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An Assessment of the Status of Redfish in NAFO Divisions 3LN

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Abstract

There are two species of redfish in Divisions 3L and 3N, the deep-sea redfish (*Sebastes mentella*) and the Acadian redfish (*Sebastes fasciatus*) that have been commercially fished and reported collectively as "redfish" in fishery statistics. Nominal catches increased to a 79 000 t high in 1987, and declined steadily to approximately 450 t in 1996. The stock was placed under a moratorium on directed fishing in 1998 and the fishery was reopened in 2011. TAC and catches increased until 2018. TAC increased again in 2019 but landings have remained well below the TAC since that time. Beginning in 2022, new survey vessels have been used to conduct the Canadian multi-species surveys. For redfish in NAFO Divs. 3LN, conversion factors that would allow data from the new vessels to extend existing time series data from the former primary research vessels were generally not available. As a result, the spring Canadian Campelen series and the autumn Canadian Campelen series have ended, and new survey series begun for this stock. The current assessment of the 3LN redfish stock is based on research vessel data. A new combined standardized biomass index was calculated, and indicates that the stock biomass has decreased since 2015. B_{2023}/B_{lim} is estimated at 1.4 and there is a 42% risk of the stock being below B_{lim} in 2023. Recruitment indices (abundance 15-20 cm) have been below the long-term average since the mid-2010s across all surveys, with the exception of the 2023 EU-Spain survey in 3L. Overall, the stock has declined from the 2010 highs, although uncertainty in recent stock size remains high due to gaps in the survey series.

Introduction

There are two abundant species of the genus *Sebastes* with distribution overlapping in several areas of the Northwest Atlantic: the deep sea redfish (*Sebastes mentella*) and Acadian redfish (*Sebastes fasciatus*). *S. mentella* are typically found in deeper waters up to 400m and *S. fasciatus* prefer shallower waters of less than 300m (DFO, 2022). Both species are viviparous, long living, slow growing and have pelagic and demersal concentrations, as well as a long larval periods prior to settlement (Sévigny et al., 2000, Gascon 2003). Their external characteristics are very similar, making them difficult to distinguish both in the survey and commercial catches. Therefore, they are reported collectively as "redfish" in the commercial fishery statistics. *S. mentella* and *S. fasciatus* are also treated as a single species in the Divs. 3LN surveys carried out by Canada and EU-Spain.

These redfish species found in Divs. 3LN do not belong to isolated populations within the management boundaries but have been identified as part of a large Northwest Atlantic complex ranging from the Gulf of Maine to south of Baffin Island (Valentin et al., 2015; Benestan, et al., 2021). The identification of additional ecotypes (individuals that show medium levels of reproductive isolation) and populations (individuals that show high levels of reproductive isolation) within *S. mentella* and *S. fasicatus*, respectively, further complicates standard assessment approaches (Benestan, et al., 2021). To date, there are insufficient data available to effectively manage the 3LN redfish stock independently by species.

The previous assessment model was a non-equilibrium Schaefer production model (ASPIC) which was accepted at the 2012 stock assessment and subsequently modified (Ávila de Melo et al., 2012, 2014 and 2016). However, this model was rejected at the 2022 assessment due to diagnostic issues. The 2022 assessment was based on standardized research vessel survey indices since a management strategy evaluation (MSE) was in progress. To date, a thorough data review has been conducted for the MSE (Perreault et al., 2022, Perreault et al., 2023) and operating models, including formulations that can better account for the episodic nature of redfish recruitment, are in development (Perreault & Hatefi, 2023). The current assessment builds on the index-based approach used in 2022.

Description of the fishery

In the early 1980's the former USSR, Cuba, and Canada were the primary fleets directing for redfish in Divs. 3LN. The rapid expansion of the fishery was due to the entry of EU-Portugal in 1986 and South Korea in 1987, along with various re-flagged fleets. In the early 1990's Russia and the Baltic mid-water trawlers, together with South Korea and Portuguese bottom trawlers, were still responsible for the bulk of fishing effort. Rapid declines in catch rates resulted in the withdrawal of South Korea from the redfish fishery and the reductions of efforts by other fleets. During the moratorium, most of the redfish catches in NAFO Divisions 3L and 3N were taken as by-catch in the Greenland halibut fishery primarily undertaken by EU-Portugal and EU-Spain bottom trawl fleets. Since the lifting of the commercial fishing moratorium in 2010, Canada, Russia and EU-Portugal have been the primary fleets in this fishery.

Commercial Fishery Data

Commercial fishery sampling

Most of the commercial length sampling data available for 3LN redfish since 1990 comes from the Portuguese fisheries, with some data available from Spanish and Estonian fisheries since 2002 and 2008, respectively. Commercial length frequency data has largely been absent from the Canadian fishery since 1991, with only sporadic sampling of often small sized fish. Previous assessments have calculated commercial catch at length using primarily Portuguese fishery data. Due to time constraints, the current report does not update on catch at length; however, this does not impact the assessment of status of this stock which is based on survey information.

Nominal catches and TAC's

Reported catches during 1960-1985 oscillated without trend around an average level of 21 000 t. Catches increased rapidly to a 79 000 t high in 1987, and declined nearly as quickly to a 450 t minimum in 1996. The NAFO Fisheries Commission implemented a moratorium on directed fishing for this stock in 1998. Catches were primarily bycatch and remained at relatively low levels (450-3 000 t) until 2009. In June 2009 the Scientific Council confirmed the upward trend of the stock as shown by spring and autumn surveys (NAFO, 2009). The Commission endorsed the Scientific Council recommendations from 2011 onwards and catches steadily increased to 13 050 t in 2019, the highest level recorded since 1993. Since then, catches have been decreasing and have remained well below the TAC. In 2023, total catch was estimated to be 8 212 t (Table 1, Fig. 1). Landings from 2011-2016 were taken from the NAFO STATLANT 21 database. Landings in 2017 were estimated with the CDAG method, and the CESAG method has provided the catch estimates since 2018.

Research Survey Data

Canadian RV surveys

Consistent stratified-random bottom trawl surveys have been conducted on the Grand Bank (3LNO) since 1983 with both the CCGS Gadus Atlantica and CCGS Wilfred Templeman vessels using an Engel 145 bottom trawl (McCallum and Walsh, 1996). In the fall of 1995, the Gadus Atlantica vessel was replaced by the CCGS Teleost and the change in vessel was accompanied by a change in survey gear from the Engel 145 trawl to the Campelen 1800 shrimp trawl (Warren, 1996). The Templeman was decommissioned in 2008, and replaced with the similar CCGS Alfred Needler research vessel with a Campelen 1800 shrimp trawl, which had been conducting surveys occasionally in Divs. 3LN when there were issues with the other vessels. The survey in this area was mainly conducted by the Templeman and Needler vessels, although the Teleost was used to complement or replace the primary vessels when required.

Beginning in 2022, new survey vessels (CCGS John Cabot and CCGS Capt Jacques Cartier) have been used to conduct the Canadian multi-species surveys. Throughout the survey time series the Teleost was used to compliment the primary vessels under the assumption that catches were directly comparable to those from the Templeman and Needler vessels. However, during comparative fishing trials with the new vessels it was determined that this assumption was most likely not valid for some species. For redfish in NAFO Divs. 3LN, conversion factors that would allow data from the new vessels to extend existing time series data were only available for the Spring Teleost series. As a result, the spring Canadian Campelen series (1984-2019) and the autumn Canadian Campelen series (1990-2020) have ended, and new survey series begun for this stock (Wheeland et al., 2024).

Sensitivity analyses indicate that for redfish in Divs. 3LN, use of the Teleost in the autumn had minimal impact on indices as very little of the total biomass was represented in sets by this vessel in most years (Figs 2-3). Therefore, it was considered appropriate to keep the pre-2022 Campelen time series intact .

For the spring series, comparative fishing indicated that the Teleost is comparable to the new time series for redfish in Divs. 3LN. Years with complete/near-complete coverage with the Teleost (2016, 2018) have been removed from the 1984-2019 Campelen series, and included in a new spring time series which also includes the new survey series (modified Campelen, see Figs 2,4).

No survey was carried out on Div. 3N in spring 2006 and autumn 2014. In the spring of 2017, there were problems with 3L survey coverage and none of the redfish 3L strata were sampled (Rideout and Ings, 2020; Rideout 2020). No spring survey was completed in 2020 and 2021, nor was an autumn survey completed in 2021. The spring and autumn surveys were complete in 3LN in 2023.

Trends in historic biomass are similar for both the autumn and spring Campelen series, with the lowest levels seen in the early years and biomass peaking around the 2005 (Fig. 5). Survey biomass estimates in the autumn and spring Campelen series were generally decreasing from 2015 onward.

EU-Spain RV surveys

In 1995, EU-Spain started a new stratified-random bottom trawl spring (May-June) survey in the NAFO Regulatory Area of Divs. 3NO. All strata within the NRA were covered every year following the standard stratification (Doubleday, 1981). Early surveys were completed to a depth of 732m, and were extended to 1464 m in 1998 (González-Costas et al., 2020). Spanish surveys were initially conducted using the commercial vessel Playa de Menduiña with a Pedreira bottom trawl. In 2001, the research vessel Vizconde de Eza with a Campelen 1800 bottom trawl gear replaced the Playa de Menduiña. In 2003, this survey was extended northwards to include strata in the NRA portion of Div. 3L, but it has only been since 2006 that an adequate coverage of 3L has been accomplished for this survey (Román et al, 2020). All surveys conducted in 3L were with the Vizconde de Eza vessel with a Campelen 1800 bottom trawl. The survey was not complete in 3N in 2020 or in 3L in 2020 and 2021 due to COVID restrictions. In 2022 and 2023 the EU-Spain survey in 3L and 3N were complete (Garrido et al.; 2024 Román-Marcote et al., 2024).

Trends in historic biomass were similar for both the EU-Spain 3L and 3N series, with the lowest levels seen in the earliest years and biomass beginning to increase around 2007 (Fig. 5). As in the Canadian series, trends in the EU-Spain 3L and 3N series were generally decreasing from 2015 onward.

Recruitment

Recruitment for this stock, as with most redfish stocks, is episodic. In some years, pulses of potential recruitment are seen at smaller sizes, but do not translate to increases in abundance at larger sizes. This assessment examined abundance indices of redfish between 15 and 20 cm as a proxy for recruitment. Since 1990, only one consistent period of strong recruitment has been observed across all surveys, beginning in 2008 (Fig. 6). This cohort was consistently tracked in the survey length compositions until approximately 2017 (Fig. 7). Recruitment has been below the long-term average since the mid-2010s in all surveys, with the exception of the 2023 EU-Spain survey in 3L.

Biology and environmental interactions

The Grand Bank (3LNO) Ecosystem Production Unit (EPU) is currently experiencing low productivity conditions, with EPU biomass well below pre-collapse levels (pre-1990s). Rebuilding was observed since the 1990s, but declines across multiple trophic levels and stocks occurred after 2014. While positive signals have been observed since these declines, biomass has yet to return to the early-mid 2010s level (NAFO, 2023).

Estimation of Stock Parameters

Mean standardized biomass

This assessment uses the Canadian Campelen autumn and spring 3LN and EU-Spain 3N and 3L surveys as an index of stock status. In an effort to facilitate comparisons and enhance the detection of trends in stock dynamics, the survey biomass series used in the assessment were standardized relative to the mean of years 2003-2019. Note that this is a similar approach to the previous assessment (Rogers et al., 2022), however we updated this method slightly, standardizing the indices to the mean of an overlapping time period, rather than to each series average as applied in 2022. This time period was chosen as it represented a comparable period of stock dynamics (Fig. 8). Standardized indices (SI) were derived for each year as $SI_{y,s} = (I_{y,s} - \mu_s)/\sigma_s$, where μ_s is the mean and σ_s is the standard deviation for survey *s* for years 2003-2019 (i.e. mean zero, unit standard deviation).

Stock status was assessed from the mean of the standardized indices, $MI_y = mean(SI_{y,s})$, which we call the combined standardized biomass index. It is straightforward to calculate the confidence intervals for the combined index in each year based on the properties of the variance, i.e. $sd(MI_y) = \sqrt{\sum_n 1/n^2}$, where *n* is the number of indices in year *y.* This is a simple approach that allows for increased uncertainty when there are fewer indices available in a year. Illustrative confidence intervals are approximated based on the quantiles from the Normal distribution[1] (Fig. 9).

From the early 1990's to early 2000's, stock levels were below the combined standardized mean (solid grey line, Fig. 9). Stock size increased from 2007-2011 and has been decreasing since. Stock size has been below the combined standardized mean in the last three years of the assessment, but we note high uncertainty in recent years given incomplete and/or non-comparable survey data.

Catch/Biomass ratio

Previous assessment updates have used landings/Canadian 3LN spring survey biomass as a proxy for fishing mortality and we use a similar approach based on standardized landings, i.e. $SL_y = (L_y - \mu_l)/\sigma_l$, where μ_l and σ_l are the mean and standard deviation, respectively, across the time series*.* The f_{proxy} is then SL_y/MI_y , rescaled to be between 0 and 1 (Fig. 10).

Relative fishing mortality rates were highest in the earliest period of the time series (Fig. 10) and decreased dramatically leading up to the moratorium. Relative fishing mortality has been increasing in recent years, but remains well below the time series high seen in the early 1990's.

Size at maturity

Although maturity data are available for the stock from the Canadian and EU-Spain RV surveys, a recent data review identified strange patterns in maturity data for 3LN redfish (Perreault et al., 2022). Future work should aim to better understand size at maturity for the stock.

Reference Points

[1] Note that it is statistically more appropriate to approximate confidence intervals based on the student's t distribution since the sample sizes are small, however the confidence intervals from the student's t with one observation (i.e. df=1) are very large and swamp the overall biomass trends. Therefore, the normal distribution is used to illustrate general trends in uncertainty over the time series, but the student's t is used to determine probabilistic stock status.

An interim limit reference point was adopted at the 2022 assessment (Rogers et al., 2022) using the mean of the standardized indices for the period 1991-2005. This period was chosen as it represented a time when stock biomass recovered from a prolonged low level. As discussed above, we updated this method slightly, standardizing the indices to the mean of an overlapping time period, rather than to each series average as applied in 2022 (i.e. $B_{lim} = mean(SI_{1991-2005,s*})$, where s^* is the subset containing the Canadian autumn and spring Campelen and the EU-Spain 3N surveys). The EU-Spain 3L survey was not included in the calculation of this interim LRP as the survey does not begin until 2006. Since the sample sizes were small, the confidence intervals around the terminal year were approximated based on the quantiles from the student's t distribution.

State of the Stock

The combined standardized biomass index indicates that biomass has declined from timeseries highs in the mid-2010s and B_{2023}/B_{lim} is estimated at 1.4. There is an 42% risk of the stock being below B_{lim} in 2023. Uncertainty in recent stock size remains high due to gaps in the survey series. Recruitment (abundance 15 -20 cm) has been below the long-term average since the mid-2010s in all surveys, with the exception of the 2023 EU-Spain survey in 3L. Relative fishing mortality has been increasing in recent years, but remains well below the time series high seen in the early 1990's.

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Tables

Table 1. Summary of catch and TACs of redfish in Divs. 3LN. Landings from 2017 are estimated from CDAG (COM-SC CESAG-WP 18-01). Landings from 2018 onwards are estimated using the CESAG method. Otherwise landings are from STATLANT 21A.

Year	3L	3N	Total	TAC
1959	34107	10478	44585	
1960	10015	16547	26562	
1961	8349	14826	23175	
1962	3425	18009	21439 [a]	
1963	8191	12906	27362 [a]	
1964	3898	4206	10261 [a]	
1965	18772	4694	23466	
1966	6927	10047	16974	
1967	7684	19504	27188	
1968	2378	15265	17660 [a]	
1969	2344	22356	24750 [a]	
1970	1029	13359	14419 [a]	
1971	10043	24310	34370 [a]	
1972	3095	25838	28933	
1973	4709	28588	33297	
1974	11419	10867	22286	28000
1975	3838	14033	17871	20000
1976	15971	4541	20513	20000
1977	13452	3064	16516	16000
1978	6318	5725	12043	16000
1979	5584	8483	14067	18000
1980	4367	11663	16030	25000
1981	9407	14873	24280	25000
1982	7870	13677	21547	25000
1983	8657	11090	19747	25000
1984	2696	12065	14761	25000
1985	3677	16880	20557	25000
1986	27833	14972	42805	25000
1987	30342	40949	79031 [b]	25000
1988	22317	23049	53266 [b]	25000
1989	18947	12902	33649 [b]	25000
1990	15538	9217	29105 [b]	25000
1991	8892	12723	25815 [b]	14000
1992	4630	10153	27283 [b]	14000
1993	5897	9077	21308 [bc]	14000
1994	379	2274	5741 [bc]	14000

1995	292	1697	1989	14000
1996	112	339	451	11000
1997	151	479	630	11000
1998	494	405	899	0
1999	518	1318	2318 [b]	0
2000	657	819	3141 [bc]	0
2001	653	245	1442 [b]	0
2002	651	327	1216 [b]	0
2003	584	751	1334	0
2004	401	236	637	0
2005	581	78	659	0
2006	53	444	496	0
2007	118	1546	1664	0
2008	220	377	597	0
2009	57	994	1051	0
2010	260	3688	4120	3500
2011	2418	1254	3672	6000
2012	2781	1535	4316	6000
2013	4446	1786	6232	6500
2014	4245	1450	5695	6500
2015	8620	1320	9940	10400
2016	6652	1805	8457	10400
2017	7790	4026	11815	14200
2018	7300	3979	11279	14200
2019	6357	6693	13050	18100
2020	4806	6285	11091	18100
2021	4228	5944	10172	18100
2022	2765	6196	8961	18100
2023	1712	6519	8224	18100

[a]Includes catch that could not be identified by division
[b]Includes estimates of unreported catches
[c]Catch could not be precisely estimate due to discrepancies in available sources

Table 2. Survey biomass ('000 t) from bottom trawl surveys on Divs. 3LN considered in the assessment

survey.year	Spring Campelen	Autumn Campelen	EU Spain 3N	EU Spain 3L	Spring Teleost	Autumn New
1985	140					
1986	11.4					
1987	24					
1988	16.5					
1989	8.4					
1990	6.8	22.6				
1991	10.7	37.9				
1992	10.1	136.4				
1993	22.7	19.2				
1994	4.1	31.8				
1995	5.9	90.4	46.1			
1996	22.8	8.8	6.6			
1997	15	57.8	4.8			
1998	59.4	110.6	22.5			
1999	61.5	71.9	46.5			
2000	87.9	75.6	68.9			
2001	41.6	130.3	53.9			
2002	31.4	50.1	7.6			
2003	27.7	70.9	11	81.8		
2004	79.7	50.1	27	30.8		
2005	66.5	58.6	146.9			
2006	35.3	91.9	87.8	70.1		
2007	218.9	124.8	87.6	31.4		
2008	140	201	68.1	75.6		
2009		246.8	735.7	103.7		
2010	165.4	461.5	359.5	266.8		
2011	173.7	576.2	418.3	170.6		
2012	322	596.7	265.2	481.5		
2013	271.6	289	429.5	235.2		
2014			178.1	216.4		
2015	480.6	425.1	523.5	130.4		
2016		215.3	117.3	98.8	654.3	
2017	98.8	192.2	265.9	56.6		
2018		191.4	292.8	40.3	106	
2019	136.5	286.5	174.6	54		
2020		199.3				
2021			73.2			
2022			131.1		121.8	
2023			68.1	94.2	106.7	216.5

Figures

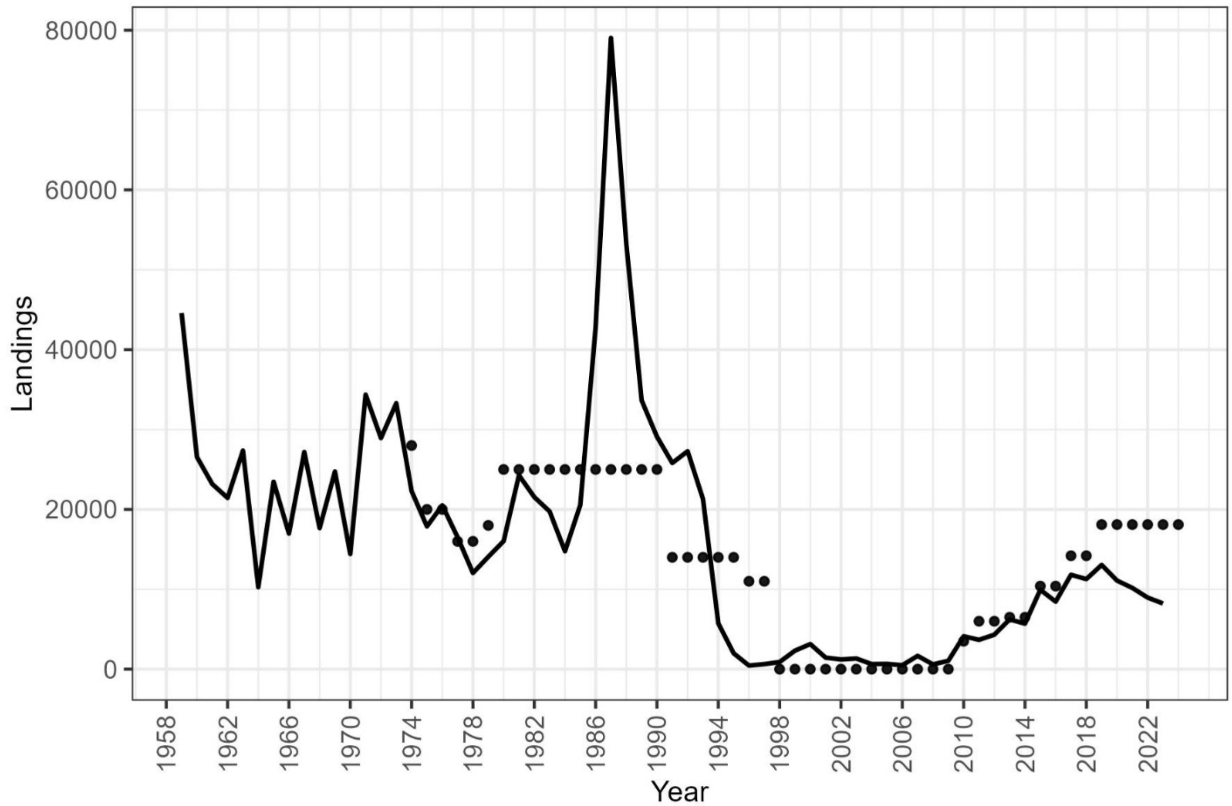

Figure 1. Landings (solid line) and TAC (points) of Divs. 3LN redfish since 1959.

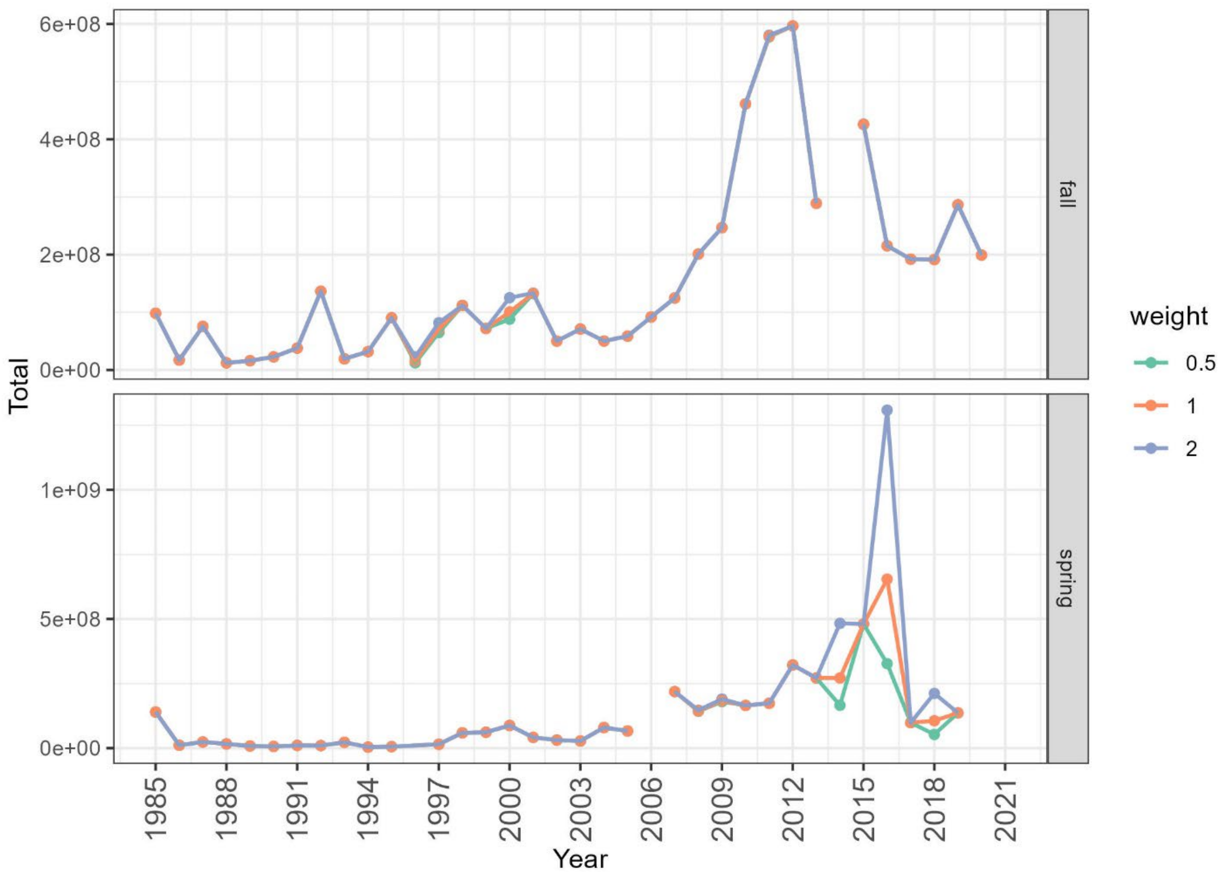

Figure 2. Comparison of stock biomass index trends under 0.5 (green), 1 (orange), and 2x (purple) multipliers of Teleost catchability relative to the Needler and Templeman in the Canadian Autumn (top) and spring (bottom) surveys for redfish in Divs. 3LN. For additional details see NAFO SCR Doc. 24/037.

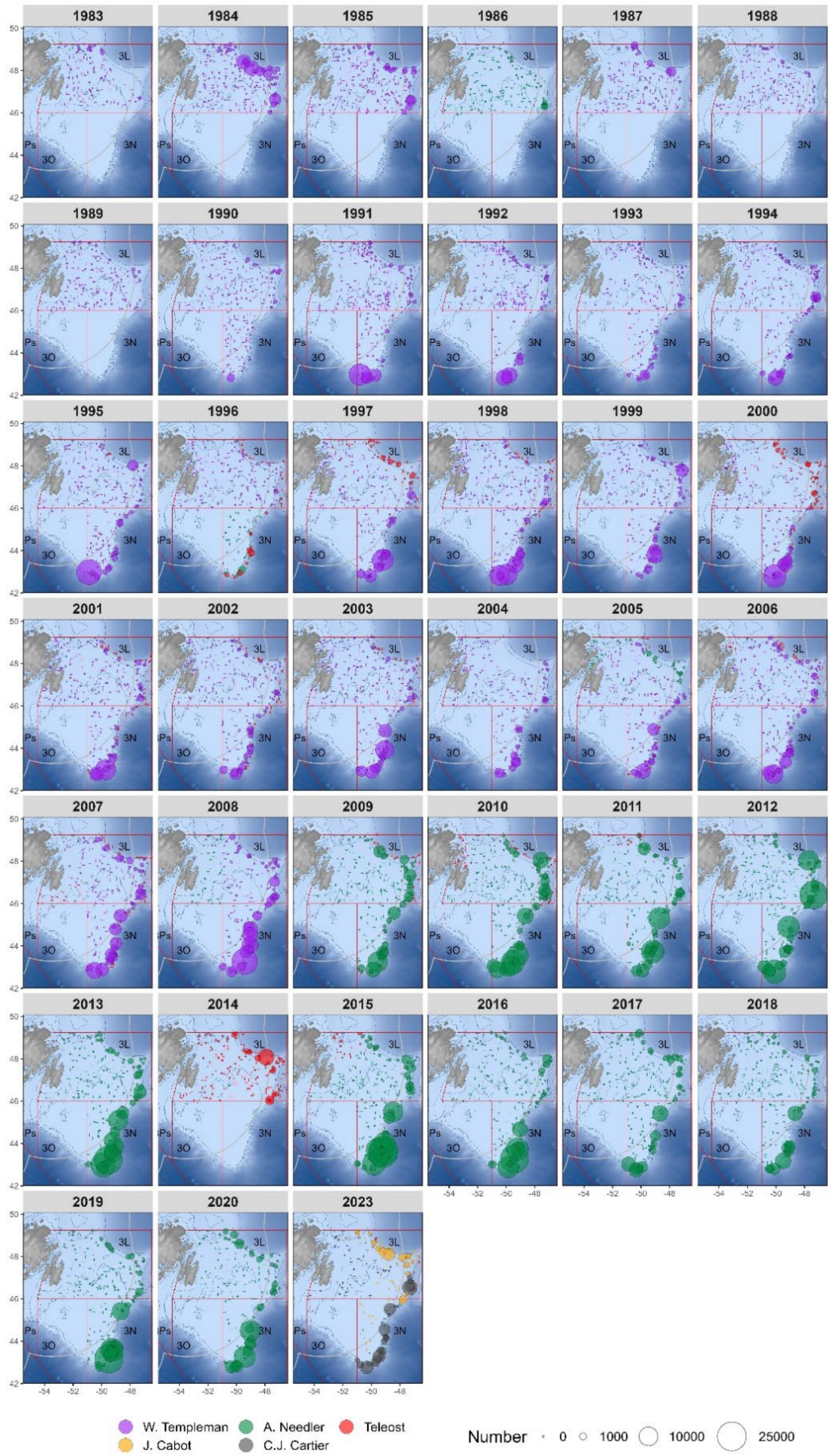

Figure 3. Distribution of Divs. 3LN redfish (total kg per tow) from Canadian autumn RV surveys from 1983-2023. Catches may not be comparable across vessels over time and are shown for illustrative purposes.

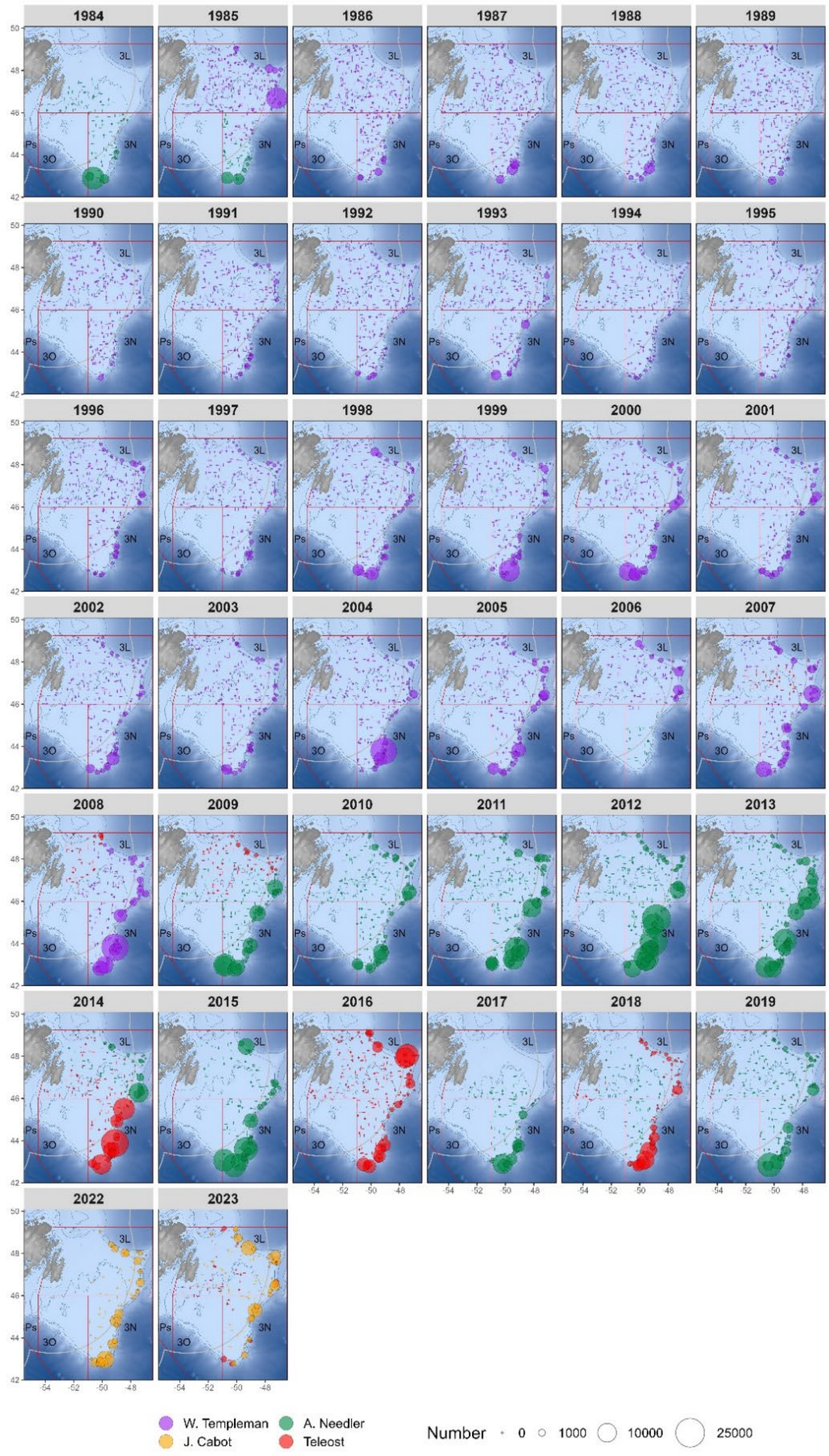

Figure 4. Distribution of Divs. 3LN redfish (total kg per tow) from Canadian spring RV surveys from 1983-2023. Catches may not be comparable across vessels over time and are shown for illustrative purposes.

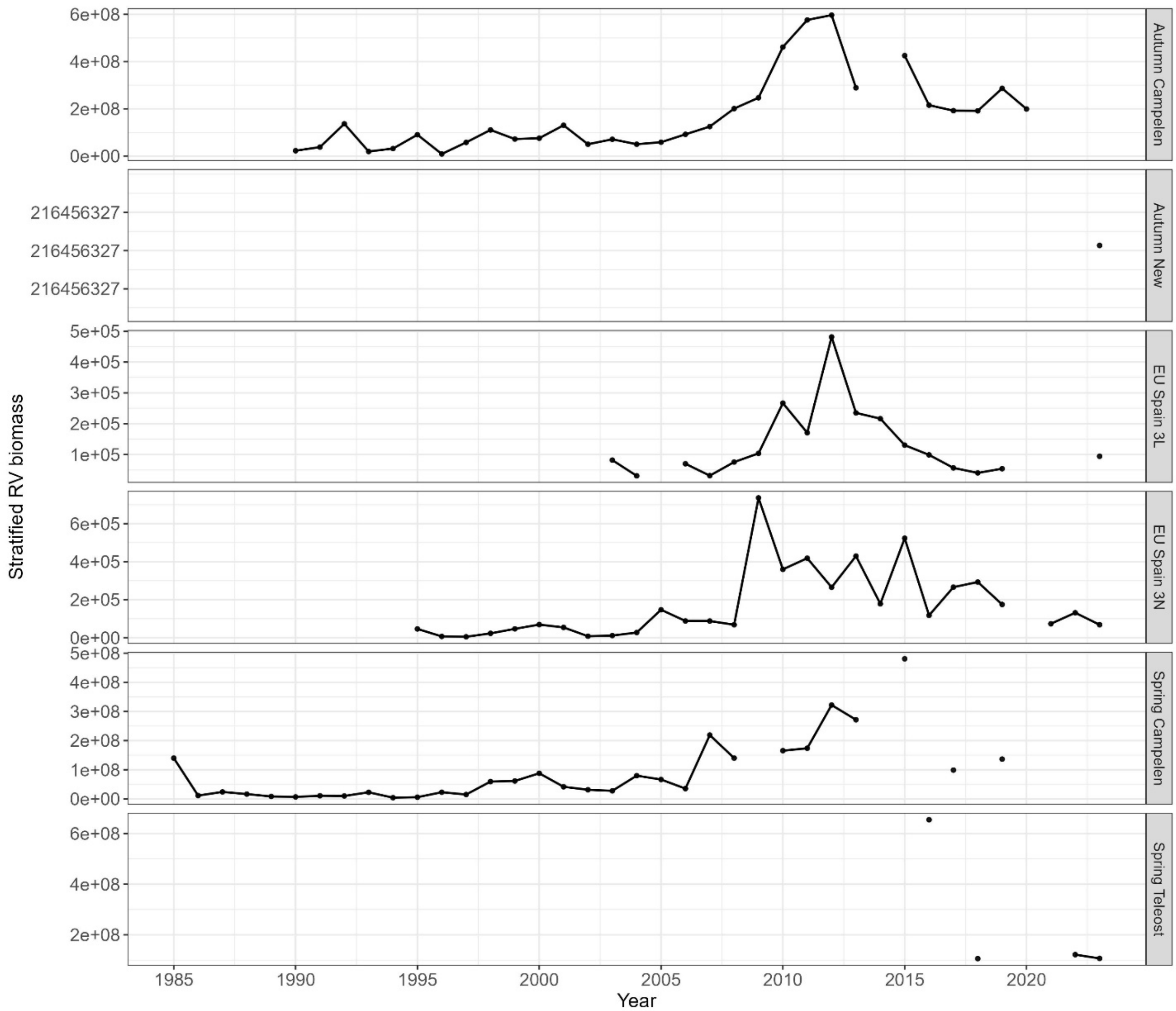

Figure 5. Stratified RV biomass estimates for the new survey time series for Divs. 3LN redfish.

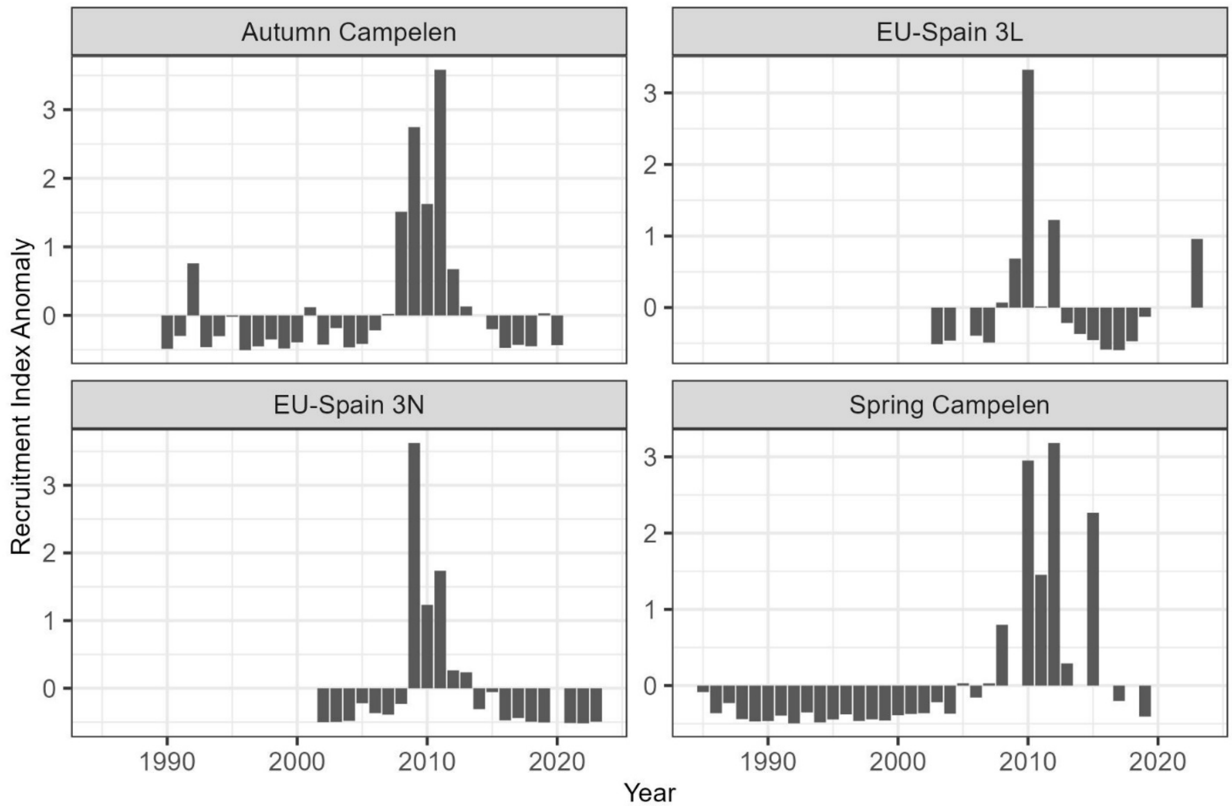

Figure 6. Recruitment index anomalies of Divs. 3LN redfish (15-20cm) from spring and autumn Campelen and EU-Spain 3L and 3N surveys.

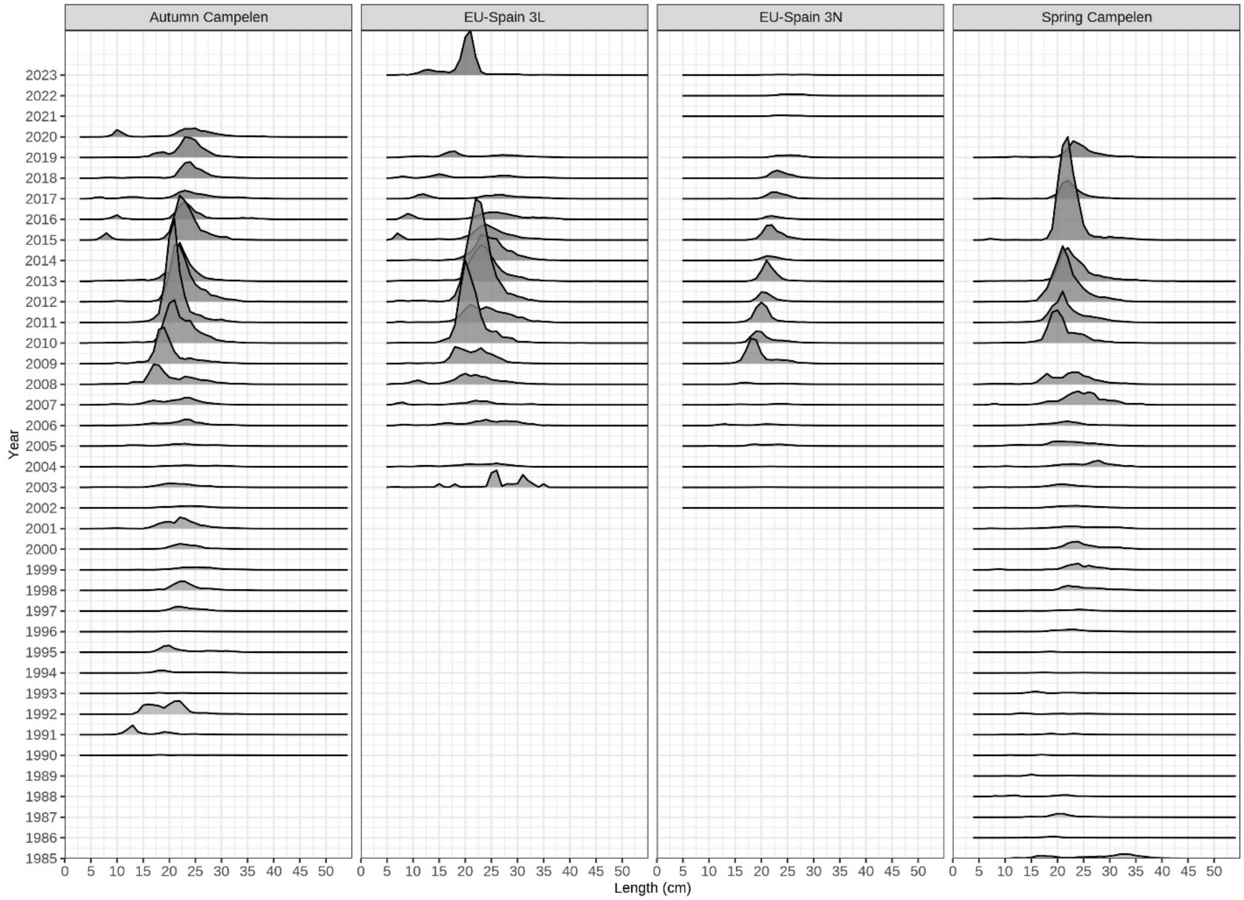

Figure 7. Stratified RV length frequencies from spring and autumn Campelen and EU-Spain 3L and 3N surveys.

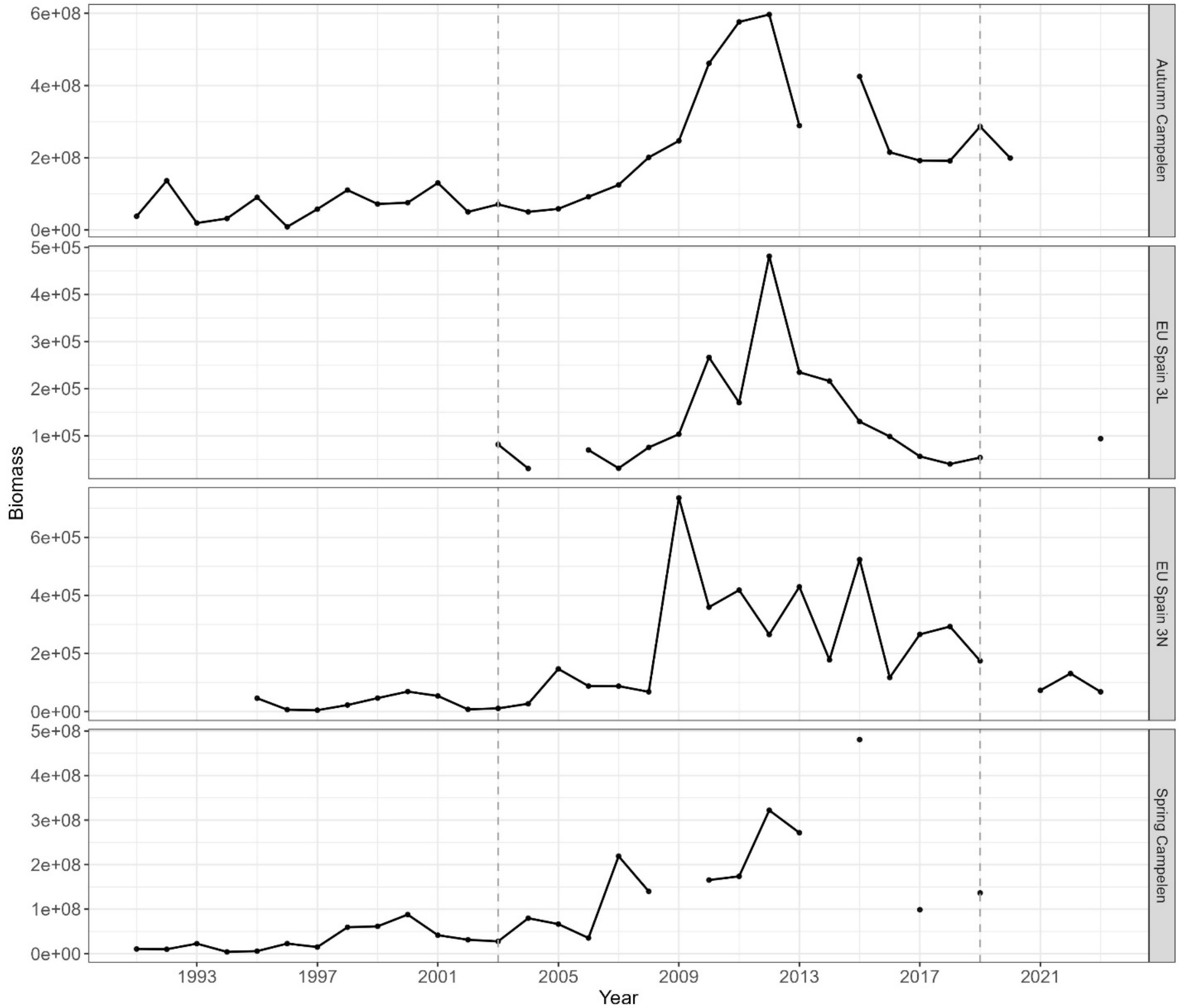

Figure 8. Subset of stratified RV survey indices used in the Divs. 3LN redfish assessment. The dashed line represents the reference period that the time series are standardized to (2003-2019).

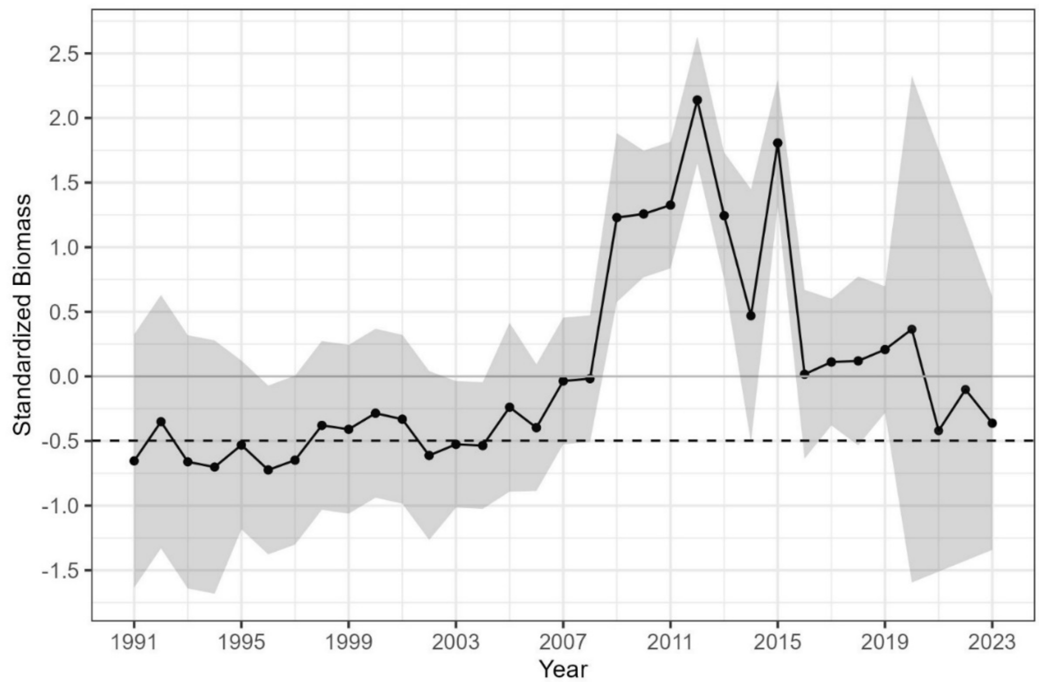

Figure 9. Combined biomass index based on Canadian spring and autumn Campelen surveys and EU-Spain 3L and 3N survey with 95% confidence intervals. Horizontal dashed line indicates B=B_{lim} and solid grey line indices mean zero.

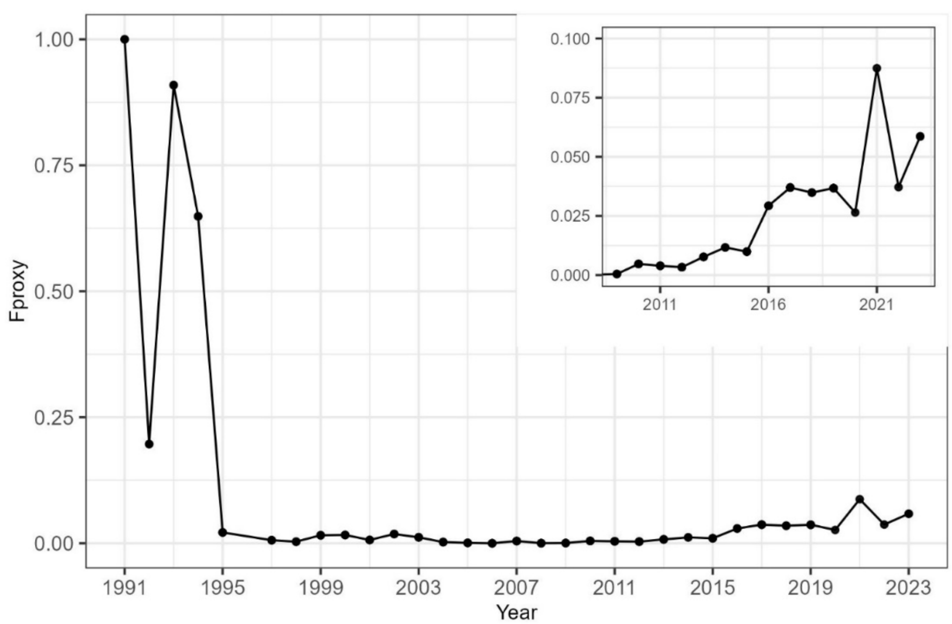

Figure 10. F_{proxy} based on the ratio of the standardized landings and the combined biomass index.