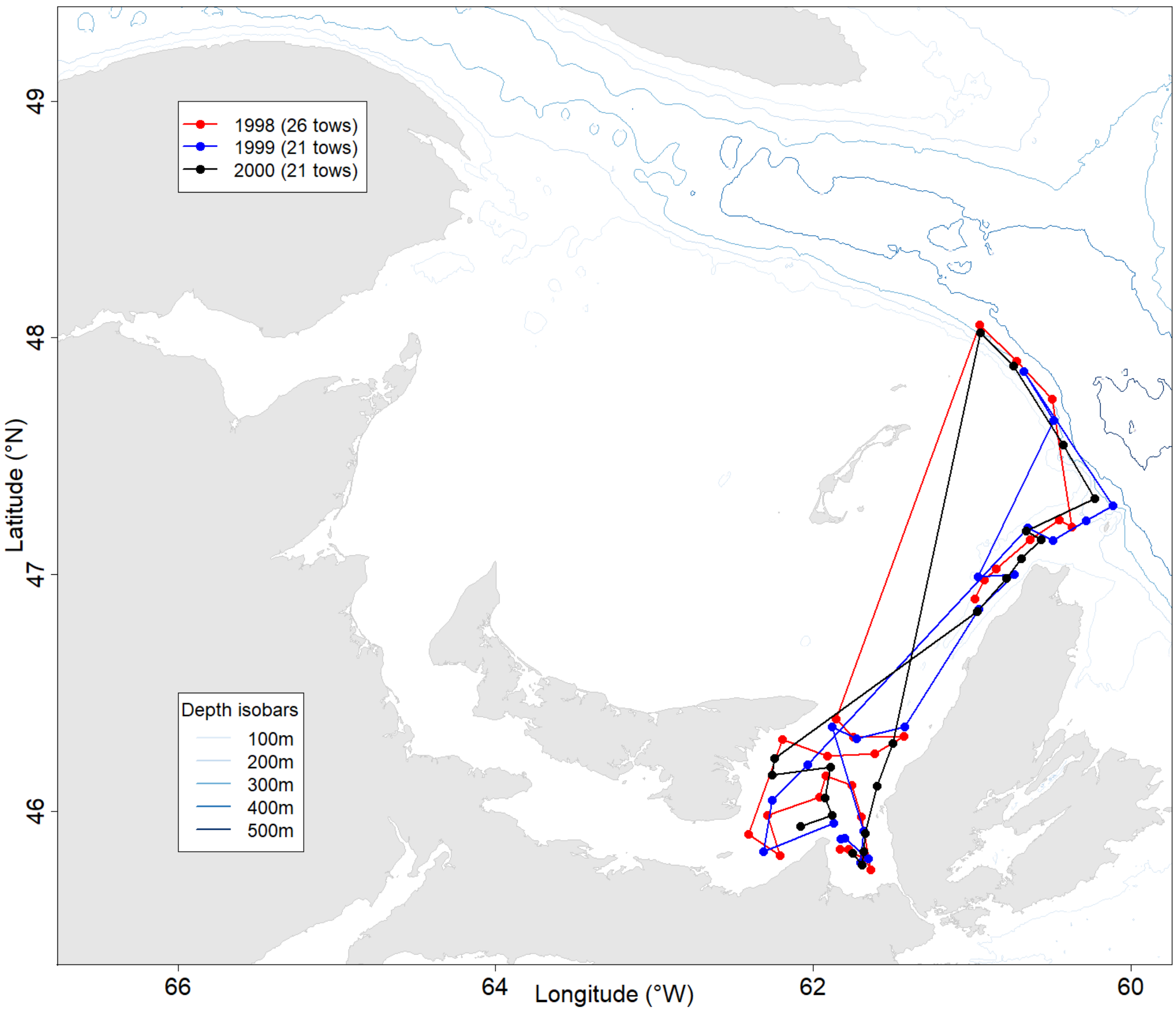

Figure A12. Location and sequence of the 68 diurnal comparative tows conducted by the CCGS Alfred Needler *using a Western IIA trawl in the southern Gulf of St. Lawrence during the 1998, 1999 and 2000 comparative fishing experiments. Each tow location was sampled twice within a 24 hour period, once during the day (between 0700 and 1900) and once during the night (between 1900 and 0700).*

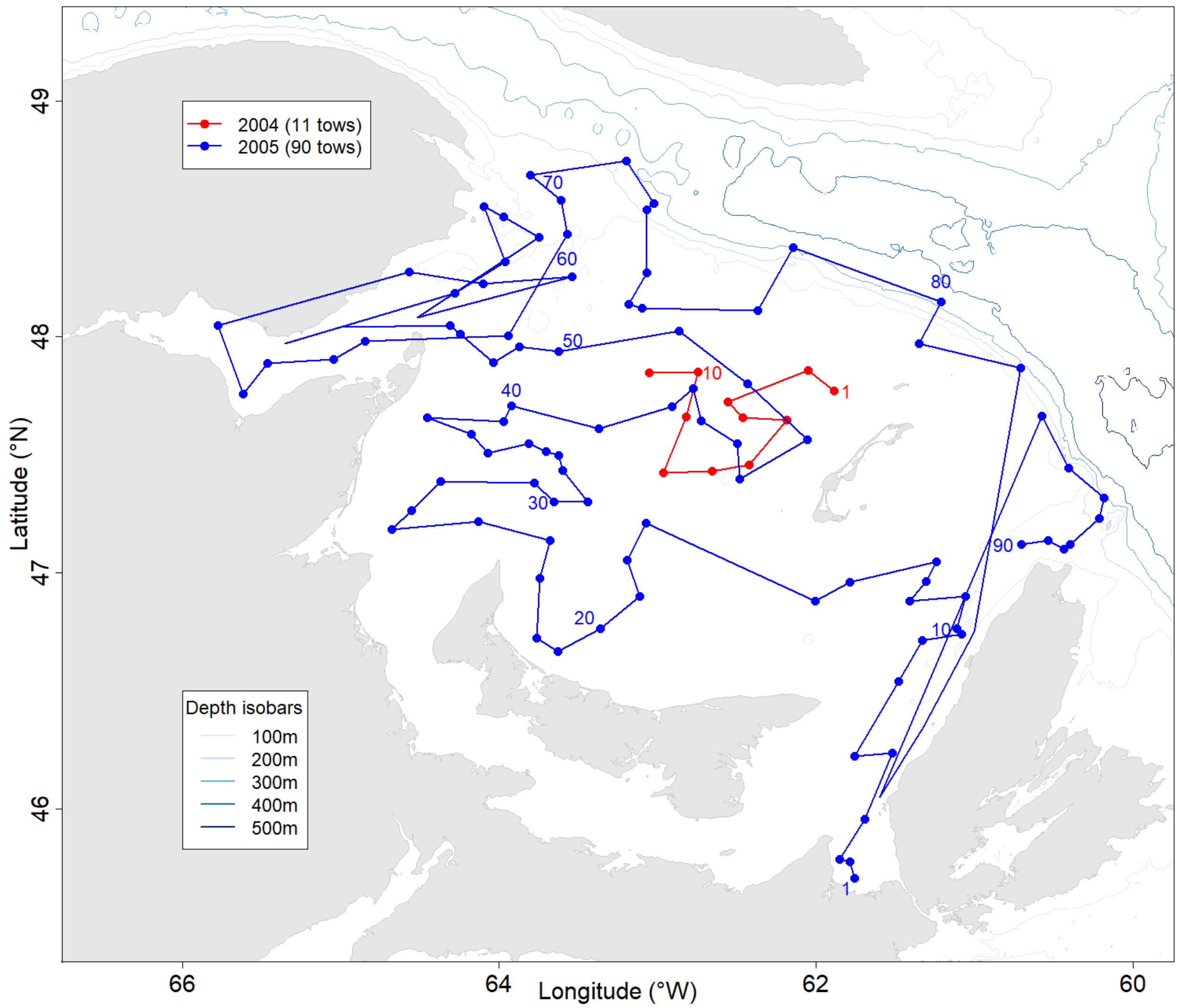

Figure A13. Location and sequence of the 101 comparative paired tows conducted by the CCGS Alfred Needler *and the CCGS Teleost, both using a Western IIA trawl, during the 2004 and 2005 comparative fishing experiments.*

APPENDIX B. METHODOLOGICAL DETAILS OF THE COMPUTATION OF GULF-WIDE INDEX FOR NAFO 4RST WITCH FLOUNDER BASED ON MOBILE SENTINEL SURVEY DATA

The sentinel survey data from the Quebec Region is accessed through a network drive where data are accessible in a variety of formats. Since the computation of the Witch Flounder indices require information about the length of individuals captured, both catch and length information were used in the computations. The text files that contain these data were produced using the contents of the relational database where the survey data are archived.

The trawl survey data from the Gulf Region is accessed through the bespoke gulf package in R (R Core Team 2021).

Mobile sentinel survey data are normalised to a 1.25 nm tow and the stratification scheme used includes more strata than those used in the scientific trawl surveys. The stratified random estimate of 30+ cm catch biomass per tow is computed as:

$$\bar{Y_t} = \sum_{i=1}^{s} \bar{y}_{ts} \frac{N_s}{N} \qquad \text{(B1)}$$

where *s = 1, 2, 3, ..., S* are the different strata, $\bar{y}_{ts}$ is the catch sample mean for stratum *s* in year *t*, N_s is the number of trawlable units in stratum s and *N* is the total number of trawlable units in the survey area. The fraction $\frac{N_s}{N}$ represents the proportional area of each stratum.

B.1. TABLES

Table B1. Stratum weights for the northern Gulf of St. Lawrence DFO Quebec Region mobile sentinel survey used for the computation of the NAFO 4RST combined index. Shading identifies the strata that overlap between the two surveys and for which the area of each stratum is multiplied by a weighting of 0.5 in the stratified calculations.

Stratum	Area (km^2)	Weight	Proportion
401	545	0.5	0.0015554
402	909	0.5	0.0025942
403	1,190	0.5	0.0033962
404	792	0.5	0.0022603
405	1,478	0.5	0.0042181
406	2,579	0.5	0.0073603
407	2,336	1	0.0133336
408	2,734	1	0.0156053
409	909	1	0.0051884
410	1,818	1	0.0103769
801	1,214	1	0.0069293
802	1,369	1	0.0078141
803	6,976	1	0.0398180
804	2,490	1	0.0142126
805	5,762	1	0.0328887
806	2,127	1	0.0121406
807	2,370	1	0.0135276
808	2,428	1	0.0138587
809	1,547	1	0.0088301
810	765	1	0.0043665
811	1,506	1	0.0085960
812	4,648	1	0.0265301
813	3,958	1	0.0225917
814	1,029	1	0.0058734
815	4,407	1	0.0251545
816	5,032	1	0.0287220
817	3,646	1	0.0208109
818	2,774	1	0.0158336
819	1,441	1	0.0082250
820	1,358	1	0.0077513
821	1,272	1	0.0072604
822	3,245	1	0.0185220
823	556	1	0.0031736
824	837	1	0.0047775
827	3,231	1	0.0184421
828	2,435	1	0.0138986
829	2,692	1	0.0153656
830	1,917	1	0.0109420
831	1,204	1	0.0068723
832	3,962	1	0.0226145

Stratum	Area (km^2)	Weight	Proportion
833	559	1	0.0031907
835	2,641	1	0.0150745
836	3,149	1	0.0179741
837	2,668	1	0.0152286
838	3,378	1	0.0192812
839	4,390	1	0.0250575
840	765	1	0.0043665
841	816	1	0.0046576

Table B2. Stratum weights for the southern Gulf of St. Lawrence DFO Gulf Region mobile sentinel survey used for the computation of the NAFO 4RST combined index. Shading identifies the strata that overlap between the two surveys and for which the area of each stratum is multiplied by a weighting of 0.5 in the stratified calculations.

Stratum	Area (km^2)	Weight	Proportion
415	2,625	0.5	0.0074916
416	3,666	1	0.0209250
417	1,804	1	0.0102970
418	1,354	1	0.0077284
419	1,522	1	0.0086874
420	2,656	1	0.0151601
421	1,130	1	0.0064499
422	4,274	1	0.0243954
423	11,033	1	0.0629748
424	3,608	1	0.0205940
425	2,165	0.5	0.0061788
426	1,333	1	0.0076086
427	3,268	1	0.0186533
428	694	1	0.0039613
429	5,827	1	0.0332597
431	4,876	1	0.0278315
432	1,034	1	0.0059019
433	4,082	1	0.0232995
434	4,161	1	0.0237504
435	2,196	1	0.0125345
436	3,292	1	0.0187903
437	1,701	1	0.0097091
438	577	1	0.0032934
439	1,213	0.5	0.0034618

Table B3. Number of valid tows by stratum for all years and strata sampled in the northern Gulf of St. Lawrence Sentinel survey, 2003 to 2012. Shaded cells show stratum and year combinations with zero valid tow.

survey	stratum	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
northern	401	3	3	3	3	3	3	3	3	3	3
northern	402	3	3	3	3	3	3	3	3	3	3
northern	403	3	3	3	3	3	3	3	3	3	3
northern	404	3	3	3	3	3	2	3	3	3	3
northern	405	3	3	3	3	3	3	3	3	3	3
northern	406	3	3	3	3	3	3	3	3	3	3
northern	407	3	3	3	3	3	3	3	3	3	0
northern	408	3	3	3	3	3	1	3	3	3	3
northern	409	3	3	3	3	3	3	3	3	3	3
northern	410	3	3	3	3	3	3	3	3	3	3
northern	801	3	4	4	4	4	4	4	4	4	4
northern	802	4	4	4	4	4	4	4	4	4	4
northern	803	13	13	13	13	14	14	14	14	14	6
northern	804	5	5	5	4	5	5	5	4	5	5
northern	805	4	0	11	11	11	10	11	11	11	10
northern	806	4	4	4	4	4	4	4	4	4	4
northern	807	4	4	4	4	4	4	4	4	4	4
northern	808	4	3	3	4	4	4	4	4	4	4
northern	809	6	5	5	5	5	5	5	5	5	5
northern	810	4	4	4	4	4	4	4	4	4	4
northern	811	6	5	5	5	5	5	5	5	5	5
northern	812	15	13	14	14	14	14	14	14	14	14
northern	813	14	13	13	13	13	13	13	13	13	13
northern	814	3	3	3	3	3	3	3	3	3	3
northern	815	8	8	8	8	9	9	8	9	9	8
northern	816	10	9	10	10	10	10	7	9	8	8
northern	817	7	7	7	7	7	7	7	6	6	5
northern	818	5	5	5	5	5	5	5	4	5	5
northern	819	3	3	1	3	3	3	3	3	1	3
northern	820	4	4	4	4	4	4	4	4	4	4
northern	821	4	4	4	4	4	4	4	4	4	4
northern	822	11	10	10	10	10	10	10	10	10	10
northern	823	4	4	4	4	4	4	4	4	4	4
northern	824	4	4	4	4	4	4	4	4	4	4
northern	827	5	3	4	6	6	4	3	4	5	6
northern	828	3	2	2	4	1	1	2	1	2	2
northern	829	5	5	2	4	4	5	1	2	2	4
northern	830	4	4	3	4	3	4	4	2	4	4
northern	831	3	3	3	3	3	3	2	1	3	0
northern	832	7	7	7	6	5	7	7	6	6	7
northern	833	3	3	3	3	3	3	3	3	3	3
northern	835	10	8	9	9	9	9	9	9	9	9
northern	836	11	10	10	10	10	10	10	10	10	10
northern	837	10	9	9	9	9	9	9	9	9	9
northern	838	13	12	11	12	12	12	12	12	12	12
northern	839	3	8	5	6	5	4	3	4	4	8
northern	840	4	4	4	4	4	4	4	4	4	4
northern	841	3	3	2	3	2	3	2	2	2	1
	all	263	249	253	264	260	258	251	249	254	246

Table B4. Number of valid tows by stratum for all years and strata sampled in the northern Gulf of St. Lawrence Sentinel survey, 2013 to 2021. Shaded cells show stratum and year combinations with zero valid tow.

survey	stratum	2013	2014	2015	2016	2017	2018	2019	2020	2021
northern	401	3	3	3	3	3	3	2	2	2
northern	402	3	3	3	3	3	3	2	1	2
northern	403	3	3	3	3	3	2	2	2	2
northern	404	3	3	3	3	3	3	2	2	2
northern	405	3	3	3	3	3	3	2	2	2
northern	406	3	3	3	3	3	3	3	3	3
northern	407	3	3	1	3	3	3	3	2	2
northern	408	3	3	3	3	3	3	3	2	3
northern	409	3	3	3	3	3	3	2	2	2
northern	410	3	3	3	3	3	3	3	1	3
northern	801	4	4	4	4	3	3	3	0	2
northern	802	4	4	4	4	3	3	3	3	3
northern	803	12	12	11	12	12	11	9	7	8
northern	804	5	5	5	5	5	4	4	4	4
northern	805	10	10	10	10	11	9	9	6	7
northern	806	4	4	4	4	4	4	3	2	3
northern	807	4	4	4	4	4	4	4	4	4
northern	808	4	4	4	4	4	4	4	4	4
northern	809	5	5	5	5	4	4	4	4	4
northern	810	4	4	4	4	3	3	3	3	3
northern	811	5	5	5	5	4	4	4	4	4
northern	812	12	14	12	13	12	12	12	12	12
northern	813	13	13	13	14	10	10	10	8	4
northern	814	3	3	3	3	3	3	3	2	2
northern	815	8	8	8	8	8	7	7	7	7
northern	816	9	9	9	9	9	8	8	8	8
northern	817	7	7	7	7	6	6	6	6	6
northern	818	5	5	5	5	5	4	4	4	4
northern	819	3	3	3	3	3	3	3	2	2
northern	820	4	4	4	4	4	4	4	6	4
northern	821	4	4	4	4	4	4	4	4	4
northern	822	10	10	10	10	8	8	8	8	8
northern	823	4	4	4	4	3	3	3	3	3
northern	824	4	4	3	4	3	3	3	3	3
northern	827	6	6	6	6	6	4	5	3	4
northern	828	2	0	2	0	3	3	4	4	4
northern	829	5	5	5	5	5	4	4	3	4
northern	830	4	4	5	5	5	3	3	3	3
northern	831	2	3	3	3	3	3	3	2	2
northern	832	6	7	8	8	7	6	6	6	6
northern	833	3	3	3	3	3	3	3	2	2
northern	835	9	8	9	9	7	7	7	6	7
northern	836	10	10	10	10	8	8	8	8	8
northern	837	9	9	8	9	7	7	7	7	7
northern	838	12	12	12	10	9	9	9	9	9
northern	839	7	6	5	6	7	5	7	6	7
northern	840	4	4	4	3	3	3	3	3	3
northern	841	3	1	4	4	2	3	3	2	2
	all	259	257	257	260	240	225	221	197	204

Table B5. Number of valid tows by stratum for all years and strata sampled in the southern Gulf of St. Lawrence Sentinel survey, 2003 to 2011. Shaded cells show stratum and year combinations with zero valid tow.

survey	**stratum**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
southern	415	9	9	8	8	8	8	7	7	7
southern	416	9	11	12	10	10	10	8	8	8
southern	417	6	7	7	7	7	7	6	6	6
southern	418	6	6	5	7	7	7	6	6	5
southern	419	6	6	6	7	7	7	6	6	5
southern	420	9	8	9	8	8	8	7	7	7
southern	421	5	4	5	5	6	5	4	4	4
southern	422	12	13	12	10	10	10	9	9	8
southern	423	19	26	26	17	17	17	14	14	14
southern	424	10	11	11	10	10	10	8	8	8
southern	425	8	8	10	9	9	9	8	8	8
southern	426	6	6	7	8	8	8	7	7	7
southern	427	8	10	10	9	9	9	8	8	8
southern	428	4	5	5	6	6	4	5	5	4
southern	429	16	16	14	11	11	11	9	9	8
southern	431	14	14	13	10	12	10	8	9	8
southern	432	6	4	6	5	6	6	4	4	4
southern	433	10	12	12	10	10	10	8	8	8
southern	434	13	12	12	10	10	10	8	8	8
southern	435	8	8	7	7	8	8	7	7	4
southern	436	9	10	11	9	9	9	8	8	8
southern	437	7	7	10	9	10	9	8	8	8
southern	438	4	4	6	8	8	9	7	7	6
southern	439	6	6	9	10	10	8	10	9	9
	all	210	223	233	210	216	209	180	180	170

Table B6. Number of valid tows by stratum for all years and strata sampled in the southern Gulf of St. Lawrence Sentinel survey, 2012 to 2021. Shaded cells show stratum and year combinations with zero valid tow.

survey	stratum	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
southern	415	7	7	6	4	6	5	3	2	0	0
southern	416	8	7	6	6	6	6	6	3	0	0
southern	417	6	5	5	5	4	4	4	3	0	0
southern	418	5	5	5	5	5	5	5	4	0	0
southern	419	5	4	5	5	5	5	5	4	0	0
southern	420	7	7	7	7	5	5	5	4	0	0
southern	421	4	4	3	0	3	4	3	2	0	0
southern	422	7	9	9	6	8	5	7	6	0	0
southern	423	14	13	10	12	11	9	11	6	0	0
southern	424	8	8	8	7	7	5	7	5	0	0
southern	425	8	5	5	5	5	3	5	2	0	0
southern	426	7	5	5	5	4	3	5	3	0	0
southern	427	7	8	7	7	8	6	6	3	0	0
southern	428	3	3	4	4	3	2	4	4	0	0
southern	429	9	10	10	6	9	7	9	4	0	0
southern	431	9	10	8	7	8	7	8	4	0	0
southern	432	4	4	4	4	4	2	4	4	0	0
southern	433	8	7	6	6	5	3	5	4	0	0
southern	434	8	9	8	7	7	6	7	6	0	0
southern	435	4	4	4	4	4	2	3	3	0	0
southern	436	8	8	6	6	6	5	7	4	0	0
southern	437	8	8	6	6	6	4	5	4	0	0
southern	438	6	6	6	6	6	4	5	4	0	0
southern	439	9	6	5	5	5	3	5	4	0	0
	all	169	162	148	135	140	110	134	92	0	0

Table B7. Mean numbers per tow of individuals greater than 30 cm for all strata sampled in the northern and southern Gulf of St. Lawrence sentinel surveys, 2003 to 2011.

survey	stratum	2003	2004	2005	2006	2007	2008	2009	2010	2011
July	401	8.33	11.86	8.33	0.00	2.88	0.00	2.74	8.33	0.00
July	402	0.00	0.00	0.00	10.90	0.96	1.92	5.79	6.00	0.67
July	403	7.05	0.00	1.28	0.00	0.00	13.16	0.00	5.67	0.67
July	404	0.00	0.00	0.00	0.00	0.00	0.00	3.33	3.00	0.00
July	405	0.00	0.64	0.00	0.00	0.00	0.67	1.25	2.70	0.00
July	406	0.00	2.67	0.00	0.00	0.00	1.00	0.00	0.62	0.00
July	407	1.60	1.60	0.00	0.00	1.00	0.00	0.00	2.40	0.00
July	408	0.00	3.85	1.92	0.00	2.00	0.00	4.85	1.01	0.00
July	409	0.00	0.00	4.01	1.00	3.00	1.25	0.63	0.67	2.21
July	410	0.00	0.00	0.00	0.00	0.65	2.00	0.00	0.00	0.00
July	801	0.00	0.00	0.00	1.75	0.00	0.50	0.00	0.00	0.00
July	802	2.00	0.75	1.50	0.00	1.50	0.00	0.00	0.00	0.50
July	803	0.37	0.38	0.98	0.77	1.40	0.00	0.69	1.57	0.00
July	804	0.96	0.00	3.65	0.00	2.20	0.00	0.00	2.91	1.20
July	805	0.48	NA	0.00	0.00	0.28	0.19	0.00	0.00	0.00
July	806	0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00
July	807	0.00	0.00	0.00	0.00	3.17	0.00	0.89	3.50	0.00
July	808	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	809	1.33	0.00	1.80	0.40	1.00	0.00	0.00	0.00	0.00
July	810	2.50	0.00	3.50	0.00	0.00	0.00	0.00	0.00	0.50
July	811	7.00	2.20	4.66	3.40	5.80	0.00	0.00	0.00	0.00
July	812	1.01	0.38	1.21	1.36	0.00	0.00	1.00	0.14	1.29
July	813	0.29	0.31	0.69	0.00	0.00	1.08	0.00	0.00	0.00
July	814	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.23
July	815	0.00	0.00	0.00	0.00	0.22	0.82	0.00	3.19	0.47
July	816	0.00	0.41	5.13	2.75	0.30	1.93	5.09	6.98	1.38
July	817	0.00	0.00	0.00	0.00	3.14	7.30	0.29	1.48	1.67
July	818	0.77	0.00	0.60	0.00	1.60	0.00	2.98	2.00	0.00
July	819	0.00	0.00	6.20	0.00	0.00	0.00	0.00	0.00	0.00
July	820	2.50	4.75	0.00	48.00	6.70	9.25	3.68	3.75	2.75
July	821	3.00	0.00	2.25	2.00	3.75	0.00	0.00	1.50	2.25
July	822	2.18	6.40	3.60	1.50	4.30	3.62	0.00	7.40	6.70
July	823	0.00	1.75	0.00	0.75	2.00	0.50	3.25	3.00	0.00
July	824	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00	0.00
July	827	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	828	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.05
July	829	0.00	0.00	1.50	0.00	0.00	0.00	0.00	4.40	0.00
July	830	0.48	0.00	0.00	0.00	0.00	0.00	1.35	0.00	0.72
July	831	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	832	0.00	0.00	0.30	0.00	5.00	1.57	3.09	8.07	2.50
July	833	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	835	0.60	0.94	3.56	2.78	0.00	0.00	0.00	0.56	5.33
July	836	0.00	1.50	0.00	0.00	0.40	0.00	0.00	0.00	4.60
July	837	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	838	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	839	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	840	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	841	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	415	4.31	0.55	3.51	1.01	2.72	2.94	3.91	7.43	4.30
August	416	1.23	1.47	2.22	0.73	3.97	3.93	5.08	2.05	0.64
August	417	0.17	0.29	0.30	0.29	0.00	0.00	0.00	0.00	0.19
August	418	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	419	0.00	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00
August	420	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	421	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	422	0.08	0.59	0.18	0.19	0.00	0.22	0.00	0.00	0.00
August	423	0.14	0.32	0.13	0.17	0.00	0.07	0.00	0.00	0.13
August	424	0.30	1.44	0.00	2.00	0.00	0.42	0.13	0.00	0.00

survey	stratum	2003	2004	2005	2006	2007	2008	2009	2010	2011
August	425	6.80	2.48	18.79	8.81	0.94	5.64	5.35	18.74	4.54
August	426	1.32	24.77	3.42	4.11	0.12	2.07	7.90	0.53	2.88
August	427	0.11	0.91	0.10	0.20	0.11	0.15	0.26	0.00	0.00
August	428	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	429	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	431	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	432	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	433	0.00	0.22	0.00	0.41	0.37	0.00	0.12	0.00	0.00
August	434	0.32	5.76	3.48	1.49	2.69	0.29	0.82	0.12	1.38
August	435	0.00	0.22	0.00	0.00	0.00	0.70	0.00	0.12	0.00
August	436	0.00	0.88	0.48	1.97	0.11	0.00	1.57	0.00	0.00
August	437	34.25	26.00	29.69	88.67	18.34	20.10	23.79	3.03	5.41
August	438	2.96	36.25	44.53	13.49	13.48	23.34	11.16	8.77	6.41
August	439	19.84	10.70	6.08	5.75	4.69	4.35	6.13	20.73	3.04

Table B8. Mean kg per tow of individuals greater than 30 cm for all strata sampled in the northern and southern Gulf of St. Lawrence sentinel surveys, 2012 to 2021.

survey	stratum	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
July	401	2.33	0.00	20.74	1.28	0.00	6.67	3.33	3.50	9.00	0.00
July	402	4.67	0.00	32.37	1.00	0.00	8.33	0.00	0.00	0.00	0.00
July	403	22.04	5.38	6.67	46.00	18.00	115.83	1.00	194.93	29.95	73.00
July	404	0.00	0.00	3.53	1.00	0.67	1.67	0.00	3.26	0.00	1.92
July	405	5.73	0.00	6.00	0.00	1.33	2.00	1.67	0.00	7.00	0.00
July	406	0.00	0.67	0.00	9.33	0.96	29.67	18.52	12.00	3.33	6.67
July	407	NA	0.00	1.00	2.00	0.00	0.67	0.00	1.04	0.00	0.00
July	408	4.76	0.00	9.33	1.33	0.00	3.00	1.33	0.00	0.00	0.00
July	409	57.67	0.00	33.67	107.67	55.00	28.75	0.00	0.00	54.35	47.52
July	410	4.49	0.00	17.00	8.33	1.38	7.47	5.00	12.33	0.00	12.00
July	801	0.00	0.75	6.31	0.00	0.00	1.33	0.00	0.00	NA	0.00
July	802	0.00	0.50	0.00	3.00	0.00	0.00	0.00	0.00	1.03	0.00
July	803	0.50	0.00	2.25	0.27	0.17	0.17	0.00	0.33	0.43	0.00
July	804	5.30	0.00	1.37	0.80	0.00	2.00	0.00	0.00	0.00	0.00
July	805	0.70	0.21	4.56	0.20	0.20	1.11	0.23	1.89	0.87	3.28
July	806	0.75	0.72	1.50	0.00	2.25	2.50	0.00	0.00	1.50	0.00
July	807	14.53	0.00	0.00	0.00	0.00	3.50	0.00	0.00	0.00	0.00
July	808	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	809	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	810	0.00	0.00	1.75	0.00	0.00	0.00	0.00	0.00	3.21	0.00
July	811	0.00	1.00	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	812	0.29	0.00	7.35	1.58	0.00	0.00	0.00	0.31	0.00	0.63
July	813	0.15	0.00	4.06	1.94	0.00	0.30	0.00	0.00	1.62	0.75
July	814	0.00	0.00	1.28	0.00	0.64	1.33	0.00	1.60	0.00	0.00
July	815	0.00	6.83	2.66	0.23	3.77	0.93	1.43	2.10	9.76	0.00
July	816	1.43	2.10	1.02	1.07	1.38	2.69	0.50	0.00	2.56	0.91
July	817	1.15	3.42	3.67	1.71	0.00	0.50	2.02	1.00	0.00	1.17
July	818	3.60	0.62	1.00	0.00	0.94	1.78	5.55	2.25	0.00	19.81
July	819	0.00	0.00	0.00	0.76	0.67	0.00	0.00	0.00	0.00	0.00
July	820	20.25	2.00	2.26	0.00	4.75	0.00	30.25	0.00	65.67	3.50
July	821	9.00	0.00	7.25	6.25	0.00	1.25	6.25	3.75	12.25	7.94
July	822	3.30	0.30	20.67	20.20	0.00	4.00	0.84	22.48	28.25	16.76
July	823	1.00	0.00	30.53	22.96	69.75	0.00	0.00	0.00	72.00	83.00
July	824	0.00	0.00	1.50	6.00	5.75	0.00	0.00	1.00	0.00	2.00
July	827	0.00	0.00	0.00	0.32	1.78	0.96	0.00	0.00	10.44	0.00
July	828	0.00	0.00	NA	0.00	NA	0.00	0.00	0.00	0.00	0.00
July	829	0.00	0.00	0.00	2.42	0.00	6.20	0.00	0.00	0.69	0.00
July	830	3.57	5.79	6.78	0.00	1.18	3.27	0.00	2.67	3.67	0.00
July	831	NA	0.00	0.00	1.74	0.00	0.00	0.00	0.00	0.00	0.00
July	832	0.45	11.28	8.81	1.55	0.41	1.64	0.33	0.00	2.60	0.00
July	833	0.00	0.00	0.00	0.00	0.00	0.00	1.92	0.00	0.00	0.00
July	835	21.87	0.00	2.12	2.67	0.00	3.57	0.00	1.14	0.00	31.71
July	836	0.50	0.00	0.00	6.10	0.00	0.00	0.00	0.62	0.00	0.00
July	837	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00
July	838	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	839	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	840	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	841	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	415	11.96	8.87	9.44	11.03	10.30	22.27	45.90	26.54	NA	NA
August	416	2.16	3.91	5.74	8.07	10.29	18.79	1.50	2.13	NA	NA
August	417	0.33	0.00	0.00	0.40	0.52	0.48	2.16	1.59	NA	NA
August	418	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	419	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	420	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	421	0.00	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA
August	422	0.00	0.55	0.00	0.50	0.60	0.19	0.42	0.00	NA	NA
August	423	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	424	0.90	0.40	0.00	0.64	0.84	0.00	0.44	1.19	NA	NA

survey	stratum	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
August	425	3.81	4.49	3.09	2.12	4.29	3.17	4.55	0.00	NA	NA
August	426	1.39	4.88	7.62	3.08	14.03	1.38	0.20	0.99	NA	NA
August	427	0.00	0.27	0.14	0.11	1.31	0.00	0.00	0.00	NA	NA
August	428	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	429	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	431	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	432	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	433	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	434	0.23	0.00	0.12	0.14	0.00	0.00	0.13	0.00	NA	NA
August	435	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	NA	NA
August	436	0.76	3.36	0.31	0.48	0.43	0.21	0.29	0.00	NA	NA
August	437	17.03	14.15	7.17	3.97	18.74	3.91	1.42	5.93	NA	NA
August	438	8.82	10.31	15.38	3.47	4.84	29.67	3.88	0.98	NA	NA
August	439	10.70	4.55	12.88	6.04	2.96	7.44	11.53	13.45	NA	NA

Table B9. Mean kg per tow of individuals greater than 30 cm for all strata sampled in the northern and southern Gulf of St. Lawrence sentinel surveys, 2003 to 2011.

survey	stratum	2003	2004	2005	2006	2007	2008	2009	2010	2011
July	401	2.05	1.79	1.55	0.00	0.41	0.00	0.22	1.24	0.00
July	402	0.00	0.00	0.00	0.93	0.06	0.21	0.61	0.61	0.07
July	403	0.48	0.00	0.51	0.00	0.00	2.01	0.00	0.63	0.15
July	404	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.72	0.00
July	405	0.00	0.23	0.00	0.00	0.00	0.08	0.24	0.65	0.00
July	406	0.00	0.57	0.00	0.00	0.00	0.07	0.00	0.06	0.00
July	407	0.28	0.31	0.00	0.00	0.14	0.00	0.00	0.25	0.00
July	408	0.00	0.86	0.46	0.00	0.17	0.00	0.41	0.18	0.00
July	409	0.00	0.00	1.02	0.16	0.64	0.13	0.06	0.11	0.17
July	410	0.00	0.00	0.00	0.00	0.13	0.40	0.00	0.00	0.00
July	801	0.00	0.00	0.00	0.08	0.00	0.06	0.00	0.00	0.00
July	802	0.37	0.05	0.14	0.00	0.19	0.00	0.00	0.00	0.08
July	803	0.06	0.04	0.16	0.04	0.13	0.00	0.14	0.18	0.00
July	804	0.09	0.00	0.47	0.00	0.20	0.00	0.00	0.45	0.26
July	805	0.09	NA	0.00	0.00	0.02	0.02	0.00	0.00	0.00
July	806	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00
July	807	0.00	0.00	0.00	0.00	0.52	0.00	0.11	0.51	0.00
July	808	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	809	0.11	0.00	0.27	0.05	0.16	0.00	0.00	0.00	0.00
July	810	0.48	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.05
July	811	0.87	0.26	0.91	0.23	0.54	0.00	0.00	0.00	0.00
July	812	0.09	0.02	0.10	0.10	0.00	0.00	0.12	0.04	0.24
July	813	0.01	0.04	0.06	0.00	0.00	0.14	0.00	0.00	0.00
July	814	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20
July	815	0.00	0.00	0.00	0.00	0.03	0.12	0.00	0.39	0.03
July	816	0.00	0.06	0.24	0.12	0.02	0.41	0.38	0.24	0.19
July	817	0.00	0.00	0.00	0.00	0.44	0.36	0.06	0.15	0.20
July	818	0.03	0.00	0.03	0.00	0.20	0.00	0.26	0.14	0.00
July	819	0.00	0.00	0.83	0.00	0.00	0.00	0.00	0.00	0.00
July	820	0.37	1.19	0.00	13.71	1.56	2.76	0.33	0.97	0.46
July	821	0.53	0.00	0.17	0.76	0.60	0.00	0.00	0.11	0.32
July	822	0.33	0.77	0.71	0.36	0.48	0.34	0.00	1.76	1.29
July	823	0.00	0.42	0.00	0.22	0.49	0.09	1.20	0.35	0.00
July	824	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00
July	827	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	828	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34
July	829	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.16	0.00
July	830	0.12	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.09
July	831	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	832	0.00	0.00	0.07	0.00	0.63	0.08	0.10	0.49	0.10
July	833	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	835	0.11	0.13	0.94	0.85	0.00	0.00	0.00	0.15	1.35
July	836	0.00	0.42	0.00	0.00	0.08	0.00	0.00	0.00	1.02
July	837	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	838	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	839	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	840	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	841	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	415	0.49	0.10	0.35	0.05	0.28	0.54	0.43	1.33	0.75
August	416	0.31	0.15	0.59	0.16	0.84	0.77	1.32	0.52	0.16
August	417	0.07	0.06	0.18	0.04	0.00	0.00	0.00	0.00	0.05
August	418	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	419	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00
August	420	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	421	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	422	0.01	0.24	0.04	0.05	0.00	0.06	0.00	0.00	0.00
August	423	0.04	0.08	0.03	0.02	0.00	0.02	0.00	0.00	0.03
August	424	0.10	0.24	0.00	0.42	0.00	0.05	0.07	0.00	0.00

survey	stratum	2003	2004	2005	2006	2007	2008	2009	2010	2011
August	425	0.83	0.77	1.84	1.21	0.40	0.85	1.37	3.36	1.30
August	426	0.32	4.70	0.95	0.96	0.04	0.57	1.73	0.12	0.78
August	427	0.04	0.22	0.02	0.02	0.02	0.07	0.08	0.00	0.00
August	428	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	429	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	431	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	432	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	433	0.00	0.09	0.00	0.16	0.10	0.00	0.00	0.00	0.00
August	434	0.11	2.05	1.21	0.46	0.89	0.12	0.20	0.04	0.44
August	435	0.00	0.07	0.00	0.00	0.00	0.20	0.00	0.04	0.00
August	436	0.00	0.33	0.16	0.56	0.05	0.00	0.46	0.00	0.00
August	437	10.98	8.87	9.09	25.72	5.10	5.28	6.76	0.87	1.65
August	438	0.81	11.67	11.47	3.80	2.82	3.32	2.93	2.24	1.70
August	439	3.32	3.86	2.55	1.09	1.09	1.67	1.35	5.42	0.76

Table B10. Mean kg per tow of individuals greater than 30 cm for all strata sampled in the northern and southern Gulf of St. Lawrence sentinel surveys, 2012 to 2021.

survey	stratum	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
July	401	0.54	0.00	3.93	0.05	0.00	1.63	0.92	0.51	1.04	0.00
July	402	0.37	0.00	5.68	0.06	0.00	2.04	0.00	0.00	0.00	0.00
July	403	1.95	0.47	1.33	5.48	4.16	33.64	0.09	26.03	7.41	18.18
July	404	0.00	0.00	1.08	0.14	0.11	0.40	0.00	1.00	0.00	0.51
July	405	1.50	0.00	1.12	0.00	0.30	0.54	0.47	0.00	2.30	0.00
July	406	0.00	0.13	0.00	1.02	0.17	7.86	3.07	2.30	0.86	1.55
July	407	NA	0.00	0.06	0.20	0.00	0.10	0.00	0.07	0.00	0.00
July	408	0.26	0.00	1.58	0.27	0.00	0.94	0.25	0.00	0.00	0.00
July	409	2.67	0.00	4.72	17.24	10.97	5.96	0.00	0.00	12.25	9.24
July	410	0.38	0.00	2.86	1.07	0.13	1.30	1.40	2.59	0.00	3.54
July	801	0.00	0.05	0.84	0.00	0.00	0.49	0.00	0.00	NA	0.00
July	802	0.00	0.08	0.00	0.63	0.00	0.00	0.00	0.00	0.19	0.00
July	803	0.07	0.00	0.33	0.05	0.02	0.02	0.00	0.05	0.11	0.00
July	804	1.07	0.00	0.24	0.13	0.00	0.41	0.00	0.00	0.00	0.00
July	805	0.04	0.03	0.63	0.02	0.03	0.12	0.04	0.16	0.17	0.68
July	806	0.04	0.12	0.14	0.00	0.42	0.54	0.00	0.00	0.17	0.00
July	807	2.56	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00
July	808	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	809	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	810	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.25	0.00
July	811	0.00	0.24	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	812	0.04	0.00	1.25	0.24	0.00	0.00	0.00	0.06	0.00	0.15
July	813	0.01	0.00	0.70	0.42	0.00	0.06	0.00	0.00	0.09	0.12
July	814	0.00	0.00	0.07	0.00	0.05	0.14	0.00	0.05	0.00	0.00
July	815	0.00	0.82	0.39	0.03	0.55	0.10	0.34	0.25	1.16	0.00
July	816	0.20	0.25	0.08	0.16	0.11	0.38	0.07	0.00	0.32	0.14
July	817	0.04	0.24	0.29	0.20	0.00	0.07	0.46	0.09	0.00	0.20
July	818	0.36	0.07	0.07	0.00	0.15	0.29	1.03	0.42	0.00	2.68
July	819	0.00	0.00	0.00	0.21	0.10	0.00	0.00	0.00	0.00	0.00
July	820	5.26	0.37	0.46	0.00	0.90	0.00	9.82	0.00	18.61	0.83
July	821	2.22	0.00	1.14	1.42	0.00	0.22	1.41	0.44	3.08	1.90
July	822	0.62	0.05	3.85	4.49	0.00	0.75	0.19	5.55	7.84	3.25
July	823	0.29	0.00	4.35	3.55	13.05	0.00	0.00	0.00	10.83	24.41
July	824	0.00	0.00	0.31	1.42	1.09	0.00	0.00	0.08	0.00	0.47
July	827	0.00	0.00	0.00	0.04	0.21	0.15	0.00	0.00	2.25	0.00
July	828	0.00	0.00	NA	0.00	NA	0.00	0.00	0.00	0.00	0.00
July	829	0.00	0.00	0.00	0.38	0.00	1.52	0.00	0.00	0.09	0.00
July	830	0.37	0.92	0.89	0.00	0.20	0.77	0.00	0.80	1.15	0.00
July	831	NA	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00
July	832	0.04	1.49	0.54	0.24	0.05	0.12	0.03	0.00	0.59	0.00
July	833	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00
July	835	6.43	0.00	0.59	0.78	0.00	0.91	0.00	0.30	0.00	9.79
July	836	0.15	0.00	0.00	1.67	0.00	0.00	0.00	0.18	0.00	0.00
July	837	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
July	838	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	839	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	840	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	841	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	415	1.25	1.54	2.22	2.62	2.80	6.83	12.60	8.77	NA	NA
August	416	0.65	1.06	1.59	2.09	3.55	6.72	0.63	0.75	NA	NA
August	417	0.16	0.00	0.00	0.08	0.08	0.20	1.04	0.61	NA	NA
August	418	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	419	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	420	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	421	0.00	0.00	0.00	NA	0.00	0.00	0.00	0.00	NA	NA
August	422	0.00	0.18	0.00	0.26	0.19	0.08	0.14	0.00	NA	NA
August	423	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	424	0.34	0.10	0.00	0.19	0.26	0.00	0.18	0.45	NA	NA

survey	stratum	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
August	425	1.08	0.70	0.75	0.52	1.01	1.04	1.32	0.00	NA	NA
August	426	0.37	1.22	1.46	0.97	3.28	0.51	0.05	0.37	NA	NA
August	427	0.00	0.08	0.05	0.04	0.33	0.00	0.00	0.00	NA	NA
August	428	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	429	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	431	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	432	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	433	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
August	434	0.07	0.00	0.04	0.04	0.00	0.00	0.04	0.00	NA	NA
August	435	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	NA	NA
August	436	0.28	0.88	0.11	0.18	0.13	0.04	0.12	0.00	NA	NA
August	437	5.10	3.32	1.97	1.29	5.18	1.61	0.34	1.15	NA	NA
August	438	2.50	3.02	2.48	1.16	1.09	8.25	1.40	0.38	NA	NA
August	439	2.37	1.34	3.09	2.35	1.06	1.91	3.48	4.30	NA	NA

APPENDIX C. POPULATION MODEL CODE AND INPUT DATA

The Bayesian Surplus Production model used for the assessment of NAFO Divisions 4RST Witch Flounder is implemented in JAGS (Just Another Gibbs Sampler; Plummer 2021a). The model code along with the input data used for the assessment to 2021 is presented in this Appendix.

Table C1. Data inputs to the Bayesian Schaefer surplus production model used for Witch Flounder in NAFO Divisions 4RST. The first column are total annual landings (in 1,000 t) of Witch Flounder in NAFO Divisions 4RST for the period 1961 to 2021. As the population model estimates the stock biomass in September, the values of annual landings shown in this table are the sum of January to August catches in a given year and of September to December catches from the previous year. The value of the three indices used to for the population model are in trawlable biomass units (in 1,000 t) for the NAFO 4T September survey (column "RV 4T"), the combined NAFO 4RST August and September surveys (column "RV 4RST") and the combined NAFO 4RST July and August Sentinel surveys (column "SENT 4RST"). Values that are not provided as inputs to the population model appear as not available (NA).

Year	Landings	RV 4T	RV 4RST	SENT 4RST
1961	3.260	NA	NA	NA
1962	3.457	NA	NA	NA
1963	4.283	NA	NA	NA
1964	3.468	NA	NA	NA
1965	3.379	NA	NA	NA
1966	3.672	NA	NA	NA
1967	2.903	NA	NA	NA
1968	3.427	NA	NA	NA
1969	3.938	NA	NA	NA
1970	4.946	NA	NA	NA
1971	4.553	4.008	NA	NA
1972	2.263	3.124	NA	NA
1973	2.025	3.615	NA	NA
1974	3.153	3.514	NA	NA
1975	2.466	3.467	NA	NA
1976	7.353	4.550	NA	NA
1977	3.023	6.560	NA	NA
1978	4.689	2.554	NA	NA
1979	4.354	3.991	NA	NA
1980	3.726	2.359	NA	NA
1981	1.766	1.721	NA	NA
1982	1.400	1.395	NA	NA
1983	1.138	1.058	NA	NA
1984	1.067	1.099	NA	NA
1985	1.613	1.368	NA	NA
1986	1.828	2.974	NA	NA
1987	2.286	2.215	9.072	NA
1988	2.611	3.053	9.353	NA
1989	2.383	2.752	7.504	NA
1990	1.657	1.913	10.173	NA
1991	1.080	1.530	6.056	NA
1992	0.934	0.665	3.475	NA

Year	Landings	RV 4T	RV 4RST	SENT 4RST
1993	1.051	NA	1.521	NA
1994	0.393	NA	3.309	NA
1995	0.345	NA	2.466	NA
1996	0.431	NA	3.483	NA
1997	0.516	NA	2.261	NA
1998	0.683	NA	2.955	NA
1999	0.927	NA	6.166	NA
2000	1.036	NA	6.524	NA
2001	0.643	NA	4.166	NA
2002	0.865	NA	4.466	NA
2003	0.783	NA	5.420	1.058
2004	0.775	NA	2.420	1.776
2005	0.938	NA	3.998	1.639
2006	1.118	NA	2.784	2.541
2007	0.811	NA	2.726	1.083
2008	0.761	NA	4.964	0.965
2009	0.660	NA	2.653	1.063
2010	0.268	NA	3.839	1.068
2011	0.376	NA	3.112	0.873
2012	0.446	NA	4.781	2.173
2013	0.315	NA	6.740	1.128
2014	0.261	NA	5.925	2.532
2015	0.258	NA	5.686	2.453
2016	0.253	NA	8.529	1.997
2017	0.273	NA	7.966	3.365
2018	0.329	NA	7.794	1.815
2019	0.308	NA	10.902	2.223
2020	0.193	NA	9.538	NA
2021	0.212	NA	8.537	NA

JAGS computer code for the Bayesian Surplus Production Model used in the assessment of NAFO Divisions 4RST Witch Flounder.

```
# Schaefer model for 4RST witch flounder
# informative prior for r
# prior for obs error sd uniform between cv and 3*cv
# indices are 30+ trawlable biomass
# 1960 proportion of K a parameter with uninformative prior
# inputs in 1000 t
# catch(t) is sep-dec catch t-1 + jan-aug catch t
# log(0.4776) = -0.7389817 prior for q2
# back to 1961
#

model{
# priors
 b0~dlnorm(4.127134,8.163265) # mean=log(62), sd=0.35
 q[1]~dunif(0.1,0.6)
 q[2]~dlnorm(-0.7389817,9.467456)
 q[3]~dunif(0.1,1.0)
 r~dnorm(0.1687,400)
 logK~dunif(2,6)
 k <- exp(logK)
 sdobs[1]~dunif(0.35,1)
 sdobs[2]~dunif(0.35,1)
 sdobs[3]~dunif(0.25,0.75)
 for (ndx in 1:3) {
   tau[ndx]<-pow(sdobs[ndx],-2)
 }
 sdpro~dunif(0.05,1)
 taup<-pow(sdpro,-2)

# process model
    btmp[1]<-b0+b0*r[1]*(1-b0/k)-cobs[1]
    bpred[1]<-max(btmp[1],0.01)    #this prevents stock biomass from dropping below 1%
of carrying capacity
    lbpred[1]<-log(bpred[1])
    b[1]~dlnorm(lbpred[1], taup)
    perr[1]<-log(b[1]/(bpred[1]))
    for (i in 2:61) {
      btmp[i]<-b[i-1]+b[i-1]*r*(1-b[i-1]/k)-cobs[i]
      bpred[i]<-max(btmp[i],0.01)
      lbpred[i]<-log(bpred[i])
      b[i]~dlnorm(lbpred[i], taup)
      perr[i]<-log(b[i]/(bpred[i]))
    }

# observation model
   for (i in 1:61){
         for (ndx in 1:3) {
            xpred[ndx,i]<-log(b[i]*q[ndx])
            x[ndx,i]~dlnorm(xpred[ndx,i],tau[ndx])
   }
```

```
# Exploitation rate, B over Bmsy, F over Fmsy and Surplus production
for (t in 1:61)  {
E[t] <- cobs[t]/b[t]
BoverBmsy[t] <- b[t] / (k/2)
FoverFmsy[t] <- (cobs[t]/b[t]) / (r/2)
SP[t] <- (r*b[t])*(1-(b[t]/k))
}

# Maximum surplus production
C_MSY <-  r*k/4

# Biomass at maximum surplus production
B_MSY <- k/2

# Exploitation rate at MSY
F_MSY <- C_MSY / B_MSY
Bratio <-b[61]/B_MSY
BoverLRP <- b[61]/(0.4*B_MSY)
BoverUSR <- b[61]/(0.8*B_MSY)
LRP <- (0.4*B_MSY)
USR <- (0.8*B_MSY)
}
```