Northwest Atlantic Fisheries Organization

Serial No. N7321 **NAFO SCR Doc. 22/044**

SCIENTIFIC COUNCIL MEETING – June 2022

An Assessment of the Status of Redfish in NAFO Division 3O

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Abstract

Two species of redfish are commercially fished and reported collectively as "Redfish" in fishery statistics in Div. 3O, the deep-water redfish (*Sebastes mentella*) and the Acadian redfish (*Sebastes fasciatus*). Nominal catches have ranged from 3 000 tonnes to 35 000 tonnes since 1960, with the peak in 1988. After 1988 catches generally declined, reaching a a low of 3,000 tonnes in 1995. Catch increased over the next five years to a high of 20 000 tonnes in 2001, and subsequently decreased. Catch has remained below 10,000 t since 2008 with a mean of approximately 6000 t taken annually during 2019-2021. Assessment of this stock is based primarily on research vessel (RV) survey data. Indices from Canadian-Spring, Canadian-Autumn, and EU-Spain RV surveys in Div. 3O suggest the stock may have increased between the early and mid-1990s, fluctuated at a higher level in the mid- to late-1990s, then declined to the early 2000s. Indices increased to time series highs in the early 2010s, but have declined to lower levels since. While trends in biomass indices among the three surveys have been generally consistent, there is some evidence for a recent divergence, with declines evident outside the Canadian EEZ. Canadian autumn indices in the recent period are near the time series mean, while the EU-Spain index in 2021 was the second lowest in the time series (lowest since 1997). There is concern that there has been little sign of pre-recruit sized fish in recent surveys; the last strong year class evident in the survey data was born in the early 2000s.

Introduction

Two species of redfish are commercially fished in Div. 3O: the deep-sea redfish (*Sebastes mentella*) and the Acadian redfish (*S. fasciatus*). The two species are difficult to distinguish based on external characteristics, and as a consequence are reported collectively as "redfish" in the commercial fishery statistics. Most of the redfish stock area in Div. 3O lies within Canada's 200 mile exclusive fishery zone and has been subject to management regulation since 1974. Approximately 8% of the area within Div. 3O that is considered to be "redfish habitable area" lies within the NAFO Regulatory Area (NRA) and was brought under Total Allowable Catch (TAC) regulation starting in 2005.

Nominal catches have ranged between 3 000 tonnes and 35 000 tonnes since 1960 (Table 1, Fig. 1). Catches averaged 13 000 t up to 1986 and then increased to 27 000 t in 1987 and 35 000 t in 1988 (exceeding TACs by 7 000 t and 21 000 t, respectively). Catches declined to 16 000 t by 1993 then to about 3 000 t in 1995, partly due to reductions in foreign allocations within the Canadian fishery zone since 1993. Catches increased to 20 000 t by 2001 and subsequently declined to 4000 t in 2008 and have been in the 6000 to 9000 t range since 2008. The large redfish catches in 1987 and 1988 were due mainly to increased activity in the NRA by

South Korea and Non-Contracting Parties (NCPs), primarily Panama. There has been no activity by NCPs in the NRA since 1994. Estimates of under-reported catch which have occurred primarily before 1995 (Shelton and Atkinson 1994), have ranged from 200 tonnes to 23 500 tonnes. There have also been estimates of over-reported catch in the recent period since 2000, with a maximum value of 4 300 t in 2003. There were no alternate sources of catch estimates available until 2016 to compare with the reported catch. A TAC of 16 000 tonnes was first implemented by Canada within its 200-mile limit in 1974. The TAC was increased in 1978 to 20 000 tonnes and generally remained at that level through to 1987. The TAC for 1988 was reduced to 14 000 tonnes and remained unchanged until 1994 when it was reduced to 10 000 tonnes as a precautionary measure and maintained at that level to 2003. In September 2004, the NAFO Fisheries Commission adopted TAC regulation for redfish in 3O, implementing a level of 20 000 tonnes for the entire division in 2005; this TAC level has remained in effect up to 2022.

Description of the Fishery

Russia predominated in the 3O redfish fishery until 1993 and generally caught about 50% of the total non-Canadian allocation, which accounted for about 2/3 of the Canadian TAC. Russia and Cuba, impacted by the reduction and eventual elimination of foreign allocations by Canada, ceased directed fishing in 1994. Russia resumed directed fishing in 2000, rapidly increasing their catch from 2 200 tonnes to about 11 000 tonnes from 2001-2003 before a large reduction in catch to only 240 t in 2004 (Table 2). Russian catches increased from 50 t in 2007 to about 2000 tonnes in 2016, but decreased to 350 t in 2018.

Portugal began fishing redfish in Div. 3O in 1992 and catches averaged about 1 800 tonnes between 1992 and 1998. Portuguese catches increased to 5 500 tonnes in 1999 and have ranged between 3 200 – 6 400 tonnes thereafter with 3000 tonnes taken in 2018. Catches in 2021 were 1 500 tonnes, the lowest level since 1998.

Spain, which had taken less than 50 tonnes before 1996, increased catches from 1 200 tonnes in 1997 to a peak of 4 500 tonnes in 1999 with a subsequent decline to 300 tonnes in 2004. Since then, Spanish catch ranged between 600 – 2 000 tonnes with about 1000 tonnes taken in 2021.

Canadian fleets have had limited interest in a redfish fishery in Div. 3O, reportedly because of small sizes of redfish encountered in areas suitable for trawling. Canadian landings were less than 200 tonnes annually from 1983-1991. In 1994, Canada took 1 600 tonnes which is attributed to improved markets related to lobster bait, but reduced catch to less than 200 tonnes in 1995. Between 1996 and 1999 Canadian catches alternated between levels of about 8 000 tonnes and 2 500 tonnes based on market acceptance for redfish near the 22 cm minimum size limit regulated within Canada. From 2000-2006 Canada averaged about 3 600 tonnes, followed by a decrease to 1000 tonnes in 2007. Canadian landings decreased further in 2008 and have been near or below 500 tonnes since then.

Estonia has been an active participant in the fishery for redfish in Div. 3O since 2007, averaging 310 t in annual catch (Table 2).

The redfish fishery in Div. 3O typically occurs throughout the year (Ings and Rideout 2019). The vast majority (>90%) of catch has been taken via bottom trawling by Canadian, Portuguese, Russian and Spanish fleets (Table 2). Catches via midwater trawl prior to 2005 were taken predominantly by Russia. Since 2011, an average of 96% of the catch has been taken within the NRA portion of Div. 3O.

Commercial Fishery Data

Commercial fishery sampling

Sampling of the redfish fisheries was conducted by Spain (González-Costas et al. 2022), Portugal (Vargas and Alpoim 2022) and Estonia (Näks 2022) from the 2021 trawl fishery (Fig. 2). In 2021 catches sampled by Estonia were generally between 15 and 30cm. Catches from Spain and Portugal were generally between 20 and 32cm. In the recent period there has typically been no length sampling available from Canadian catches (Rogers and Simpson 2022); since 2011, length samples were only available in 2018 and only for catches landed in the Newfoundland and Labrador region. A compilation of catch at length from various fleets from 1995 to 2004 suggested that the size composition has changed over the time period with fleets catching a smaller portion of fish >25 cm since 1998 (Power 2005). Size compositions were converted to catch at length; 2014 to 2018 are presented in Figure 3, while earlier years can be found in Ings and Rideout (2019). Generally the fishery after 1998 has caught primarily redfish 15 to 30cm, with few caught >30cm.

Research Survey Data

Abundance and Biomass Indices

Stratified random groundfish surveys have been conducted by Canada in the spring and autumn in Div. 3O since 1991, with regular coverage of depths to 730 m (and sporadic coverage of deeper strata in the autumn). In addition, a summer survey was conducted in 1993. Data are also available from EU-Spain spring surveys conducted in the NAFO regulatory area (NRA) of Div. 3O from 1997 to 2021 (Garrido et al. 2022).

In the 2022 assessment the strata >731m that have sporadic coverage in the Canadian spring survey (strata 764, 768, 772) were removed from the calculation of spring indices. These strata have not been sampled since 2012 and are no longer allocated in the survey. In years they were covered they typically accounted for <1% of the biomass indices, so their exclusion from calculations has not resulted in noticeable changes in the impression of stock trends or dynamics.

Canadian surveys utilized an Engel 145 otter trawl (1.75 n. mi. standard tow) from 1991 to spring 1995 and a Campelen 1800 shrimp trawl (0.75 n. mi. standard tow) from autumn 1995 to the present. The Engel 145 data were converted into Campelen 1800 trawl equivalent data based on comparative fishing trials (see Power and Atkinson 1998a). Vessel problems during the 2006 spring survey resulted in the completion of only a single tow in redfish depths. There was no fall survey in 2014, or 2020, and no spring survey in 2020 or 2021. See Rideout et al. (2022) for details of recent Canadian surveys. Abundance (Tables 3 and 5) and biomass (Tables 4 and 6) estimates based on spring and autumn data from the Canadian surveys demonstrate large fluctuations between seasons and years for some strata. This is usually due to the influence of one or two large sets. It is difficult to reconcile year to year changes in the indices, but generally, the survey biomass indices from both surveys (Fig. 3) suggests the stock increased between the early and mid-1990s, and subsequently declined to the early 2000s. The stock then stayed at a low level to the mid-2000s before increasing to around 2010. The stock has subsequently decreased and survey indices remain at a low level.

Spatial distribution in the Canadian surveys is presented in Fig. 6 and 7, and survey length frequencies are found in Fig. 8.

For distribution in the EU-Spain 3O survey see Garrido et al. (2022).

It should be noted that the 1996 Canadian autumn estimate does not include important strata that were not sampled due to problems on the survey, and the low 1997 Canadian spring biomass index is considered to be a sampling anomaly (Power and Atkinson 1998a).

Estimates of the proportion of survey biomass within the NRA are variable in both the spring and autumn, but on average less than 20% of the survey biomass is in the NRA. Survey catches in Canadian autumn and EU-Spain suggest recent declines in biomass in the NRA, but this pattern is not evident in the Canadian spring survey (Fig. 9, Fig. 10).

Recruitment

Size distributions from the Canadian spring and autumn surveys plus the EU-Spain survey indicated that there was a relatively large pulse near 17cm in the 2007 surveys, corresponding to a year class born in the early 2000s that has remained the dominant mode until 2018 (Fig. 6). This pulse fully recruited to the fishery by 2018. No recent strong recruitment pulses are apparent at smaller sizes in the Canadian or EU-Spain surveys.

The size distributions of the survey catches indicate only a narrow range of sizes caught each year in Div. 3O. Generally, fish smaller than about 10 cm and larger than about 25 cm are absent in survey catches from 1991-2000 which cover strata down to 732 m (400 fathoms). It is well documented that the Engel survey gear (e.g. Power 1995) and the Campelen survey gear (e.g. Power and Atkinson, 1998b) can catch both smaller (than 10 cm) and larger (than 25 cm) redfish. Length sampling from the commercial fisheries in the mid-1990s revealed a higher proportion of fish greater than 25 cm than was observed in the survey catches (see Power 2005). However, in the recent period size ranges have been relatively consistent between the surveys and the fishery; both have recorded few fish over 30cm.

Several options were explored for the definition of a recruitment index for this stock. These included abundance <=10cm, <=15cm, 10-15cm and <=20cm from each of the Canadian spring, Canadian autumn, and EU-Spain surveys. Data suggest poor catchability of redfish <=10cm, therefore this size range was not considered suitable for a recruitment index. The EU-Spain survey catches few fish <15cm, therefore this series was also not considered appropriate for quantifying recruitment. Commercial fishery catch typically starts between 15-20cm in this stock, and tends to begin at smaller sizes than in the adjacent Div. 3LN stock (Rogers et al. 2022).

Recruitment indices were accepted as the abundance of redfish 10-15cm in the Canadian spring and autumn surveys (Fig. 11). An early 2000's year class shows the last indication of a good recruitment event that is apparent in both spring and autumn indices. Recruitment indices since 2012 have generally been at or below the series averages. It is noted that pulses of recruitment sometimes fail to track through to sizes caught in the commercial fishery and uncertainty remains about potential contributions to recruitment from areas outside of Div. 3O.

Estimation of Stock Parameters

Catch/Biomass ratio

A fishing mortality (F) proxy was derived by calculating simple catch to survey biomass ratios. Most of the catch for this fishery is taken in the last three quarters of the year. therefore to derive an F proxy, the catch in year "y was divided by the average of the Canadian Spring (year = y) and Autumn (year = y-1) survey biomass estimates to better represent the relative biomass at the time of the year before the catch was taken. In years when only one survey index is available that index is used in place of the mean. All fish sizes were included in the survey biomass estimate. The results (Fig. 12) suggest that relative fishing mortality increased from 1998 to the highest estimate in the series in 2002. This relatively high value was maintained in 2003 but declined substantially in 2004. In 2005, relative fishing mortality increased once more and was around the series average. In 2007-2008 the estimate of fishing mortality dropped to some of the lowest levels since the mid-1990s and remained at similar levels up to 2014. Estimates since increased to near the time series average in 2016, and have been at or near this level since.

Given that most of the commercial fishing activity for Redfish in Div. 3O occurs in the NRA an alternate F-proxy was examined based on biomass from the EU-Spain survey, however questions were raised on the appropriateness of an F-proxy calculated based on biomass from such a small portion of the stock area, and given there are no known barriers to fish movement in and out of the NRA. This index is therefore not presented here.

Size at maturity

Size at maturity for this stock is unknown.

Reference Points

No reference points had been accepted for Redfish in Div. 3O prior to the SC meeting in June 2022. This stock is assessed based on survey indices. Data (e.g. aging, limited time series) and analytical (e.g. lack of model) limitations, combined with biological characteristics of redfish (sporadic recruitment, slow growing, long-lived) make reference points difficult to define.

Several options were discussed for the proposal of a Limit Reference Point (LRP) for this stock based on survey indices. The Canadian spring and Canadian autumn surveys were used as the primary time series for consideration of an LRP as these two surveys cover the whole stock area.

Candidate approaches for setting reference points are described here:

Spasmodic stocks

Redfish stocks often have few, sporadic, large year classes, and these year classes are often not linked to an apparent stock recruit relationship. As such, redfish can be considered to be “spasmodic stocks,” and following ICES technical guidelines (ICES 2017) a candidate limit reference point for this stock could be the lowest SSB where large recruitment is observed.

Two relatively strong recruitment event are apparent in the Canadian surveys in the late 1990s-early 2000s. However, these recruitment indices are based on length; it is not known if they consist of a single or multiple cohorts. The year of origin of the cohort(s) is also uncertain and therefore cannot be linked to a biomass that would have produced these recruits. There are also no available indices of SSB.

This approach was deemed not applicable for this stock at this time given the data limitations described above.

B-recover

$B_{recover}$ (or B_{loss}) can be defined as the lowest biomass from which the stock has recovered. However, a $B_{recover}$ reference point inherently implies the stock was in a collapsed state. This stock has never been under moratorium, and available survey information does not suggest an obvious period of collapse.

This approach was deemed not appropriate for this stock given trends in indices and catch.

B_{MSY}

This stock does not appear to have been in a state of collapse during the available data series (catch from 1959, surveys from 1991), and indices have largely varied without trend with two larger pulses of recruitment (one in the late 1990s, one around 2010). Given this, the survey series may be regarded as reflecting typical conditions, and biomass averaged over the time series considered a value that is “normal” for this stock. Mean survey biomass could therefore be used as a proxy for B_{MSY} (Duplisea et al. 2012).

The Canadian spring and Canadian autumn surveys are considered to be equally representative of stock trends and status. Given overall consistency in trends and magnitude among Canadian spring and Canadian autumn, a “combined” biomass between Canadian spring and autumn surveys in year (y) is used to represent stock dynamics.

To combine Canadian spring and Canadian autumn trawlable biomass indices, and account for uncertainty associated with estimates from both surveys, annual stratified means and variances from each survey were integrated using the properties of the variance and translated to shape and scale parameters for use in the gamma distribution (see Regular et al. (2022) for computational details). This approach accounts for sampling variance from both surveys while also accounting for the positive and skewed nature of these indices. In years when a combined survey index is missing, the available survey is used in place of the mean and variance estimate. This same approach was applied to account for the uncertainty in the B_{MSY} proxy by applying the gamma distribution informed by averaged point estimates of mean and variance. The resultant distributions for the combined biomass index and B_{MSY} proxy can be used to assess stock status with probabilities (Fig. 14).

Though the abovementioned approach accounts for sampling variance, it does not account for all sources of uncertainty. The available time series (1991-2021) is relatively short considering that redfish are slow growing and long-lived, and does not provide a full understanding of potential stock dynamics. The true value for MSY is likely to vary from this proxy. The level and influence of connectivity between Redfish in Div. 3O and adjacent stocks is also uncertain.

Notwithstanding uncertainty associated with time-series length and stock mixing, it was agreed that an interim limit reference point be established at a level corresponding to 30% of the proxy B_{MSY}. This reference point is not considered perfectly known; uncertainty around this point is informed by variances from the survey indices. Determining status relative to the LRP considering uncertainty in both the proxy-B_{MSY} and the current biomass level provides the most fulsome formulation of uncertainty in stock status with the current data and the most precautionary approach to advice.

As survey indices can show unrealistic fluctuations year over year, data from a single year is insufficient to indicate a change in stock status. Large inter-annual changes have been observed in the past and, in 2 out of 30 years (1996, 2016), such changes resulted in a >10% probability of this stock being below B_{lim} in a single year. Rather than constituting a conservation concern, these extreme changes were more likely associated with sampling noise. The stock has been above B_{lim} with a high probability (Fig. 14) for most of the time series – including the most recent years – but was below B_{lim} with a probability >0.1 for a period of 3 years in the early 2000s.

State of the Stock

Combined survey biomass in 2020 was above the LRP with a >99% probability. Biomass relative to the LRP cannot be determined in 2021 as Canadian surveys did not occur in Div. 3O. However, given the slow growth of redfish and interpretation of year-over-year index fluctuations, stock status in 2021 is assumed to be similar to 2020. Current fishing mortality is near the time-series average. Recruitment indices since 2012 have generally been at or below series averages.

References

Duplisea, D.E., Power, D. and Comeau P. 2012. Reference points for eastern Canadian redfish (*Sebastes*) stocks. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/105 ii + 22 p.

Garrido, I., D. González-Troncoso, F. González-Costas, E. Román and L. Ramilo, 2022. Results of the Spanish Survey in NAFO Divisions 3NO. NAFO SCR Doc. 22/005

González-Costas, F., G. Ramilo, E. Román, J. Lorenzo, D. G, 2022. Spanish Research Report, NAFO SCS Doc. 22/06.

Ings, D.W. and R.M. Rideout. An Assessment of the Status of Redfish in NAFO Division 3O. NAFO SCR Doc. 19/038.

Näks, L. 2022. Estonian Research Report for 2021. NAFO SCS Doc. 22/07

Power, D. 1995. Status of redfish in Subarea 2 + Division 3K. DFO Atl. Fish. Res. Doc. 95/25, 25 p.

Power, D., and D. B. Atkinson. 1998a. Update on the status of Redfish in 3O. CSAS Res. Doc. 98/110, 20 p.

Power, D., and D. B. Atkinson. 1998b. The status of Redfish in Unit 2 (Laurentian Channel Management Unit). CSAS Res. Doc. 98/21, 41 p.

Power, D., 2005. An Assessment of the status of Redfish in NAFO Division 3O. NAFO SCR Doc. 05/59. Serial No. N5145, 19 p.

Regular, P., M. Koen-Alonso, S. Yalcin, A.M.J. Perreault, L. Wheeland. 2022. Approximating uncertainty around indices from stratified-random trawl surveys using the Gamma distribution. NAFO SCR Doc. 22/043

Rideout, R.M., B. Rogers, L. Wheeland and M. Koen-Alonso. 2022. Temporal And Spatial Coverage Of Canadian (Newfoundland And Labrador Region) Spring And Autumn Multi-Species RV Bottom Trawl Surveys, With An Emphasis On Surveys Conducted In 2021. NAFO SCR Doc. 22-007,

Rogers, B., A. Perreault, M. Simpson, and D. Varkey. 2022. Assessment of 3LN redfish in 2022 (*Sebastes mentella* and *S. fasciatus*). NAFO SCR Doc. 22-013.

Shelton, P.A., and D.B. Atkinson (Editors). 1994. Proceedings of the Regional Groundfish Assessment Review for Newfoundland, May 9-13, 1994 . Can. Tech. Rep. Fish. Aquat. Sci. 2020: 100 p

Vargas, J. and R. Alpoim. 2022. Portuguese Research Report for 2021. NAFO SCS Doc. 22/13.

Table 1. Estimated catches (t) and TACs of redfish in Div. 3O.

Year	Canada	Others	Catch[a]	TAC
1960	100	4900	5000	
1961	1000	10000	11000	
1962	1046	6511	7557	
1963	2155	7025	9180	
1964	1320	14724	16044	
1965	203	19588	19791	
1966	107	15198	15305	
1967	645	18392	19037	
1968	52	6393	6445	
1969	186	15692	15878	
1970	288	12904	13192	
1971	165	19627	19792	
1972	508	15609	16117	
1973	133	8664	8797	
1974	91	13033	13124	16000
1975	103	15007	15110	16000
1976	3664	11684	15348	16000
1977	2972	7878	10850	16000
1978	1841	5019	6860	16000
1979	6404	11333	17737	20000
1980	1541	15765	17306	21900
1981	2577	10027	12604	20000
1982	491	10869	11360	20000
1983	7	7133	7340	20000
1984	167	9861	16978	20000
1985	104	8106	12860	20000
1986	141	10314	11055	20000
1987	183	12837	27170	20000
1988	181	11111	34792	14000
1989	27	11029	13256	14000
1990	155	8887	14242	14000
1991	28	7533	8461	14000
1992	1219	12149	15268	14000
1993	698	12522	15720	14000
1994	1624	3004	5428	10000
1995	177	2637	3214	10000
1996	7255	2390	9845	10000
1997	2554	2558	5112	10000
1998	8972	4380	14052	10000
1999	2344	10249	12593	10200
2000	2206	10584	10003	10000
2001	4893	17681	20274	10000
2002	3000	16453	17234[b]	10000
2003	3125	18466	17246	10000
2004	2616	3848	3753	10000
2005	5501	6409	11305	20000[c]
2006	3580	7455	12610	20000
2007	1053	6472	5179	20000
2008	203	4816	4020	20000
2009	255	6233	6431	20000
2010	260	6285	5234	20000
2011	97	5875	5972	20000
2012	0	6967	6967	20000
2013	75	7720	7795	20000
2014	374	7150	7524	20000
2015	283	8073	8356[d]	20000
2016	199	8818	9017[d]	20000
2017	245	7267	7512[d]	20000
2018	411	5710	6120[d]	20000
2019	513	6042	6555	20000
2020	467	6876	7343	20000
2021	358	5219	5577	20000

[a] Totals from 1983 to 2010 may include adjustments for estimated catches from various sources

[b] Midpoint of estimates ranging between 16100-18400

[c] Prior to 2005 TACs were set by Canada within its fisheries jurisdiction

[d] Based on daily catch reports from the NRA and Statlant 21A data for Canada

Table 2. Reported and estimated catches (t) of redfish in Div. 3O by country and year since 1992.

Year	Canada	Cuba	Estonia	Faroe Islands	France (SPM)	Japan	Latvia	Lithuania	Portugal	Russia	South Korea	Spain	Ukraine	Total	TAC
1992	1219	2776				125			1468	5845	1935			13368	14000
1993	698	665				159			4794	6887	17			13220	14000
1994	1624								2918	60		26		4628	10000
1995	177					264			1935	416		22		2814	10000
1996	7255					417			1635			338		9645	10000
1997	2554				134	285			894			1245		5112	10000
1998	8972				266	355			1875			1884		13352	10000
1999	2344								5469	231		4549		12593	10200
2000	2206		49						4555	2233		3747		12790	10000
2001	4893		9						3537	11343		2792		22574	10000
2002	3000							1	4610	11182		660		19453	10000
2003	3125								6382	10794		1289	1	21591	10000
2004	2616		2			2			3279	242		320	3	6464	10000
2005	5501					1			4555	170		1683		11910	20000
2006	3580					0			5184	977		1294		11035	20000
2007	1053		100			61			4755	54		1502		7525	20000
2008	203		42	100				139	3850	82		603		5019	20000
2009	255		100						4273	169		1691		6488	20000
2010	260		103	163					3853	474		1692		6545	20000
2011	97		121				82	5	4006	570		1661		6542	20000
2012	0		181	101					4142	971		1572		6967	20000
2013	75		269	58					4820	1438		1135		7795	20000
2014	374		227						4720	1271		932		7524	20000
2015	283		817						4659	1086		1510		8355	20000
2016	199	31	701			29			4348	2031		1678		9017	20000
2017	245		603			6			4079	753		1826		7512	20000
2018	411		522			5			3019	350		1813		6120	20000
2019	513		280						3827	44		1891		6555	20000
2020	467		242			1			4259	414		1960		7343	20000
2021	358		336						3066	733		1084		5577	20000

* Prior to 2005 TACs were set by Canada within its fisheries jurisdiction

Table 3. Mean number per standard tow from Canadian Autumn surveys in Div. 3O covering strata from 93 to 731 m. Dashes (--) represent unsampled strata. Number of successful sets in brackets. Data from previous years can be found in Ings et al. (2019).

Stratum	Depth Range (m)	Area (sq mi)	Area within NRA (sq mi)	% Area within NRA	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
329	93-183	1721	0	0.00	634.8 (5)	0.4 (5)	--	0 (5)	1.2 (5)	38.2 (5)	0.2 (5)	0.2 (5)	91.3 (3)	--
332	93-183	1047	0	0.00	36.7 (3)	102 (3)	--	121 (3)	0 (3)	21.7 (3)	26.7 (3)	74.7 (3)	108 (2)	--
337	93-183	948	0	0.00	125.6 (3)	314.9 (3)	--	208 (3)	2 (3)	101.7 (3)	73 (3)	69.3 (3)	37.5 (2)	--
339	93-183	585	0	0.00	0 (2)	0 (2)	--	0 (2)	0.5 (2)	0 (2)	0 (2)	0.5 (2)	20.5 (2)	--
354	93-183	474	246	0.52	42.5 (2)	4 (2)	--	513 (2)	4 (2)	42.9 (2)	1.5 (2)	285.5 (2)	131 (2)	--
333	184-274	147	0	0.00	796.2 (2)	562.2 (2)	--	296.5 (2)	145.5 (2)	39.5 (2)	5.5 (2)	25 (2)	40.6 (2)	--
355	184-274	103	74	0.72	2039.1 (2)	364 (2)	--	531.7 (2)	278.3 (2)	352 (2)	62 (2)	65 (2)	107.9 (2)	--
334	275-366	96	0	0.00	3259.8 (2)	6271.1 (2)	--	1000.5 (2)	638.3 (2)	243 (2)	253.1 (2)	215 (2)	297.7 (2)	--
335	275-366	58	0	0.00	6804.8 (2)	7026.2 (2)	--	1728.9 (2)	443 (2)	3957.8 (2)	1920.4 (2)	167.2 (2)	745.3 (2)	--
336	184-274	121	0	0.00	630.9 (2)	394.7 (2)	--	456 (2)	--	180 (2)	89 (2)	16.8 (2)	66.7 (2)	--
356	275-366	61	47	0.77	732 (2)	3405.5 (2)	--	179.9 (2)	139 (2)	257.5 (2)	101 (2)	73.4 (2)	201 (2)	--
719	367-549	76	0	0.00	55983.3 (2)	10118.3 (2)	--	1616.5 (2)	6113.1 (2)	1319.3 (2)	4504.9 (2)	7417.9 (2)	8775.6 (2)	--
721	367-549	76	58	0.76	2881.4 (2)	4973.1 (2)	--	4672.6 (2)	197.5 (2)	1399.1 (2)	1922.2 (2)	1234.6 (2)	367.6 (2)	--
722	550-731	93	71	0.76	443.5 (2)	1021 (2)	--	1089.7 (2)	504.5 (2)	--	6.7 (2)	113.5 (2)	40 (2)	--
717	367-549	166	0	0.00	8641.1 (2)	4169 (2)	--	1751.8 (2)	1650.3 (2)	2044 (2)	5412.6 (2)	1520.5 (2)	2020.7 (2)	--
718	550-731	134	0	0.00	751.9 (2)	961.7 (2)	--	146 (2)	73.5 (2)	2804 (2)	574.8 (2)	2756.2 (2)	432.6 (2)	--
720	550-731	105	0	0.00	1048 (2)	1336.6 (2)	--	588.9 (2)	1815 (2)	343.4 (2)	749 (2)	735.8 (2)	1627.2 (2)	--
Weighted mean (by area)					1428.4	664.8	--	312.7	195.7	252.7	299.7	281.8	291.4	--
Upper (95% CI)					6989	926.9	--	525.2	309.7	602.4	429.8	480.5	391.4	--
Lower (95% CI)					-4132.3	402.8	--	100.1	81.7	-97	169.5	83.2	191.5	--
SURVEY ABUNDANCE (x10^6)					1181.1	549.7	--	258.5	158.5	205.7	247.8	233.1	241	--

Table 4. Mean weight (kg) per standard tow from Canadian Autumn surveys in Div. 30 covering strata from 93 to 731 m. Dashes (--) represent unsampled strata. Number of successful sets in brackets. Data from previous years can be found in Ings et al. (2019).

Stratum	Depth Range (m)	Area (sq mi)	Area within NRA (sq mi)	% Area within NRA	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
329	93-183	1721	0	0.00	61.1 (5)	0 (5)	--	0 (5)	0 (5)	1.1 (5)	0 (5)	0 (5)	8 (3)	--
332	93-183	1047	0	0.00	1.5 (3)	7.9 (3)	--	17.2 (3)	0 (3)	0.2 (3)	0.1 (3)	6.3 (3)	9.8 (2)	--
337	93-183	948	0	0.00	10.1 (3)	56.9 (3)	--	31 (3)	0.2 (3)	17.2 (3)	4.1 (3)	8 (3)	2 (2)	--
339	93-183	585	0	0.00	0 (2)	0 (2)	--	0 (2)	0 (2)	0 (2)	0 (2)	0 (2)	0.1 (2)	--
354	93-183	474	246	0.52	2.8 (2)	0.6 (2)	--	85.1 (2)	0 (2)	3.7 (2)	0 (2)	2.9 (2)	12.3 (2)	--
333	184-274	147	0	0.00	128.2 (2)	74.2 (2)	--	13.6 (2)	17.6 (2)	5.1 (2)	0.5 (2)	1.3 (2)	4.7 (2)	--
355	184-274	103	74	0.72	231.6 (2)	48.1 (2)	--	65.5 (2)	34.8 (2)	44.9 (2)	10 (2)	6.4 (2)	11.1 (2)	--
334	275-366	96	0	0.00	424.3 (2)	785.7 (2)	--	172 (2)	123.9 (2)	40.8 (2)	55.3 (2)	46.7 (2)	52.8 (2)	--
335	275-366	58	0	0.00	816.7 (2)	858.8 (2)	--	243.6 (2)	64.8 (2)	685 (2)	357.3 (2)	23 (2)	119.5 (2)	--
336	184-274	121	0	0.00	76.9 (2)	44.3 (2)	--	29.7 (2)	--	13.3 (2)	7.5 (2)	2.5 (2)	9.3 (2)	--
356	275-366	61	47	0.77	98.3 (2)	450.7 (2)	--	26.8 (2)	26.1 (2)	40.8 (2)	16 (2)	11 (2)	30.1 (2)	--
719	367-549	76	0	0.00	7348 (2)	1442.2 (2)	--	249 (2)	1061.1 (2)	237.3 (2)	993 (2)	1415.5 (2)	1850.3 (2)	--
721	367-549	76	58	0.76	384.3 (2)	666.5 (2)	--	838.5 (2)	33.7 (2)	253.6 (2)	352.4 (2)	267.5 (2)	85.2 (2)	--
722	550-731	93	71	0.76	116.7 (2)	225.9 (2)	--	257.1 (2)	123.6 (2)	--	1.6 (2)	31.1 (2)	15 (2)	--
717	367-549	166	0	0.00	1205.6 (2)	625.2 (2)	--	321 (2)	301.4 (2)	411.7 (2)	1225.9 (2)	351 (2)	435.1 (2)	--
718	550-731	134	0	0.00	212.3 (2)	284 (2)	--	38.5 (2)	23.7 (2)	741.7 (2)	207.9 (2)	787.8 (2)	156.4 (2)	--
720	550-731	105	0	0.00	290.3 (2)	287.2 (2)	--	153.7 (2)	470.4 (2)	103 (2)	192.9 (2)	198.5 (2)	446.4 (2)	--
Weighted mean (by area)					186.5	98.1	--	52.1	37.5	48.9	64.4	56.3	56.1	--
Upper (95% CI)					927.2	130.4	--	91.2	62.6	174.9	94.6	94.2	83.5	--
Lower (95% CI)					-554.2	65.8	--	13	12.4	-77.2	34.2	18.5	28.7	--
SURVEY BIOMASS (x10^6)					154.2	81.1	--	43.1	30.4	39.8	53.2	46.6	46.4	--

Table 5. Mean number per standard tow from Canadian Spring surveys in Div. 30 covering strata from 93 to 731 m. Dashes (--) represent unsampled strata. Number of successful sets in brackets. Data from previous years can be found in Ings et al. (2019).

Stratum	Depth Range (m)	Area (sq mi)	Area within NRA (sq mi)	% Area within NRA	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
329	93-183	1721	0	0.00	3.4 (5)	147.8 (5)	0 (3)	188 (5)	0.8 (5)	70.8 (5)	0 (5)	0 (5)	--	--
332	93-183	1047	0	0.00	3020.2 (3)	245 (3)	1969 (2)	243 (3)	2 (3)	503.7 (3)	134.3 (3)	11.7 (3)	--	--
337	93-183	948	0	0.00	1037 (3)	3.3 (3)	202 (2)	716.3 (3)	1730.5 (2)	2161 (2)	170.3 (3)	151.3 (3)	--	--
339	93-183	585	0	0.00	0.5 (2)	0.5 (2)	0 (2)	0 (2)	0 (2)	0 (2)	0 (2)	0 (2)	--	--
354	93-183	474	246	0.52	3745.5 (2)	5.5 (2)	6759.1 (2)	1638 (2)	0 (2)	0 (2)	5.1 (2)	30 (2)	--	--
333	184-274	147	0	0.00	4727.6 (2)	4168.5 (2)	985.5 (2)	2305.5 (2)	1065.5 (2)	662.6 (2)	856 (2)	1844 (2)	--	--
336	184-274	121	0	0.00	20363.5 (2)	1792.9 (2)	2148.5 (2)	1333.5 (2)	4425.6 (2)	2074.2 (2)	407 (2)	2992.1 (2)	--	--
355	184-274	103	74	0.72	4179.7 (2)	4640.3 (2)	1862 (2)	1551.5 (2)	3633 (2)	2345.7 (2)	612 (2)	60.4 (2)	--	--
334	275-366	96	0	0.00	5887.9 (2)	2254.2 (2)	8832.5 (2)	3098.1 (2)	1217.8 (2)	1587 (2)	2729.5 (2)	1417.2 (2)	--	--
335	275-366	58	0	0.00	7583.5 (2)	3716 (2)	4680.5 (2)	3701.5 (2)	909 (2)	622 (2)	1073.3 (2)	4195.4 (2)	--	--
356	275-366	61	47	0.77	10444.5 (2)	658.2 (2)	1704.5 (2)	810.5 (2)	159 (2)	627 (2)	502.5 (2)	2196.9 (2)	--	--
717	367-549	166	0	0.00	3101.3 (2)	687.1 (2)	2742.8 (2)	1320.1 (2)	--	1810.5 (2)	928.5 (2)	552.4 (2)	--	--
719	367-549	76	0	0.00	8938.9 (2)	12735 (2)	1510 (2)	629.4 (2)	538.9 (2)	487.4 (2)	1559.3 (2)	3668.2 (2)	--	--
721	367-549	76	58	0.76	2148 (2)	1493.7 (2)	987 (2)	1787.5 (2)	473.7 (2)	68.5 (2)	3992.5 (2)	3551.8 (2)	--	--
718	550-731	134	0	0.00	70.7 (2)	2 (2)	5.7 (2)	30 (2)	--	62.7 (2)	191.2 (2)	--	--	--
720	550-731	105	0	0.00	239 (2)	23.1 (2)	113 (2)	18.7 (2)	298.7 (2)	5.7 (2)	114.5 (2)	17.8 (2)	--	--
722	550-731	93	71	0.76	202.2 (2)	3.4 (2)	5.1 (2)	12.5 (2)	346.6 (2)	53.5 (2)	72 (2)	162.5 (2)	--	--
Weighted mean (by area)					2091	581.5	1320.1	609.7	530.6	644	252.5	336.9	--	--
Upper (95% CI)					3932.4	922.9	4403.8	899.6	3664.9	3915.5	416	580.2	--	--
Lower (95% CI)					249.7	240	-1763.6	319.9	-2603.7	-2627.4	89.1	93.6	--	--
SURVEY ABUNDANCE (x10^6)					1729	480.8	1091.5	504.2	416.8	532.5	208.8	272.4	--	--

Table 6. Mean weight (kg) per standard tow from Canadian Spring surveys in Div. 3O covering strata from 93 to 731 m. Dashes (--) represent unsampled strata. Number of successful sets in brackets. Data from previous years can be found in Ings et al. (2019).

Stratum	Depth Range (m)	Area (sq mi)	Area within NRA (sq mi)	% Area within NRA	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
329	93-183	1721	0	0.00	0.1 (5)	19.2 (5)	0 (3)	22 (5)	0 (5)	10.6 (5)	0 (5)	0 (5)	--	--
332	93-183	1047	0	0.00	456.6 (3)	31 (3)	294.1 (2)	30.3 (3)	0.1 (3)	67.6 (3)	3.7 (3)	0.1 (3)	--	--
337	93-183	948	0	0.00	121.6 (3)	0 (3)	24 (2)	84.2 (3)	253 (2)	334.2 (2)	1.9 (3)	15.1 (3)	--	--
339	93-183	585	0	0.00	0 (2)	0 (2)	0 (2)	0 (2)	0 (2)	0 (2)	0 (2)	0 (2)	--	--
354	93-183	474	246	0.52	463.3 (2)	1 (2)	1138.7 (2)	301.1 (2)	0 (2)	0 (2)	0 (2)	0.6 (2)	--	--
333	184-274	147	0	0.00	568.3 (2)	598 (2)	140.5 (2)	311.7 (2)	160.4 (2)	114.1 (2)	142.5 (2)	314.4 (2)	--	--
336	184-274	121	0	0.00	2527.7 (2)	240.3 (2)	271 (2)	177.8 (2)	657.1 (2)	351.2 (2)	52.8 (2)	383.1 (2)	--	--
355	184-274	103	74	0.72	429.3 (2)	727.3 (2)	258.8 (2)	221.5 (2)	580.8 (2)	400.5 (2)	81 (2)	8.5 (2)	--	--
334	275-366	96	0	0.00	795.1 (2)	307.5 (2)	1330.2 (2)	492 (2)	193.5 (2)	323.9 (2)	486.4 (2)	273.6 (2)	--	--
335	275-366	58	0	0.00	1014.5 (2)	456 (2)	616.6 (2)	526.6 (2)	140.9 (2)	112.9 (2)	183 (2)	766.5 (2)	--	--
356	275-366	61	47	0.77	1330.5 (2)	88 (2)	253.2 (2)	122.3 (2)	25.9 (2)	126.4 (2)	92 (2)	372.4 (2)	--	--
717	367-549	166	0	0.00	528.4 (2)	160 (2)	516.2 (2)	256.4 (2)	--	461.1 (2)	222.9 (2)	165.6 (2)	--	--
719	367-549	76	0	0.00	1342 (2)	2153.3 (2)	297 (2)	138.5 (2)	104 (2)	134.7 (2)	335.8 (2)	846.2 (2)	--	--
721	367-549	76	58	0.76	298.7 (2)	231.6 (2)	178.1 (2)	454.2 (2)	116.7 (2)	16 (2)	878.3 (2)	803.2 (2)	--	--
718	550-731	134	0	0.00	18.8 (2)	0.5 (2)	1.7 (2)	8.7 (2)	--	15.9 (2)	54.7 (2)	--	--	--
720	550-731	105	0	0.00	64.5 (2)	7.2 (2)	28.8 (2)	4 (2)	73 (2)	1.5 (2)	35.8 (2)	4.1 (2)	--	--
722	550-731	93	71	0.76	43.2 (2)	1.3 (2)	1.6 (2)	2.1 (2)	107.2 (2)	17.1 (2)	28 (2)	52 (2)	--	--
Weighted mean (by area)					280.9	87.8	208.7	92.7	81.5	107.1	41.1	61.2	--	--
Upper (95% CI)					562.1	146.2	762.1	134.6	530.7	597.9	76.4	106.5	--	--
Lower (95% CI)					-0.2	29.4	-344.7	50.7	-367.6	-383.7	5.8	15.9	--	--
SURVEY BIOMASS (x10^6)					232.3	72.6	172.6	76.6	64.1	88.5	34	49.5	--	--

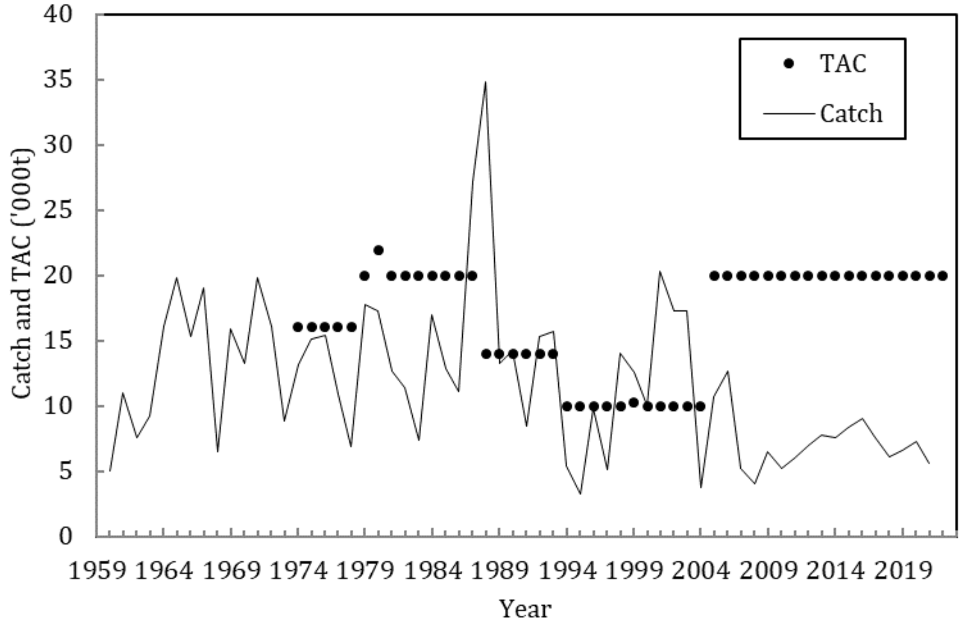


Figure 1. Nominal catches and TACs of Redfish in Div. 3O. TAC to 2004 was only for Canadian fishery zone.

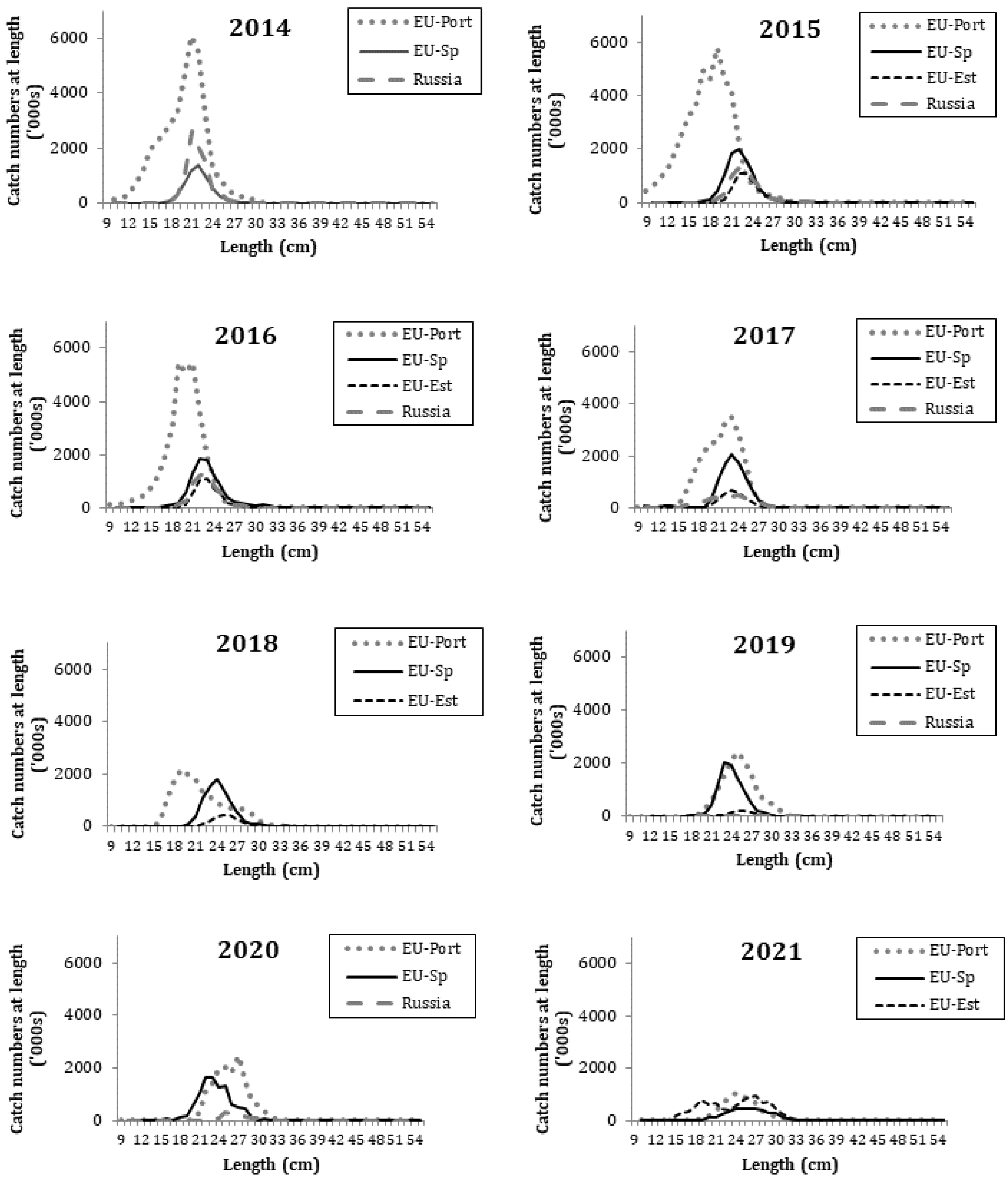


Figure 2. Commercial fishery catch numbers at length ('000s).

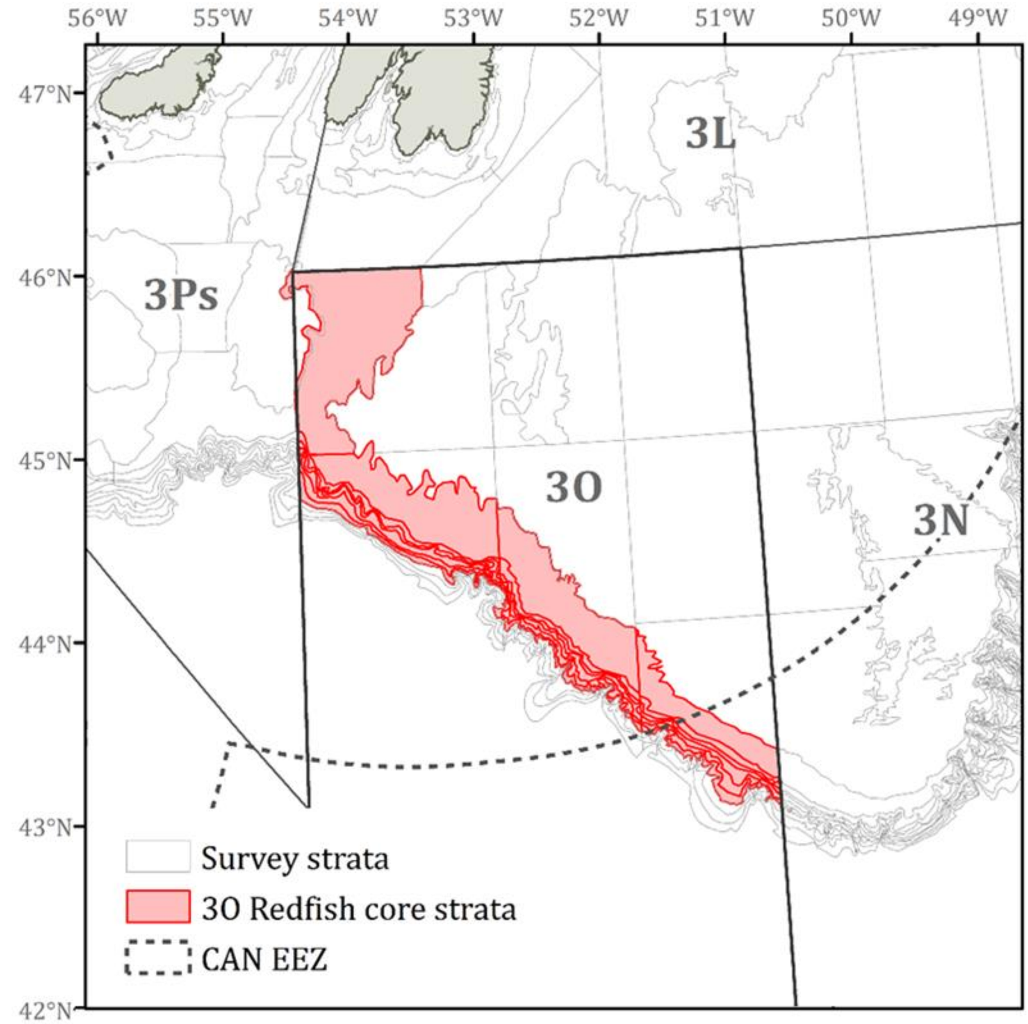


Figure 3. Map of the index ("core") strata (red) in Div. 3O that are used for indices from the Canadian spring and Canadian autumn surveys in Div. 3O.

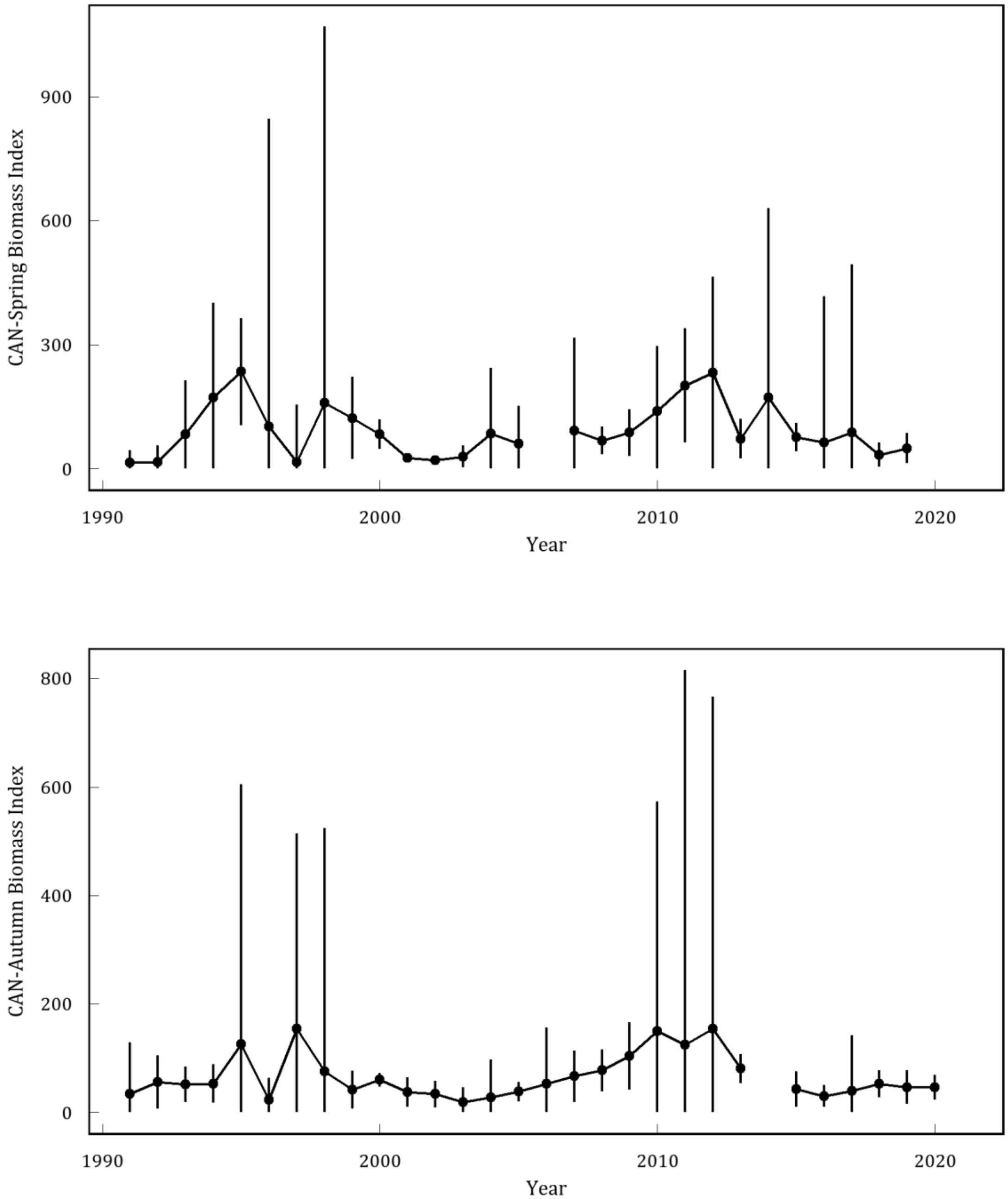


Figure 4. Survey biomass index for redfish in Div. 3O for CAN-spring and CAN-autumn surveys from 1991 - 2020 with 95% CI (lower panels). There were no Canadian RV surveys in Div. 3O in 2021, and no CAN-spring survey in 2020. Surveys prior to 1995 utilized an Engel trawl. Estimates were converted to Campelen equivalents based on comparative fishing trials.

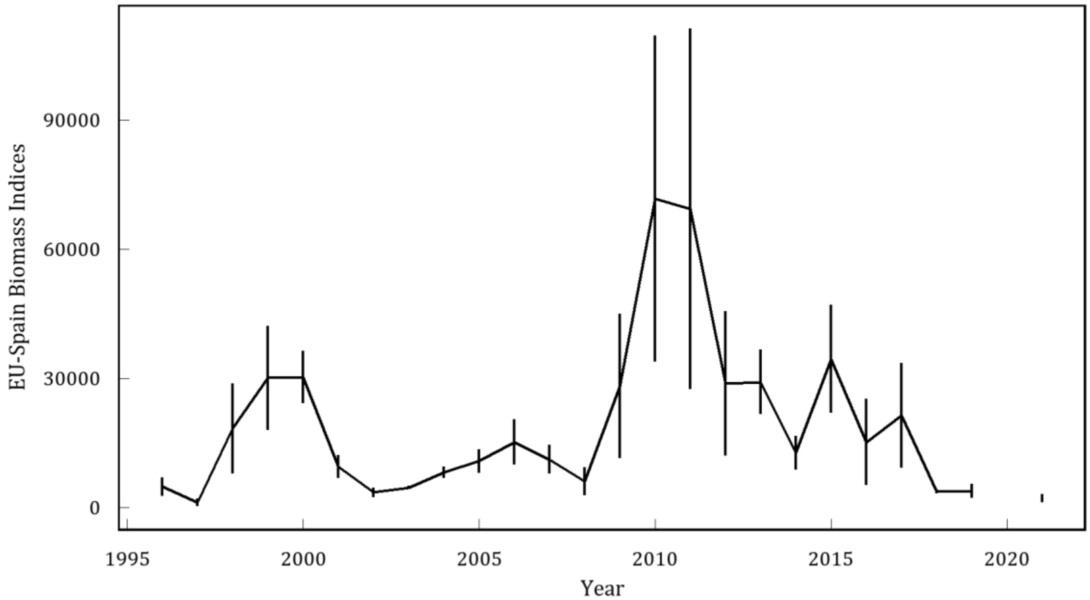


Figure 5. EU-Spain survey biomass index for redfish in Div. 3O for spring 1997 to 2021. Surveys prior to 2001 used a Pedreira trawl. The data prior to 2001 were converted to Campelen equivalent units.

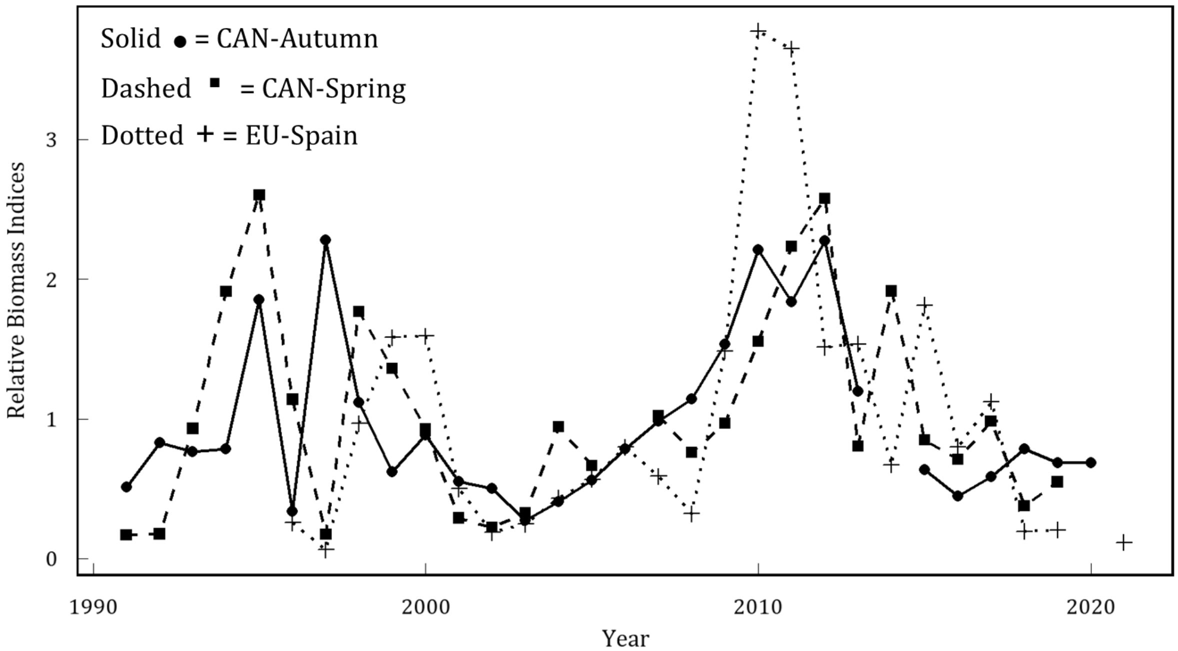


Figure 6. Biomass indices from the Canadian spring and autumn plus the EU-Spain research vessel surveys for redfish in Div. 3O. Survey indices were normalized based on average values during the period 1997 to 2021.

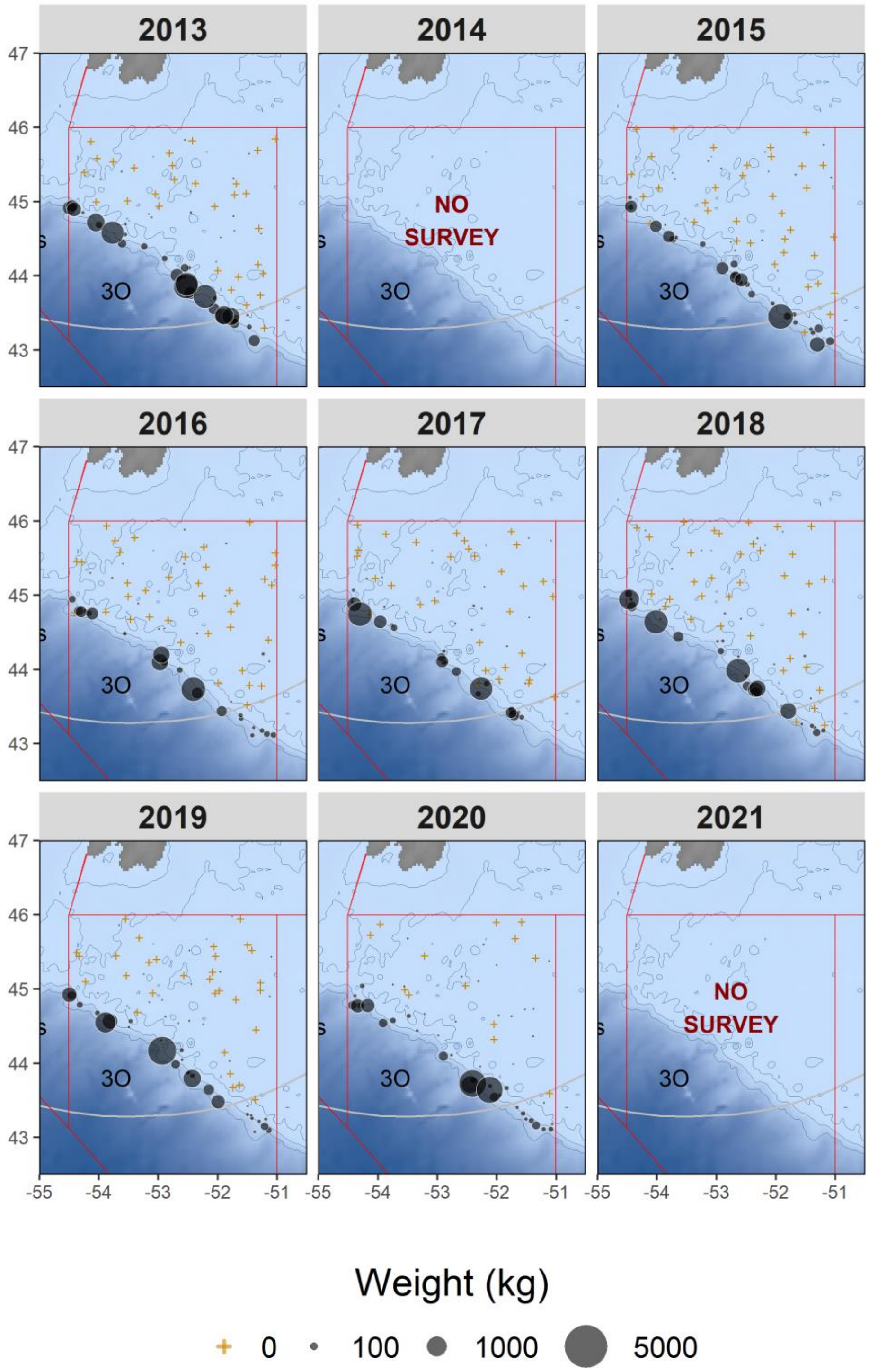


Figure 7. Distribution of redfish catches (kg per tow) in the Canadian autumn RV survey in Div. 3O.

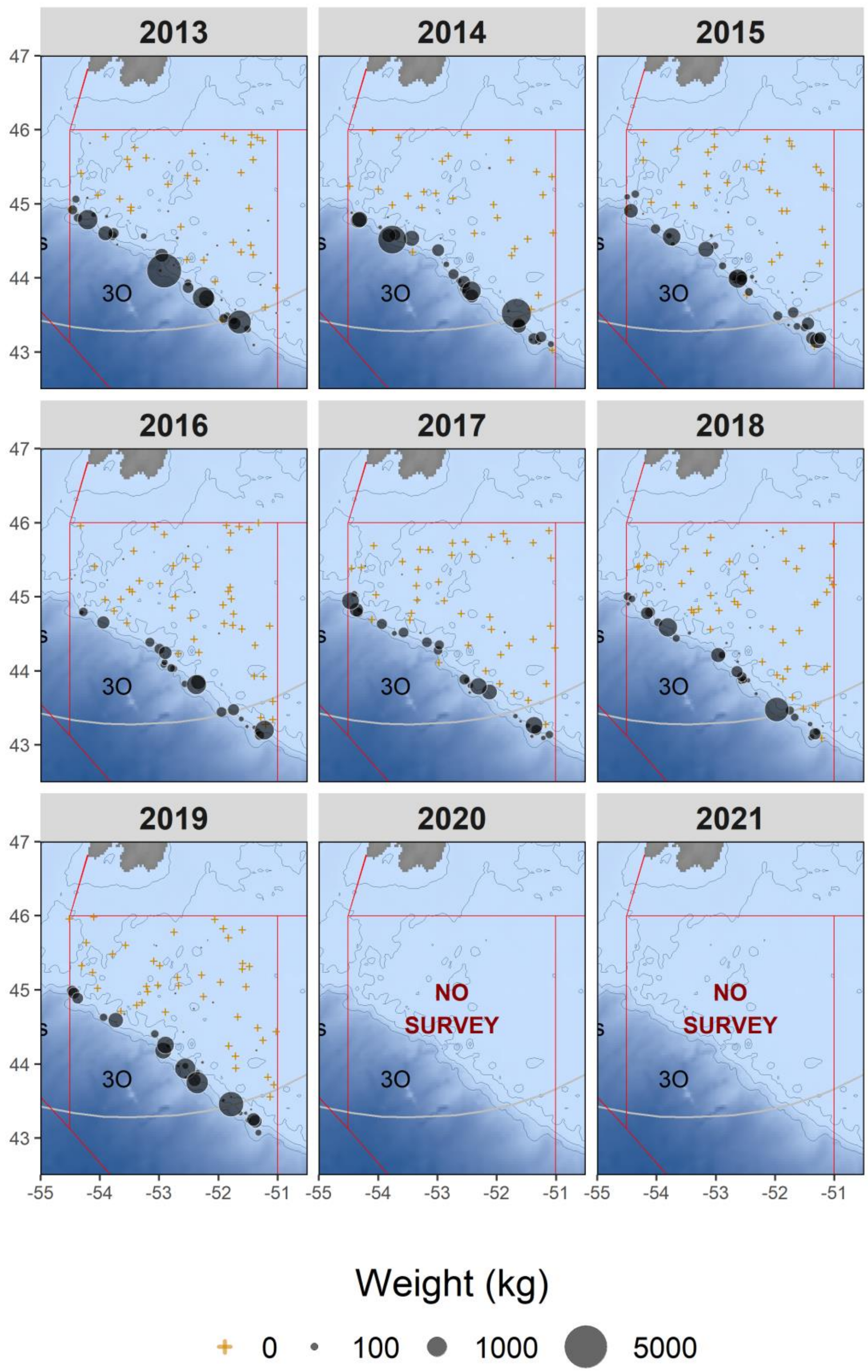


Figure 8. Distribution of redfish catches (kg per tow) in the Canadian spring RV survey in Div. 3O.

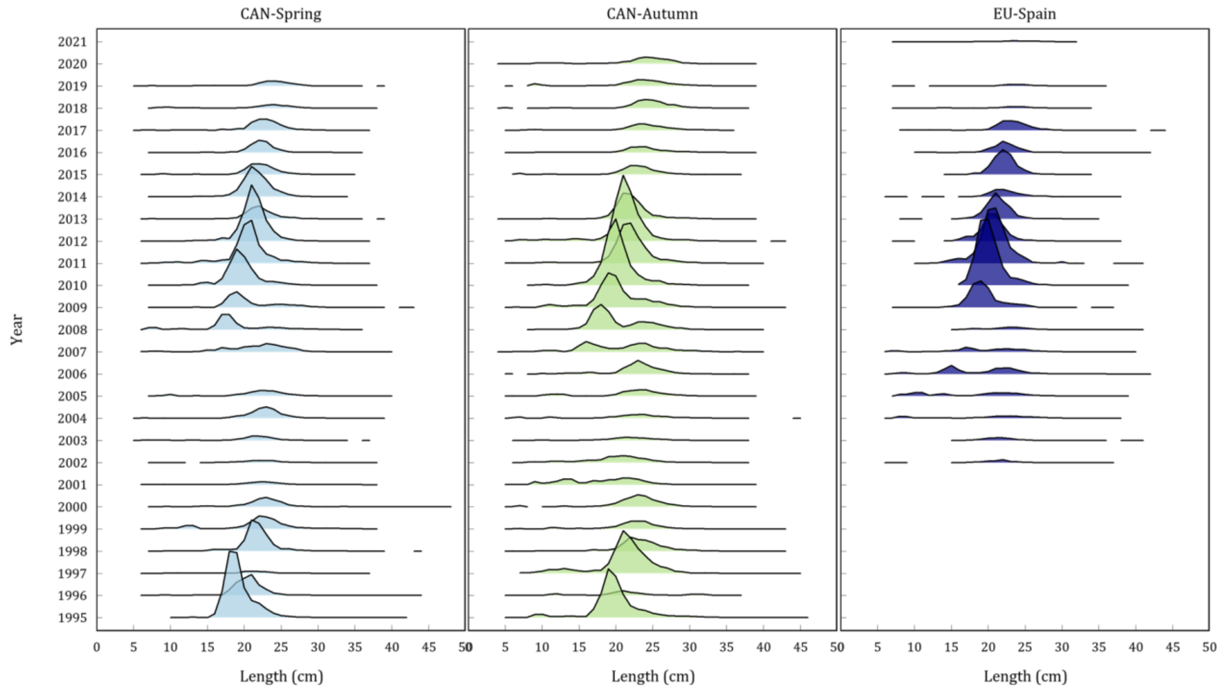
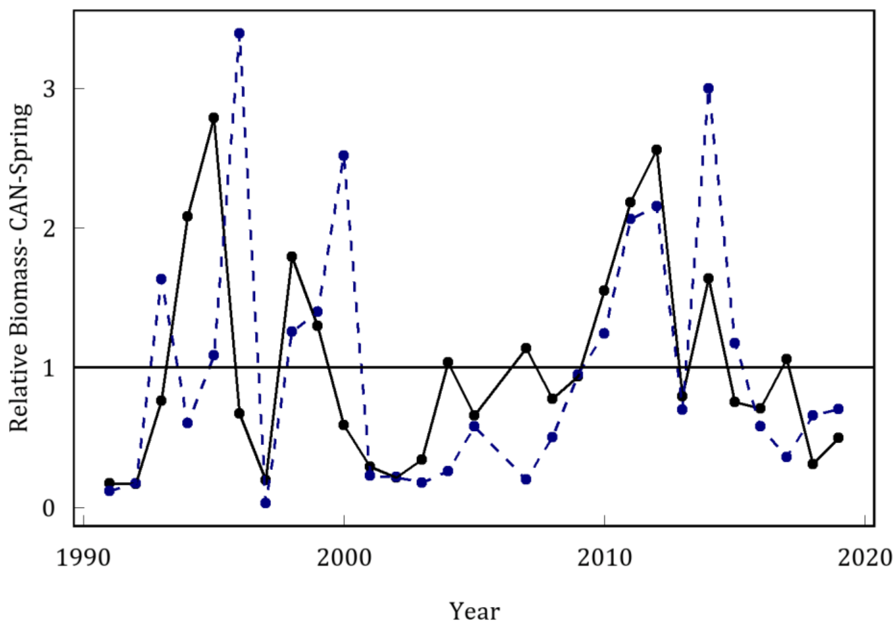


Figure 9. Length distributions (abundance at length) from Canadian RV surveys in Div. 3O during spring and autumn since 1995 (Campelen time series) and the EU-Spain survey since 2004



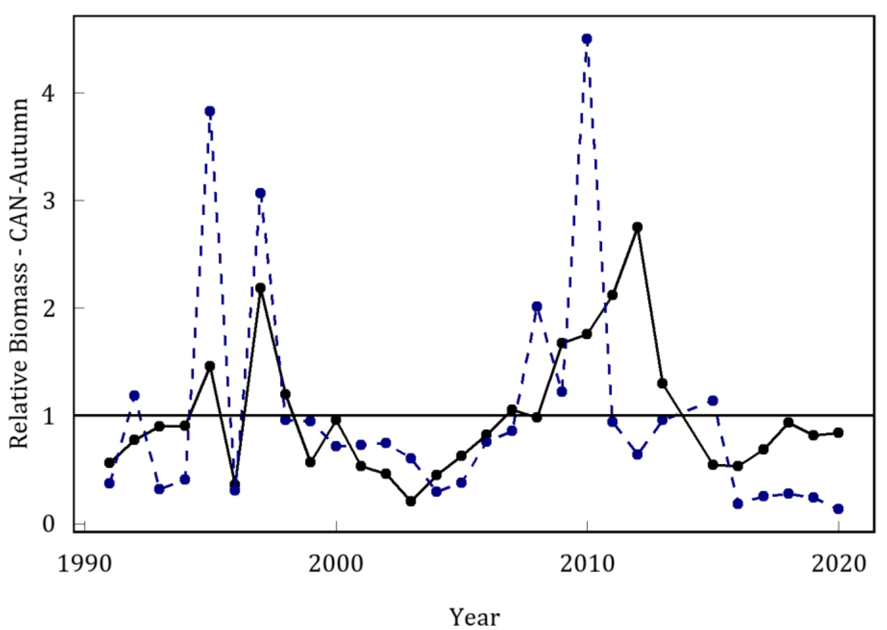


Figure 10. Trends in indices of biomass outside of (black) and within (blue dashed) the NRA for Canadian spring (top) and autumn (bottom) RV surveys. Indices have been standardized to the series mean (horizontal line at 1).

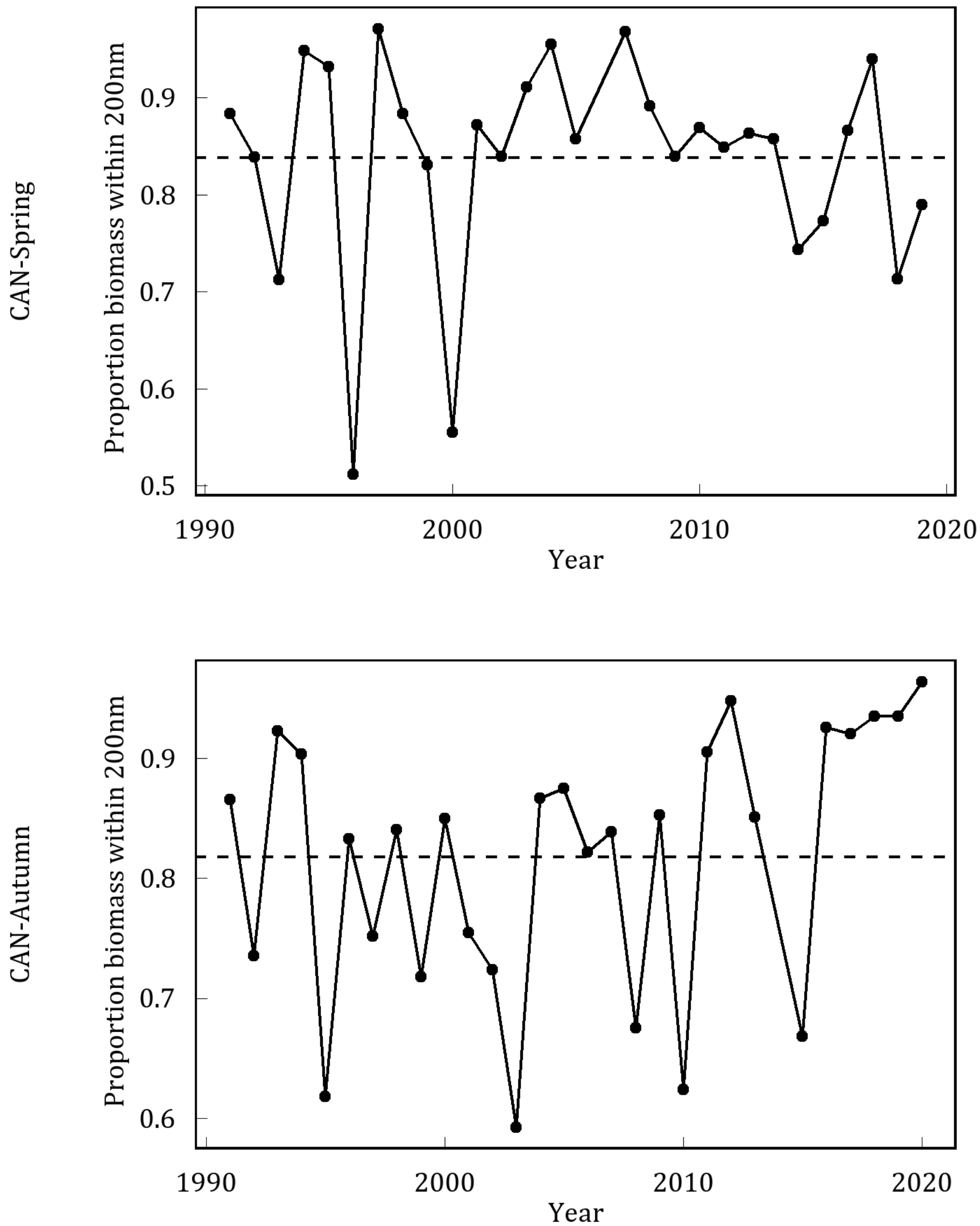


Figure 11. Proportion of survey biomass within the 200nm limit (Canadian Economic Exclusive Zone) in Div. 3O for the Canadian spring (top) and autumn (bottom) surveys. Across the time series, means (horizontal dashed lines) of over 80% of the biomass has been located outside of the NRA. Variability in this has decreased in the recent period, however recent trends in proportions differ between spring and autumn surveys.

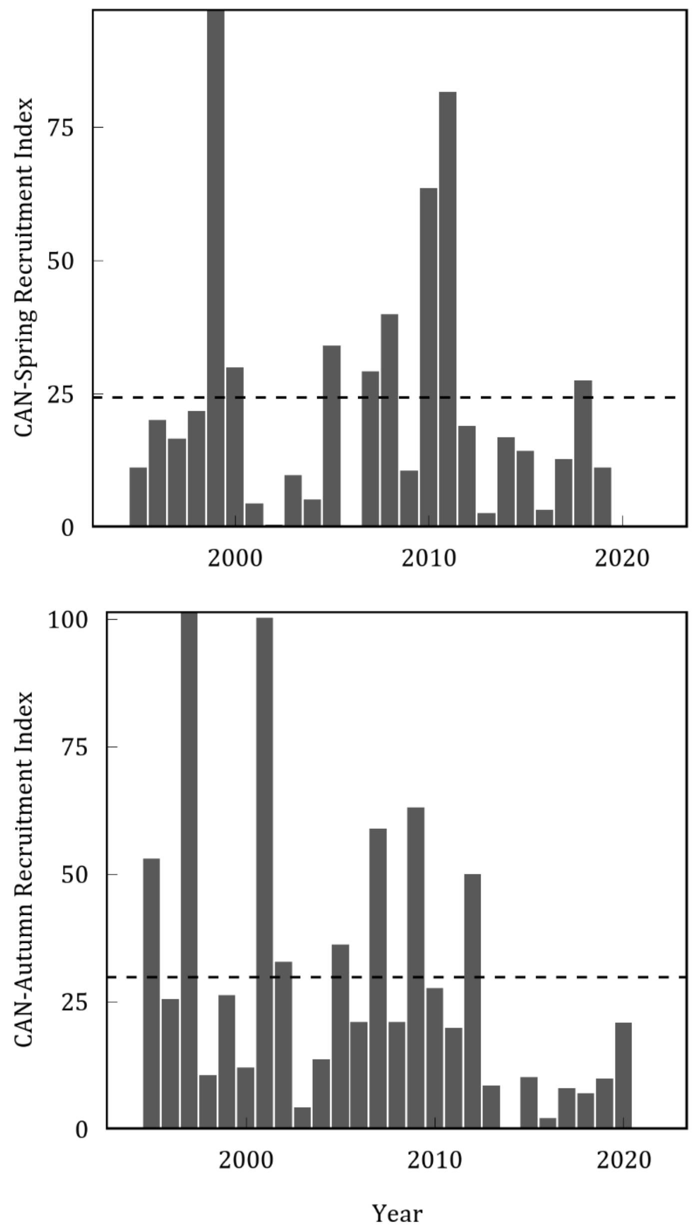


Figure 12. Recruitment indices (abundance at lengths 10-15cm) for Div. 3O from Canadian spring and autumn surveys. Horizontal line indicates each time series mean.

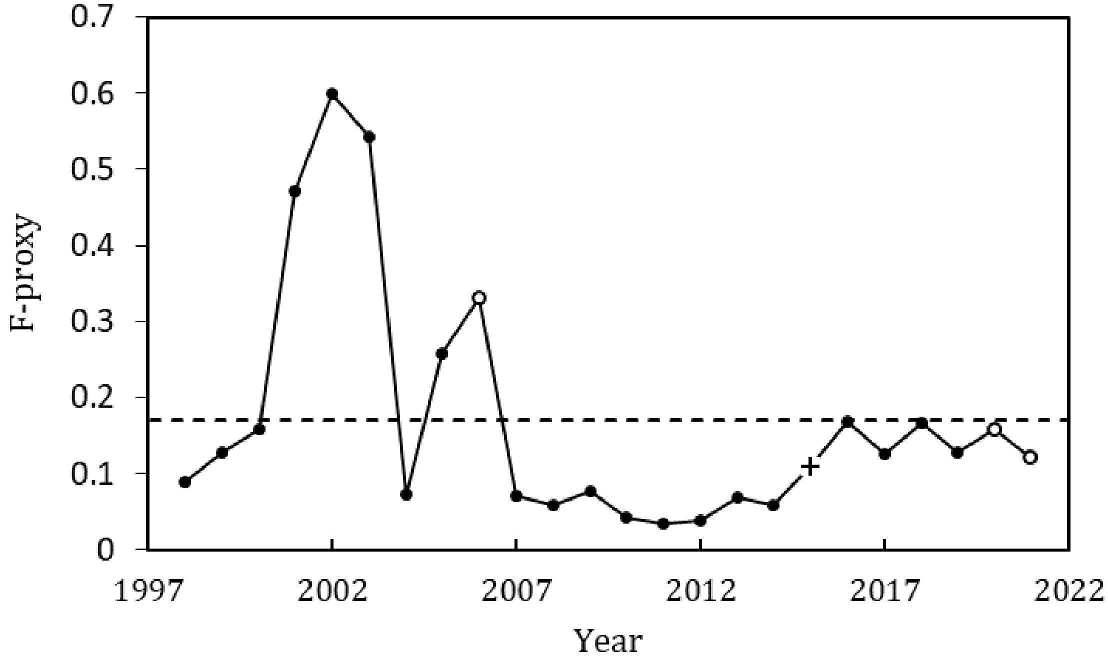
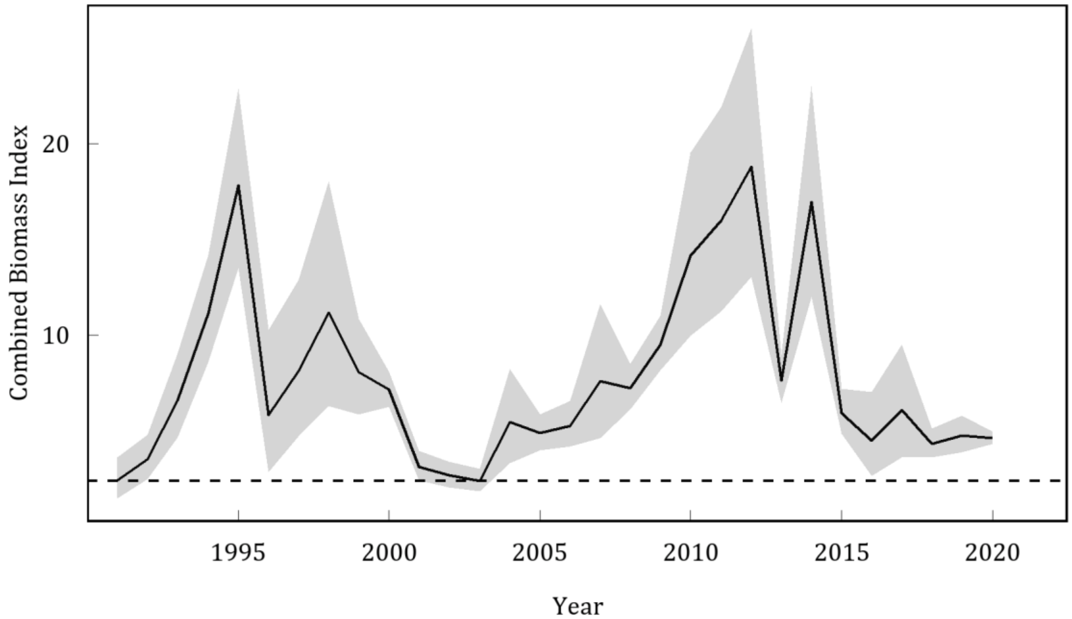


Figure 13. Catch/Biomass ratios for Div. 3O based on Canadian RV surveys. Plotted are average survey biomass between spring (y) and autumn (y-1) for year (y) in which catch was taken. The 2015 value (+) is only from the spring survey in year y . Values for 2006, 2019 and 2020 (open circles) use biomass only from the autumn survey in year y-1.



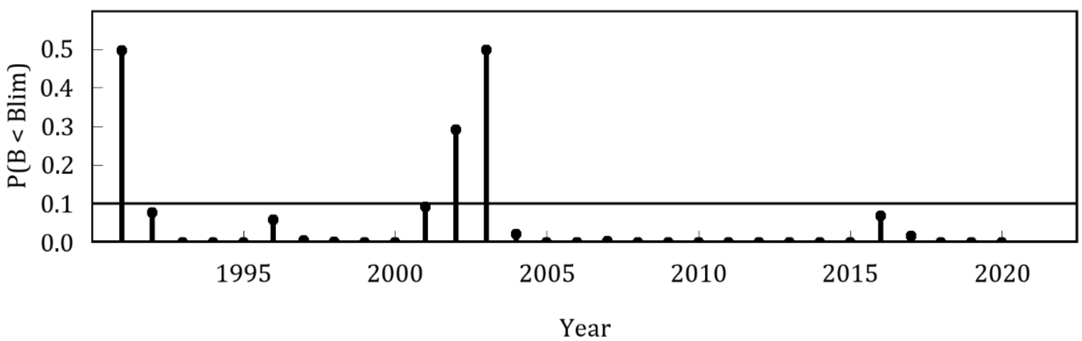


Figure 14. Combined biomass index (top) based on Canadian spring and Canadian autumn surveys, with 80% confidence intervals (see Regular et al. (2022) for method details). Horizontal dashed line indicates $B=B_{lim}$, where an interim B_{lim} has been defined as $0.3*B_{msy\text{-}proxy}$, where the time series average is considered a proxy for B_{msy}. Probability (bottom) of biomass in year *y* being below B_{lim}.