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Canadian Science Advisory Secretariat
Newfoundland and Labrador Region **Science Response 2021/004**

2020 STOCK STATUS UPDATE FOR NORTHERN COD

Context

The Atlantic cod *Gadus morhua* stock on the Newfoundland and Labrador continental shelf in NAFO Divs. 2J3KL (Northern cod) is typically assessed using an age-structured state-space model (Northern Cod Assessment Model [NCAM], Cadigan 2016a and 2016b). A conservation Limit Reference Point (LRP) was established for Northern cod in 2010 (DFO 2011), re-evaluated in 2019 (DFO 2019a), and is defined as the average spawning stock biomass (SSB) during the 1980s. This reference point is the stock level below which serious harm is occurring and the ability to produce good recruitment is seriously impaired. This reference point also defines the boundary between the critical and cautious zones within Fisheries and Oceans Canada's (DFO) Precautionary Approach (PA) framework (DFO 2009).

In 2018, the Minister of Fisheries and Oceans Canada announced that Northern cod would be assessed annually for the next five years. However, the global COVID-19 pandemic disrupted the full stock assessment scheduled for March 24-27, 2020. To provide a timely review of the most recent data, a science response was conducted remotely in lieu of a full assessment. The assessment model (NCAM) and associated projections were not run as part of this process.

The 2019 stock assessment reported that the Northern cod stock remained at 48% of the Limit Reference Point, in the Critical Zone of DFO's PA framework (DFO 2009; DFO 2019b). The advice from this assessment stated: "Consistency with the DFO decision-making framework incorporating the precautionary approach requires that removals from all sources must be kept at the lowest possible level until the stock clears the critical zone". Projections carried out at that time with six catch scenarios ranging from zero to 1.3 times the model estimated catch for 2018 (13,796 t) indicated that the probability that SSB would reach the LRP by 2022 ranged between 6-9%.

The goal of this Science Response process was to determine whether or not the advice from the 2019 full assessment was still applicable based on up-to-date data inputs. This Science Response Report results from the Regional Peer Review Process held in St. John's, NL on April 1-2, 2020 on the Stock Assessment of Northern Cod (Divs. 2J3KL).

The meeting reviewed the following information:

1. ecosystem indicators of productivity;
2. the DFO fall Research Vessel (RV) survey (specifically: indices of abundance and biomass);
3. the inshore sentinel catch rate index; and
4. removals from commercial reported catch and recreational catch estimates based on tagging data.

Analysis and Response

Oceanographic and Ecosystem Conditions

Primary (nitrate, chlorophyll) and secondary (zooplankton biomass) production indices have improved over the past three to four years (Figure 1). However, there have been significant changes in zooplankton community structure, with an increase in small zooplankton species, and decrease in large copepods (DFO 2019c). A decrease in large copepods may influence population dynamics of upper trophic level species that depend on these energy rich species.

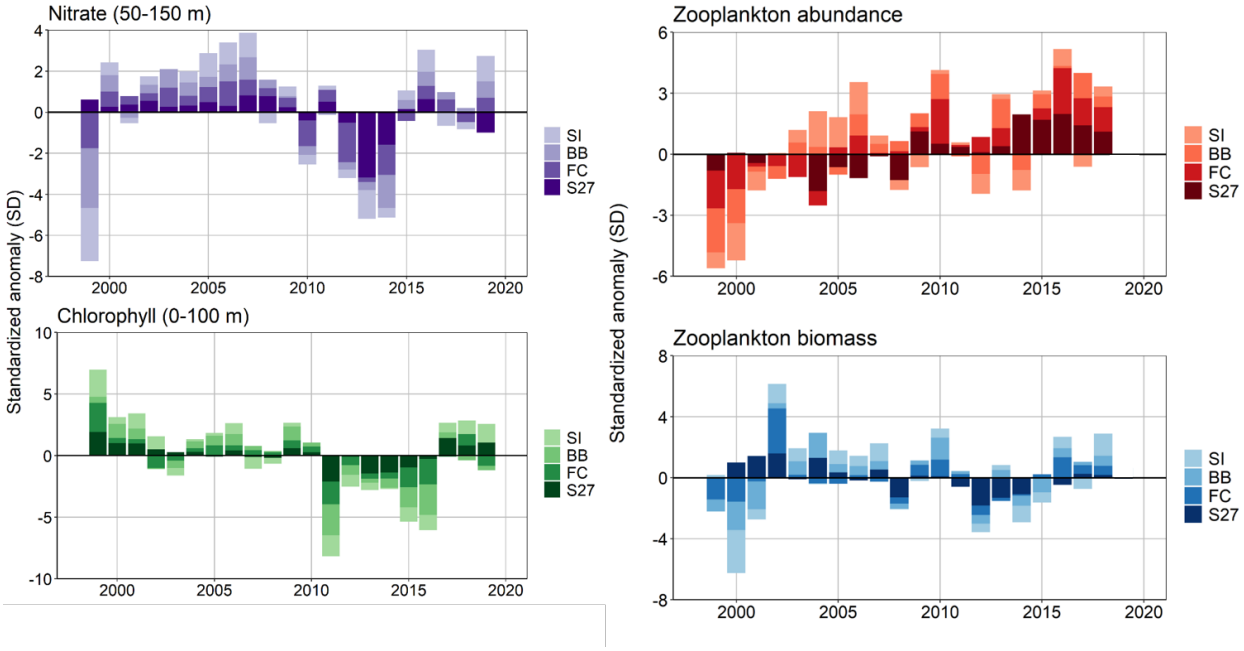

Figure 1: Indicators of primary (nitrate, chlorophyll) and secondary (zooplankton abundance and biomass) indices for NAFO Divs. 2J3KL. SI = Seal Island, BB = Bonavista Bay, FC = Flemish Cap, S27 = Station 27. Zooplankton data for 2019 were not available at the time of the update.

The fish community on the Newfoundland Shelf and Northern Grand Bank (NAFO Divs. 2J3KL) was dominated by finfishes in the 1980s. The ecosystem changes observed in the 1990s involved the collapse of the groundfish community (i.e., not just cod), and an increase in shellfish (Koen-Alonso and Cuff, 2018). Capelin also collapsed during this period (Buren et al. 2019). Even with the increases in shellfish, total RV biomass never rebuilt to pre-collapse levels (Figure 2).

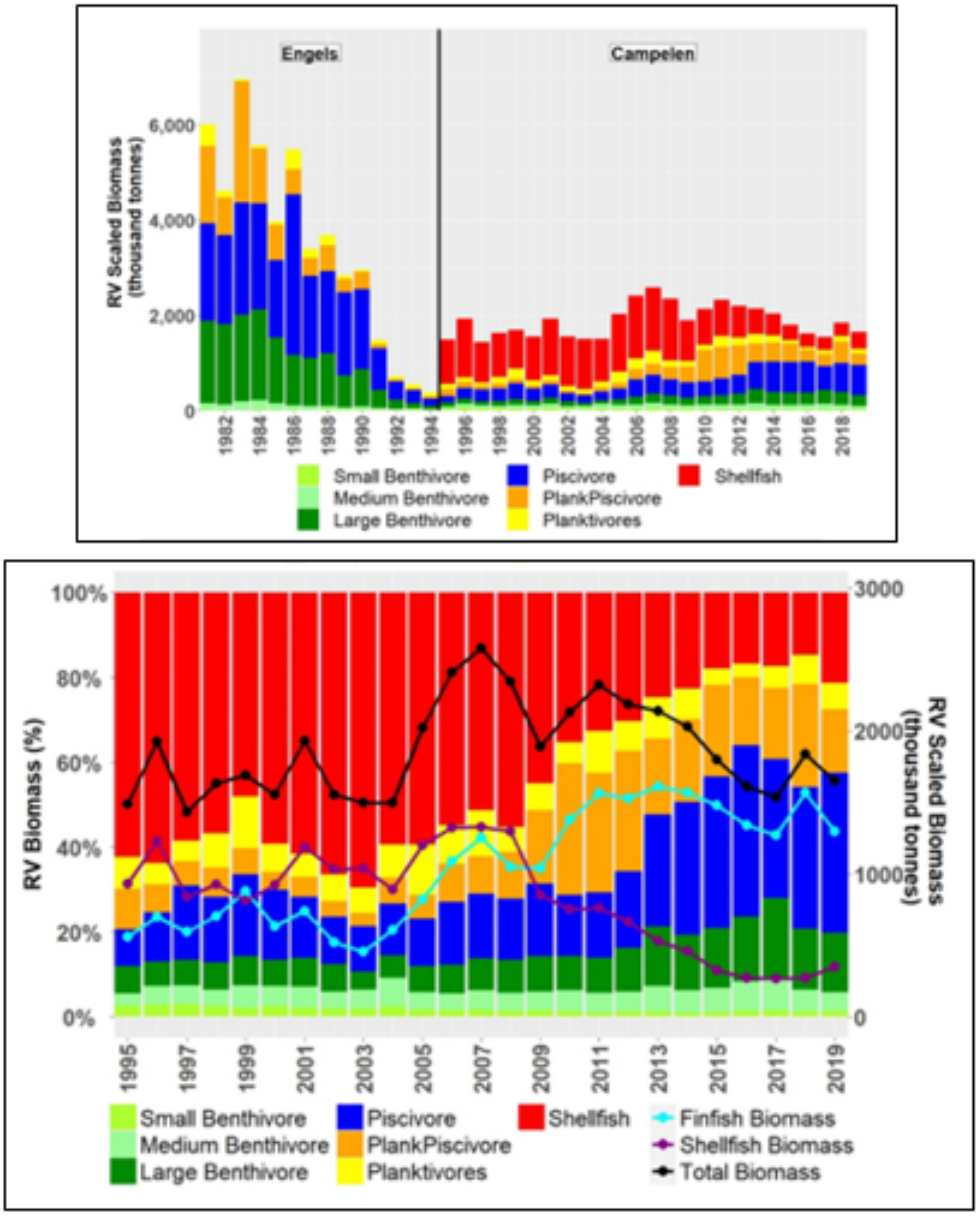

Figure 2: Summary of the structure and trends of the fish community in the Newfoundland Shelf EPU (Divs. 2J3KL). Top: total RV survey biomass indices across fish functional groups. Indices for the Engel period have been scaled to be comparable to the Campelen series. Comparable shellfish data were not collected prior to 1995. Bottom: synoptic view of the changes in the structure of the fish community during 1995-2019. Bars indicate the composition of RV survey biomass by fish functional groups, while lines indicates the trajectories of RV survey biomass by large taxonomic aggregates (finfish, shellfish, and total).

Ecosystem conditions continue to be indicative of limited productivity of the fish community. Total RV biomass levels remain much lower than prior to the 1990s collapse. The increases in finfish biomass observed in the late-2000s and early-2010s appear associated with bottom-up processes, including an improved prey field, with modest increases in capelin availability in comparison with the 1990s (Buren et al. 2019). Capelin and shrimp are key forage species in

the ecosystem. Recent declines in total finfish biomass observed in the late 2010s may be associated with simultaneous reductions in capelin and shrimp availability.

The proportional representation of capelin and shrimp in cod diet has declined in recent years. There has also been a relative increase in cannibalism (Figure 3). Stomach content weights for fish between 30-55 cm also show a declining trend, suggesting limitations in food availability (Figure 3).

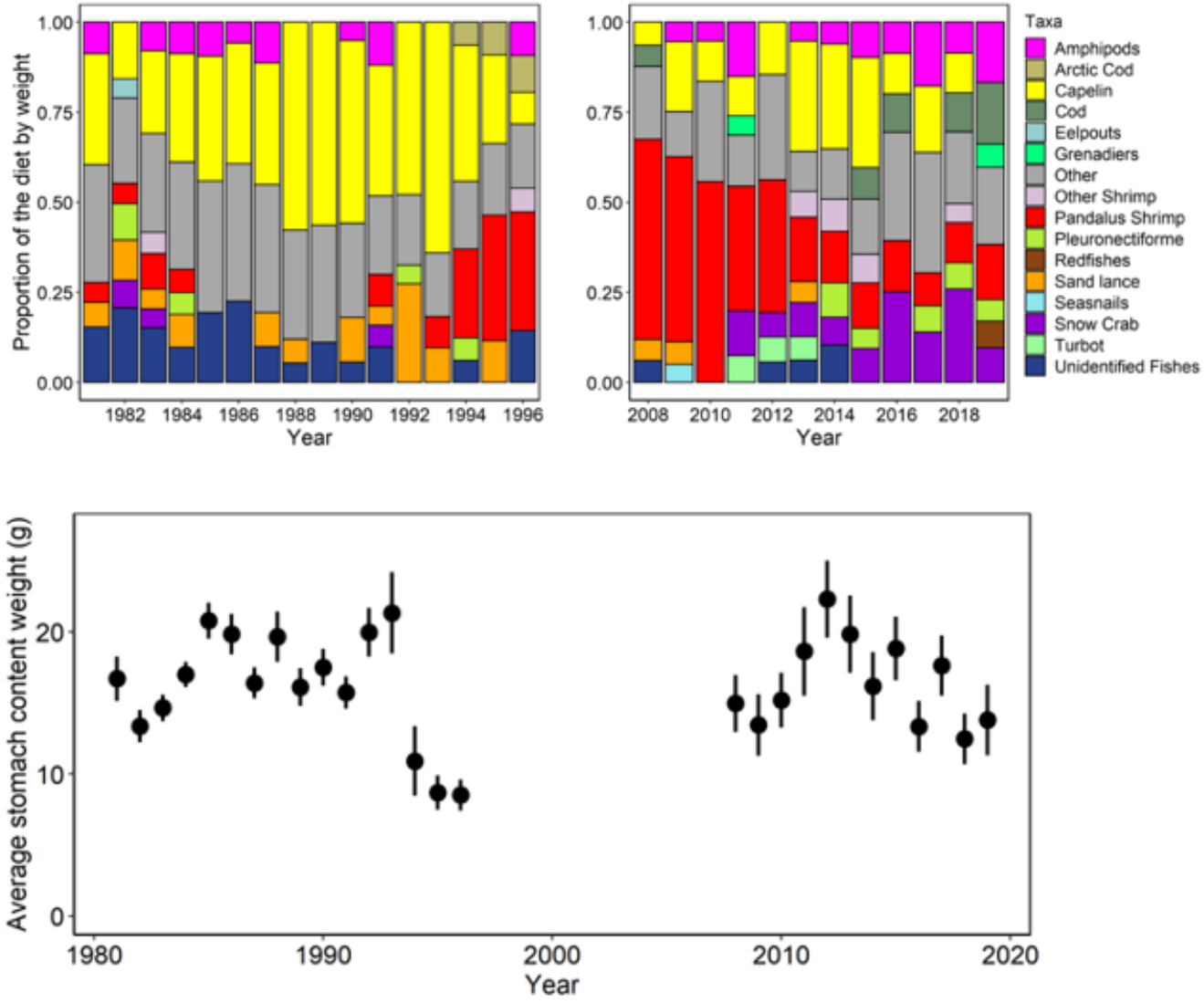

Figure 3: Food and feeding of Northern cod (Divs. 2J3KL). Top panel: Fall diet composition from stomach content analysis; Bottom panel: average stomach content weights (±95% CI) from non-empty stomachs of fish within the 30-55 cm size range.

The productivity of 2J3KL cod is associated with capelin availability (Buren et al. 2014). Capelin in this area collapsed in 1991 and have not recovered. The stock demonstrated some growth during the early 2010s to 2015, but has subsequently declined again. Capelin is forecasted to further decline in 2020 to levels comparable to those observed in 2017 (Figure 4) (DFO 2019 in

prep[1]). This reduction in capelin availability is expected to have negative impacts on the cod stock.

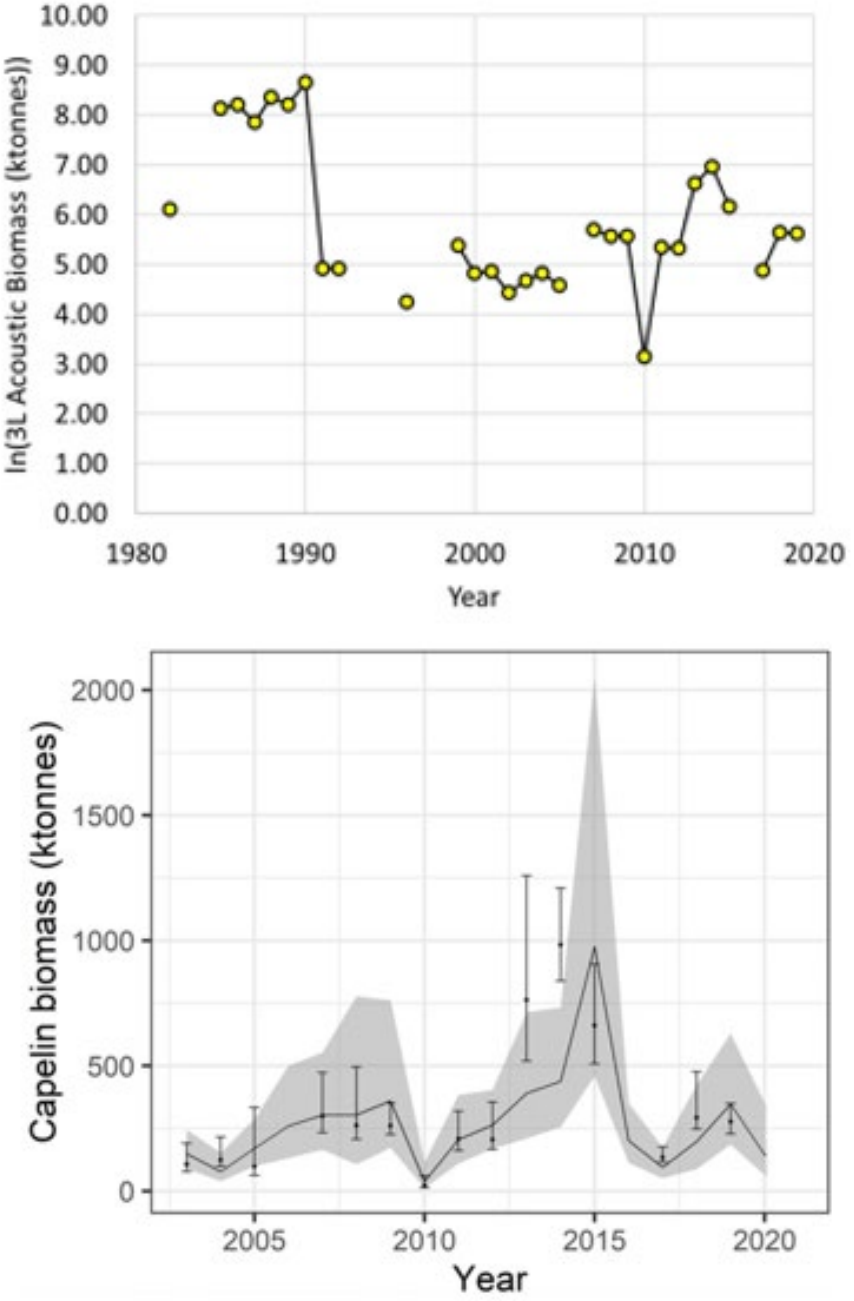

Figure 4: Capelin biomass from the DFO 3L acoustic survey (top panel) from 1981-2019 and capelin biomass estimated from the Capelin Forecast Model (bottom panel) from 2003-2020.

[1] DFO. In Prep. Assessment of 2J+3KL Capelin in 2020. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.

Fishery

Reported Landings

A stewardship fishery for cod and a recreational fishery for groundfish have been permitted in the inshore since 2006. Since 2016, commercial fishery removals have been regulated by weekly limits (lbs/week) by Division and time of year. Reported landings in 2019 were 10,559 tonnes (t), including 10,410 t in the stewardship fishery, 123 t in the sentinel surveys, and 2 t taken as by-catch. Catches outside the Canadian Exclusive Economic Zone (EEZ; 200 mile limit) during 2019 are not yet available, but have generally been <300 t during the past five years. The history of reported landings is summarized in Figure 5 and Appendix Table 1. Recreational landings are regulated by number of days and daily number of fish per person (5 per person, for a maximum of 15 fish per boat). Currently there is no requirement to report recreational landings. However, estimates from tagging data indicate that catches averaged over 2016-2019 were about 1,900 t annually (see below in Tagging Section).

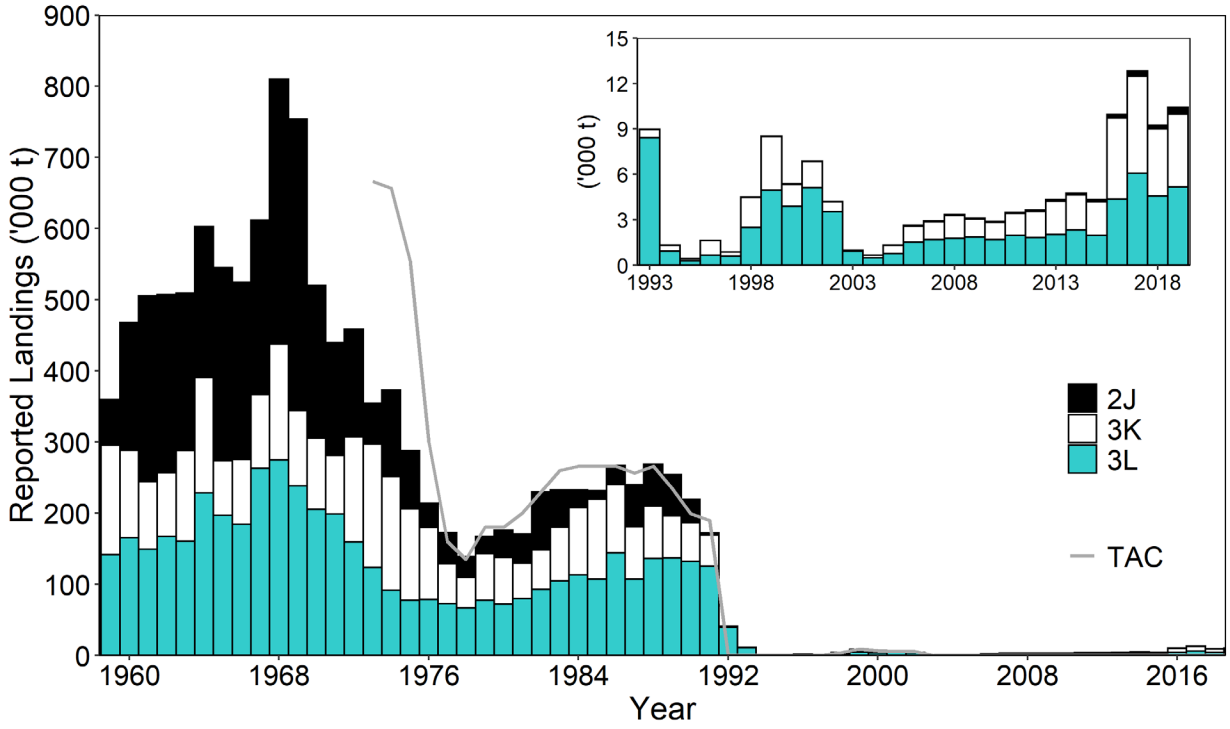

Figure 5: Reported landings (000 t) of cod in NAFO Divs. 2J3KL.

Stock Trends

Bottom-Trawl Surveys

The DFO fall Research Vessel (RV) bottom trawl surveys occur over the continental shelf and shelf edge and cover most of the stock area of Northern cod. Indexed strata (all strata <500m) in Divs. 2J3KL are used for the assessment of Northern cod. In 2019, weather impaired the survey so that a number of strata were not surveyed and the number of completed survey sets (i.e. sampled sites) was greatly reduced (346 planned sets versus 252 observed sets) (Figure

6). However, most incomplete strata were in deep water (>750m), deeper than the index strata used for this stock. Two index strata were not sampled in Div. 3K. These two missed strata are relatively unimportant to the total estimates for Northern cod (<1% on average). However, the precision of the current estimate is likely reduced by the decrease in set density in other strata.

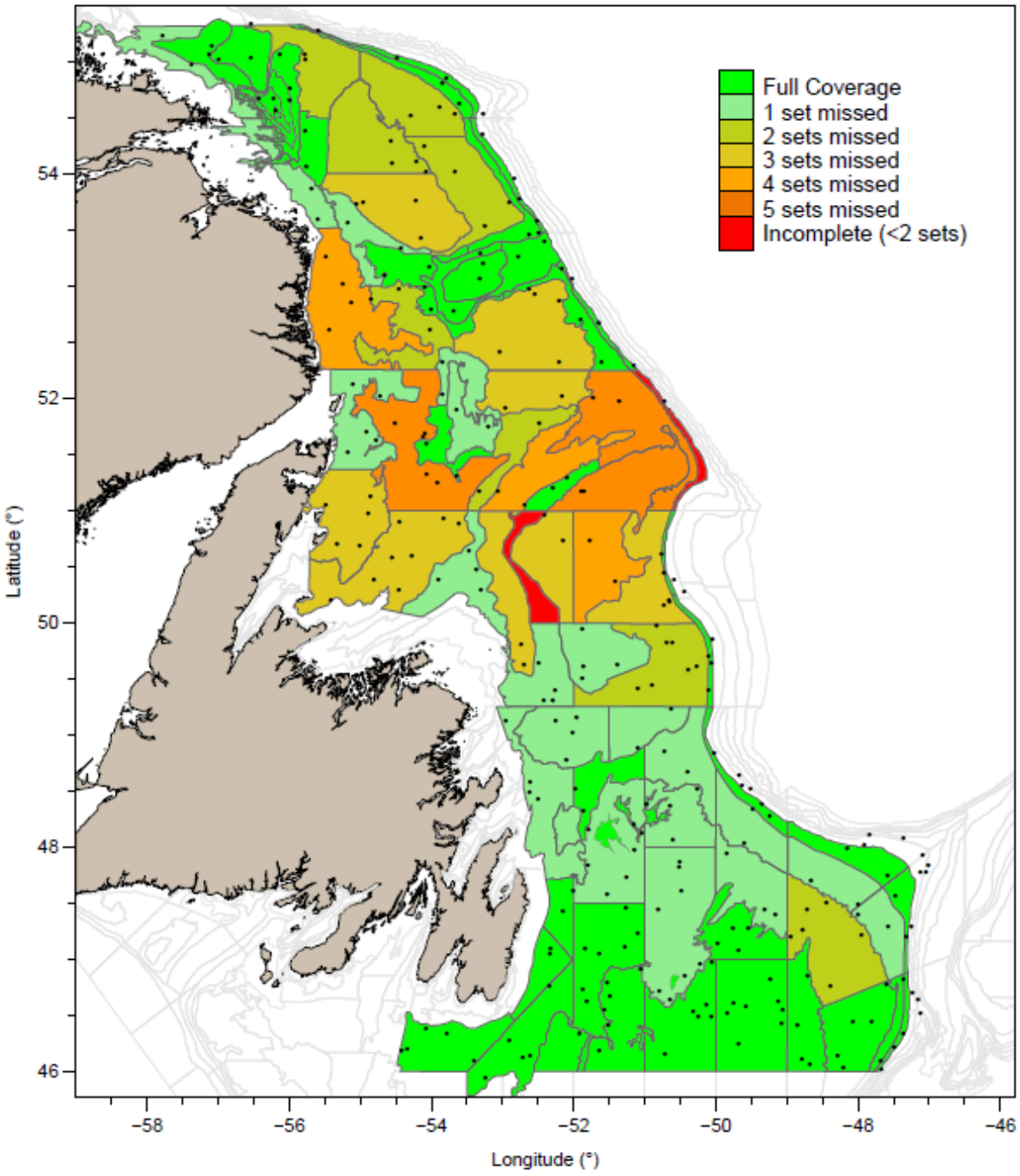

Figure 6: Survey coverage for the Northern cod index strata 2019 fall DFO RV surveys in Divs. 2J3KL. Survey strata (polygons on map) are colour-coded based on the number of intended fishing sets that were not completed. Symbols represent successful survey set locations.

The abundance and biomass indices from the DFO fall RV surveys have been low since the start of the moratorium in 1992 (Figures 7 and 8). The indices generally increased slightly during 2005-2009 and to a larger extent from 2012-2016. In general, abundance and biomass indices have leveled off since then, showing no apparent increase. The three-year averages (2017-2019) for both the total abundance and biomass indices are 29% of the average during the 1980s. Annual values for these indices are summarized (by NAFO Division) in Appendix Table 2.

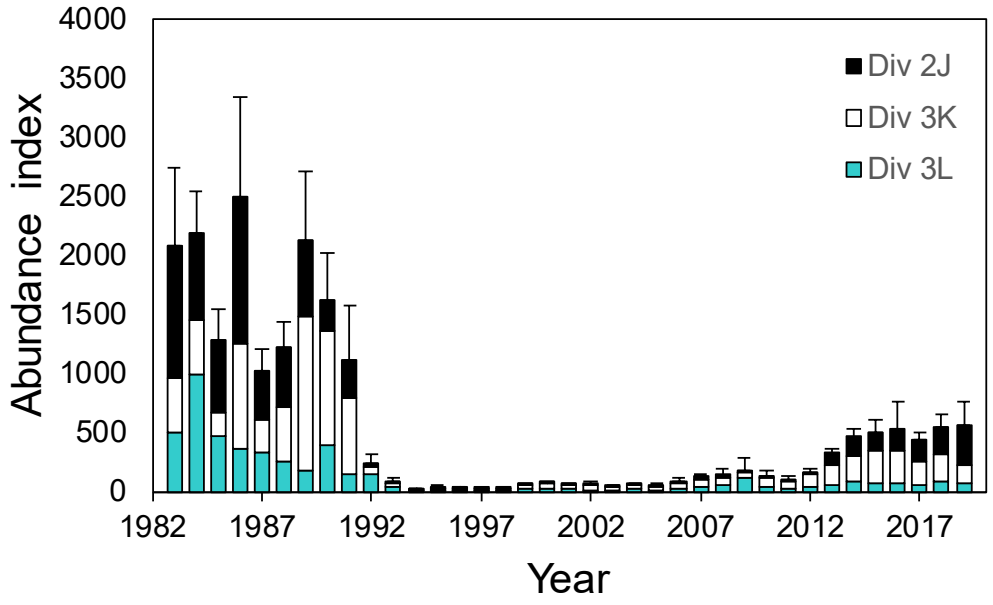

Figure 7: Offshore abundance index (+2 SEs) from fall RV surveys in Divs. 2J3KL.

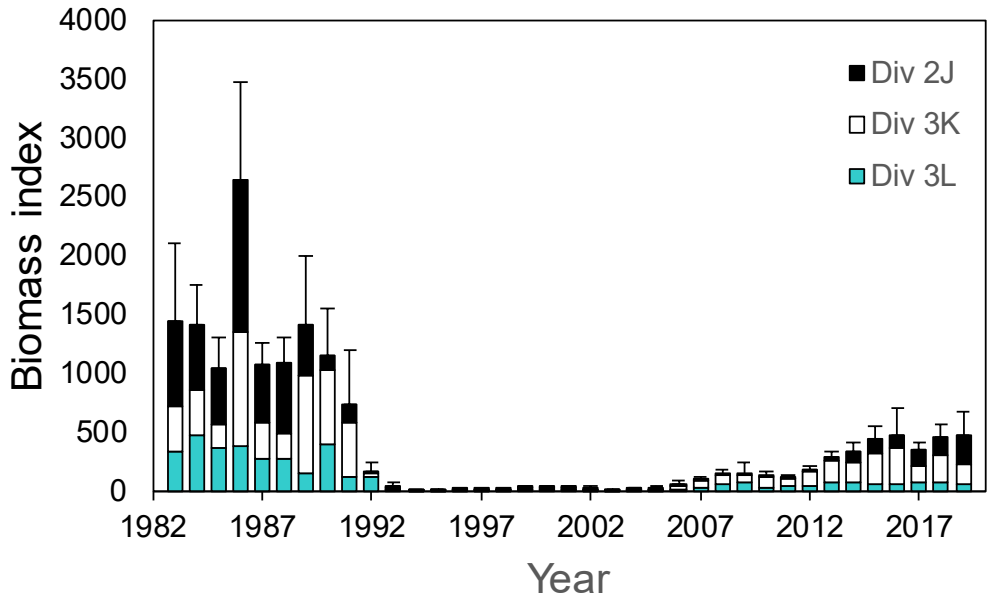

Figure 8: Offshore biomass index (+2 SEs) from fall RV surveys in Divs. 2J3KL.

In 2019, most of the abundance (60%) and biomass (52%) indices were located in the northern portion of the stock area (Divs. 2J). This higher than normal proportion in Div. 2J can be largely attributed to two large sets in Div. 2J in 2019 (Figure 9).

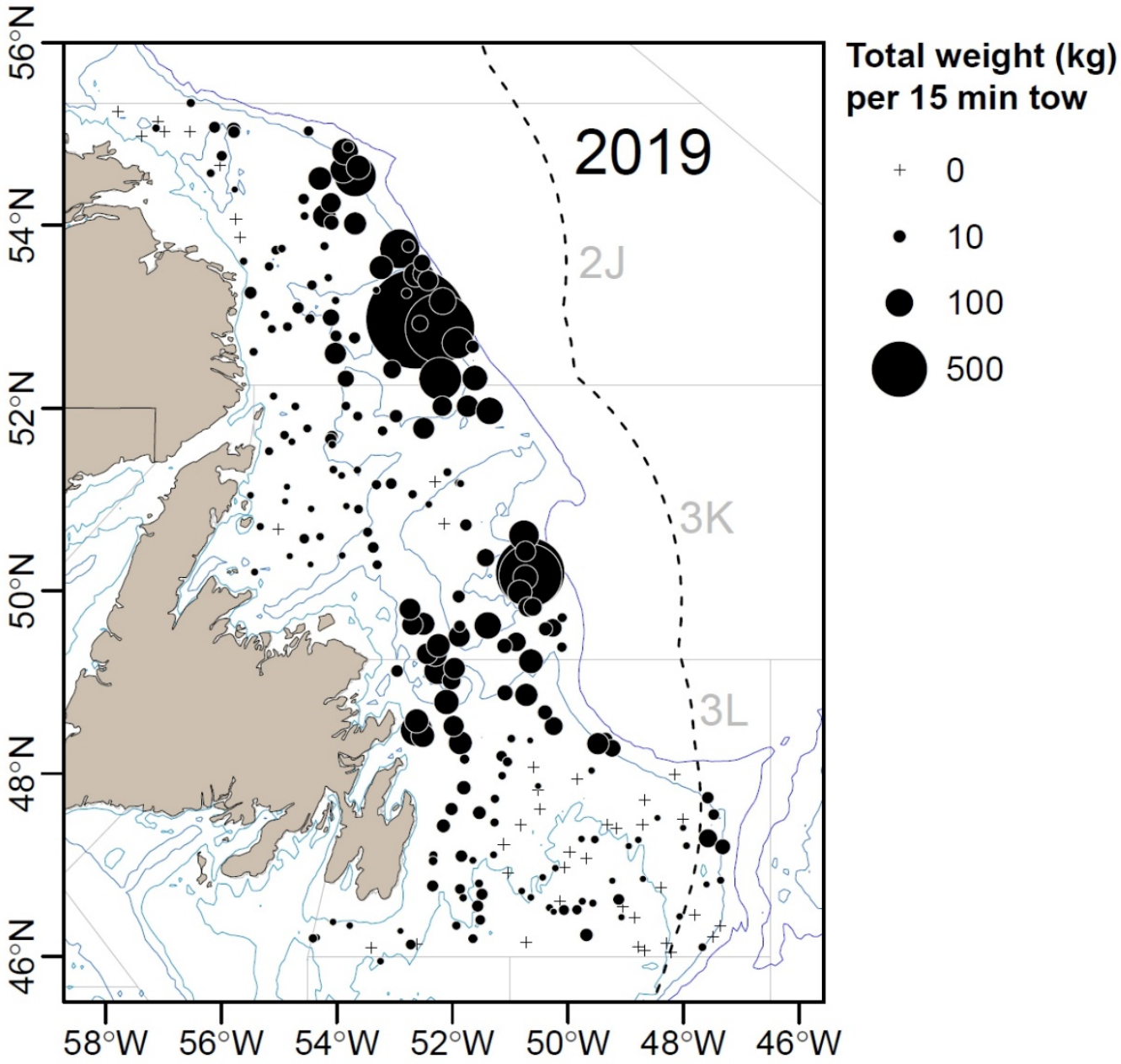

Figure 9: Distribution of Northern cod survey catch weight (kg per tow), by set, in Divs. 2J3KL for fall 2019.

Mean weight-at-age and length-at-age (not shown, but similar trend) for fish from the fall survey have declined since 2013 and both have been below average since 2017. Average deviation from mean weight and length for combined divisions for ages 3-7 have declined sharply since 2013 and are at the lowest in the time series in 2019 (Figure 10). Such reductions in growth are

consistent with poor foraging conditions and this decline coincides with the simultaneous decline in both shellfish and forage fish biomass.

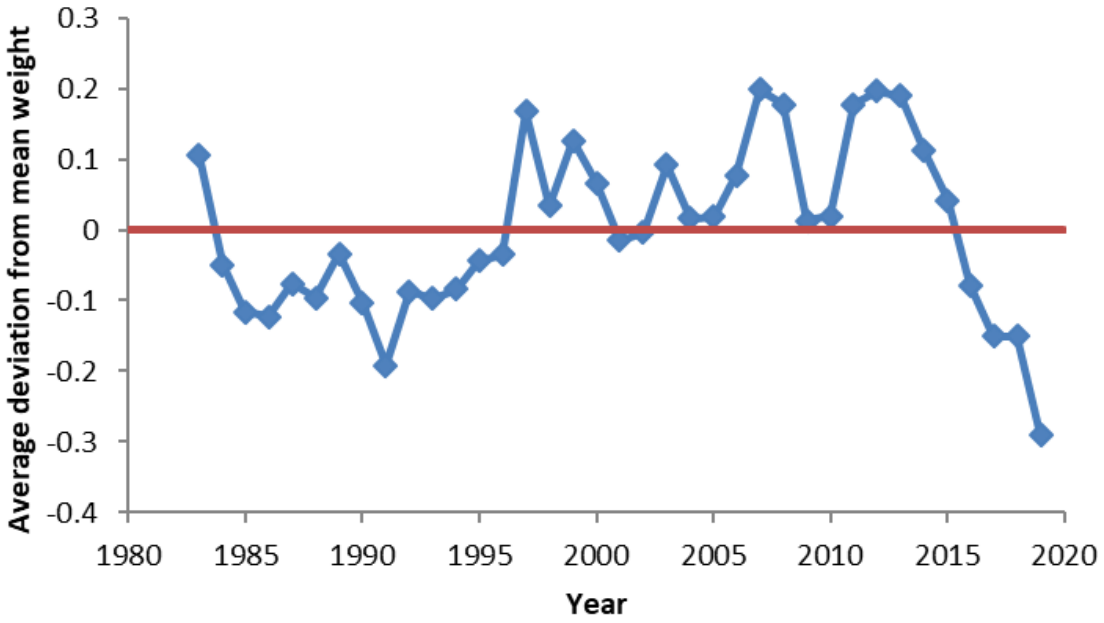

Figure 10: Deviation from mean weight-at-age for ages 3-7 combined from DFO bottom-trawl surveys from 1983-2019 in Divs. 2J3KL.

Sentinel Catch Rates – Inshore

Age-disaggregated analysis of sentinel catch rate data was carried out and combined into a total for Divs. 2J3KL (Mello in prep.[2]). Standardized catch rates for 5½ inch mesh gillnet (GN) increased from the early 2000s to 2014 but have since declined (Figure 11).

[2] Mello, L.G.S., Simpson, M.R., and D. Maddock Parsons. In Prep. Sentinel Surveys 1995-2018 – Catch rates and biological information on Atlantic Cod (*Gadus morhua*) in NAFO Divisions 2J3KL. DFO Can. Sci. Advis. Sec. Res. Doc. **DFO Working Paper.**

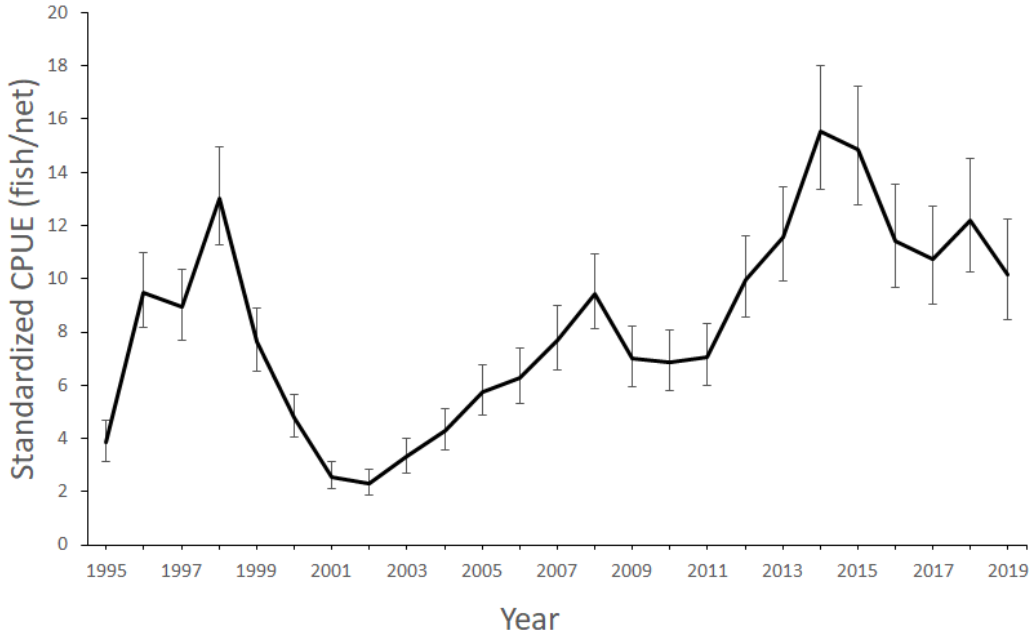

Figure 11: Trends in gillnet (5½ inch mesh) standardized mean catch rate indices from sentinel surveys for NAFO Divs. 2J3KL.

Tagging

Information from recaptures of cod tagged in various regions of Divs. 2J3KL was used to provide an estimate of the magnitude of removals from the recreational fishery. Assuming the ratio of returned tags from recreational and commercial fisheries reflects the relative size of those two catches, information on the commercial catch and the ratios of the two types of tag returns can be used to calculate the recreational catch. Tag returns are adjusted by annual estimates of reporting rates.

Recreational catch in Div. 2J3KL has ranged in the hundreds of tonnes to a few thousand tonnes in years with a recreational fishery (Figure 12). In the 1998-2002 period, catch ranged from 0.46 to 1.7 kilotonnes (kt), averaging 1.2 kt. Since 2008, recreational catch estimates range from 0.62 to 4.1 kt, averaging 1.8 kt. In spite of changes in the commercial catch over the 1997-2019 period, recreational catches generally ranged between 1 and 2 kt annually, with a few (four) years over 2 kt. The 2019 estimate of recreational catch was notably low at 0.62 ± 0.26 kt, potentially a reflection of the small number of tags returned by recreational fishers in 2019. This estimate may increase as 2019 tag captures continue to be reported.

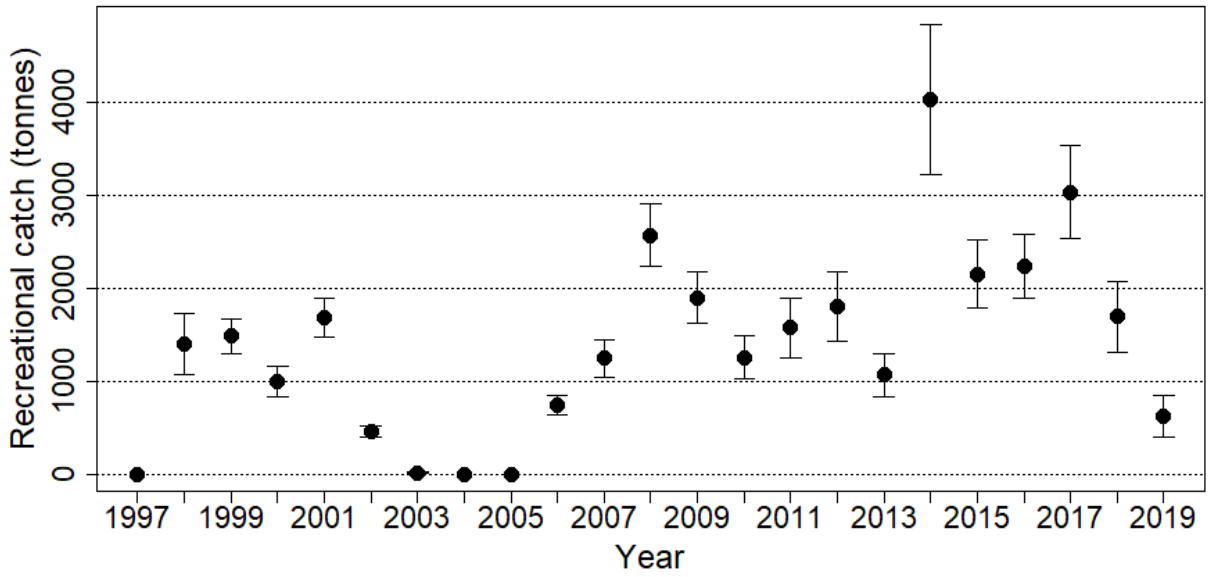

Figure 12: Estimated recreational (± 1 SE) catch in 2J3KL, using the ratio of tag returns from recreational and commercial fishers and total commercial catch.

Northern Cod Assessment Model (NCAM)

Assessments since 2016 have been based on an integrated state-space population dynamics model developed specifically for Northern cod known as the Northern Cod Assessment Model (NCAM). This model integrates much of the existing information about the productivity of the stock (Cadigan 2016 a and b). The model and associated projections were not run as part of this stock update. However, observed survey biomass in fall 2019 fell within the prediction intervals for age 2+ biomass from NCAM projections of RV survey biomass from the 2019 assessment (0.85 catch multiplier scenario, landings = 11,727 t comparable to the 2019 catch; from DFO 2019b) (Figure 13). This indicates that observed survey biomass falls in the range of expected values from NCAM from last year's assessment and the stock trajectory is in line with that projected in the last full assessment.

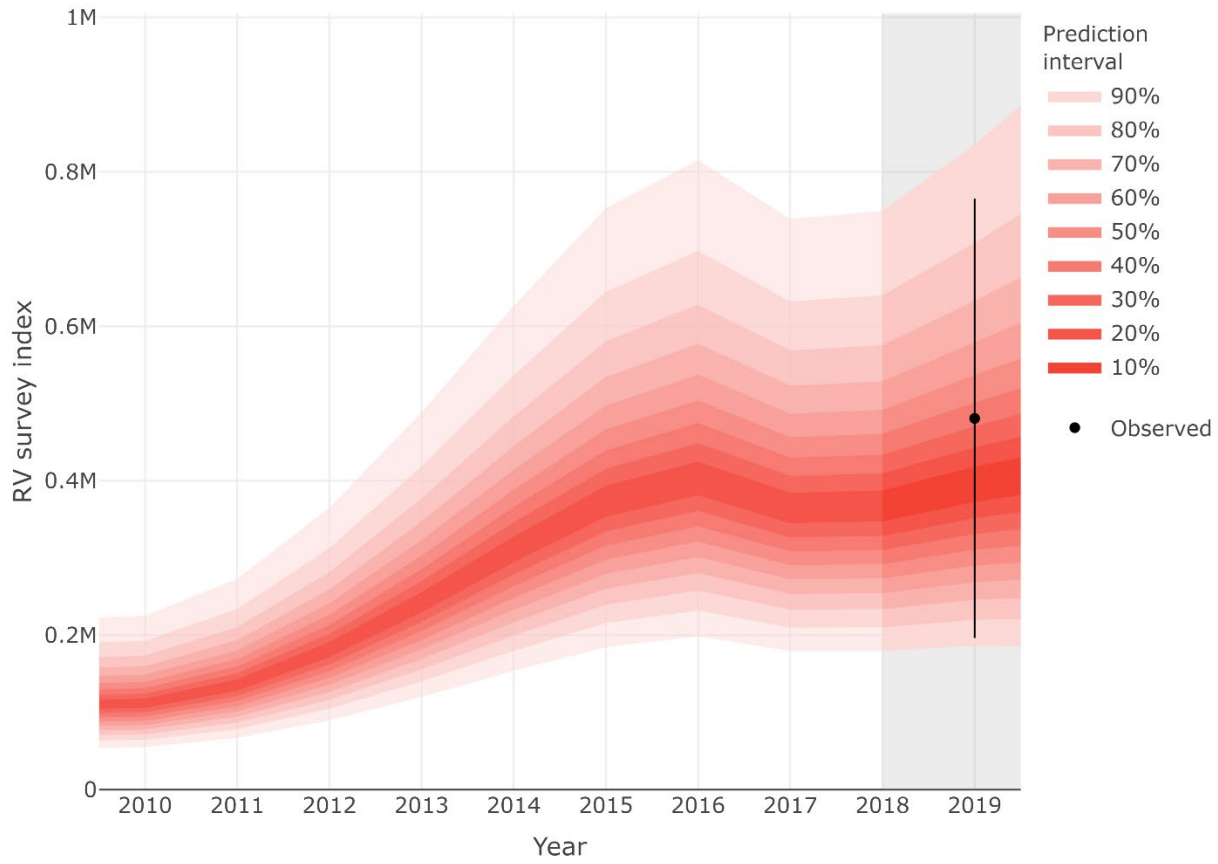

Figure 13: NCAM projected RV survey indices with prediction intervals (red envelope) from the 2019 stock assessment with observed RV biomass (black circles with 95% Confidence Intervals).

Sources of Uncertainty

Reduced RV survey density in 2019 likely increases uncertainty in biomass and abundance indices by reducing the precision of survey estimates. However, based on the distribution of catches in previous surveys the two strata that were completely missed are negligible and not considered to impact interpretation of stock status relative to the LRP.

The NCAM and associated projections were not run as part of this stock update. The projections from the previous (2019) full assessment suggested only very modest stock growth at catch levels similar to recent catch levels. It must be highlighted here that NCAM projections do not consider the ecosystem concerns that have been emphasized in this update and should therefore be treated with caution.

Conclusions

Ecosystem conditions in the Newfoundland Shelf and Northern Grand Bank (NAFO Divs. 2J3KL) are indicative of limited productivity of the fish community. Total RV ecosystem biomass level remains much lower than prior to the ecosystem collapse in the early-1990s.

Recent declines in average cod stomach content weights as well as reductions in capelin and shrimp in the diet, coupled with an apparent relative increase in cannibalism, point to a limitation

in food availability. With capelin forecasted to decline in 2020, cod productivity will likely be negatively impacted.

Mean weight-at-age and length-at-age for fish from the fall survey have declined since 2013 and are at their lowest in the time series in 2019. Such reductions in growth are consistent with poor foraging conditions.

Annual average removals from the commercial fishery were 11,000 t over 2016-2019 and removals from recreational catches were 1900 t (estimated from tagging data) over the same time period.

The fall 2019 observed RV cod survey biomass falls in the range of expected values based on projected values from NCAM from the March 2019 assessment. Therefore previous advice is valid and reiterated.

RV cod survey biomass indices increased between 2011-2016 and have subsequently leveled off, remaining low relative to the 1980s. Sentinel cod survey index increased from the early-2000s to 2014 but has since decreased.

Under current ecosystem conditions and recent levels of catch, the lack of increase in cod survey indices since 2016 suggests that stock growth may have stalled. Consistency with the DFO decision-making framework incorporating the precautionary approach requires that removals from all sources must be kept at the lowest possible level until the stock clears the critical zone.

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April 15, 2020

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Appendix

Table 1: Reported landings in NAFO Divs. 2J3KL by management year (nearest thousand metric tons).

Year	62-76 Avg.	77-91 Avg.	98	99	00/01	01/02	02/03	03/04	06/07 and 07/08[1,2]	08/09[1,2]	09/10 to 12/13[1,2]	13/14 to 15/16[1,2]	16[1,2]	17[1,2]	18[1,2]	19[1,2]
TAC	N/A	N/A	4	9	7	6	6	0	-	-	-	-	-	-	-	-
Can. Fixed	88	90	5	9	5	7	4	1	3	4	4	5	10	13	11	11
Can. Mobile	9	84	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Others	405	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Totals	502	212	5	9	5	7	4	1	3	4	4	5	10	13	11	11

[1] There is no TAC for this fishery. From 2006-2015 the fishery was managed through an IQ based system randing from 3,000-, 5,000 lbs.Since 2016, the fishery has been managed through weekly catch limits ranging from 2,000-7,000 lbs with an the introduction of a 28,000 lbs trip limit in 2019 for 2J harvesters.

[2] Does not include Canadian recreational fisheries landings or non-Canadian landings.

Table 2: Cod abundance and biomass indices from DFO fall RV surveys (1983 onwards).

-	2J Abundance	3K Abundance	3L Abundance	Total Abundance	2J Biomass	3K Biomass	3L Biomass	Total Biomass
Year	Index	Index	Index	Index	Index	Index	Index	Index
1983	1,124,316	468,804	495,838	2,088,958	722,492	384,498	336,789	1,443,779
1984	743,274	461,368	993,963	2,198,605	557,160	381,136	477,354	1,415,650
1985	615,282	208,953	464,125	1,288,360	472,147	209,685	368,519	1,050,351
1986	1,249,077	891,392	362,233	2,502,702	1,285,763	964,857	391,063	2,641,683
1987	410,570	284,540	325,352	1,020,462	491,599	303,036	284,229	1,078,864
1988	509,739	457,192	256,383	1,223,314	600,352	216,736	274,554	1,091,642
1989	647,594	1,307,523	172,300	2,127,417	425,387	830,045	160,687	1,416,119
1990	260,268	971,812	395,567	1,627,647	128,352	624,993	405,669	1,159,014
1991	323,637	649,349	144,684	1,117,670	150,136	467,502	121,759	739,397
1992	30,960	61,622	147,158	239,740	12,795	35,344	126,323	174,462
1993	16,989	36,907	36,813	90,709	5,129	14,227	24,596	43,952
1994	8,145	9,361	4,291	21,797	2,693	4,241	2,874	9,808
1995	12,305	23,200	7,735	43,240	2,312	4,578	5,115	12,005
1996	13,081	18,550	7,067	38,698	4,261	5,457	6,140	15,858
1997	6,936	8,428	9,859	25,223	3,609	3,978	8,991	16,578
1998	6,636	15,612	6,454	28,702	4,483	7,280	4,804	16,567
1999	6,074	29,308	25,281	60,663	2,527	12,230	13,611	28,368
2000	7,516	35,774	29,010	72,300	3,082	11,994	15,070	30,146
2001	7,033	28,535	27,724	63,292	2,646	9,890	18,706	31,242
2002	9,534	41,853	10,984	62,371	3,680	11,889	7,460	23,029
2003	9,315	19,908	13,638	42,861	3,065	4,912	4,849	12,826
2004	9,503	34,468	18,605	62,576	4,921	9,609	5,266	19,796
2005	18,519	33,834	8,780	61,133	5,719	16,696	5,118	27,533
2006	11,739	52,285	18,711	82,735	6,818	38,009	16,982	61,809
2007	26,656	54,122	47,249	128,027	8,755	58,427	35,722	102,904
2008	24,492	62,848	53,957	141,297	10,281	71,329	66,401	148,011
2009	15,250	47,949	111,782	174,981	6,473	51,106	85,410	142,989
2010	17,278	83,060	39,012	139,350	9,905	89,388	29,255	128,548
2011	17,937	59,233	29,204	106,374	8,542	71,541	41,615	121,698
2012	26,108	101,579	39,584	167,270	21,900	112,824	50,985	185,709
2013	97,136	170,174	58,344	325,654	37,986	181,106	78,927	298,019
2014	163,877	210,793	88,706	463,376	94,457	166,597	82,471	343,525
2015	154,411	281,296	64,706	500,413	120,154	256,608	70,820	447,581
2016	185,235	275,274	75,582	536,091	111,175	307,511	62,611	481,298
2017	181,998	194,664	61,043	437,705	132,400	144,518	72,993	349,910
2018	227,743	242,285	81,356	551,383	144,197	231,602	84,378	460,177
2019	338,767	162,861	65,339	566,968	254,767	169,670	56,302	480,739

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