



STOCK STATUS UPDATE OF UNIT 3 REDFISH

Context

A 10,000 tonnes (t) Total Allowable Catch (TAC) was implemented for Unit 3 Redfish (4X+4Wdehkl) in 1994 based on the 1991 TAC for the previous management unit (4VWX), prorated by historical (1981-1990) catches in the Statistical Unit Areas that comprise Unit 3 (Atkinson and Power 1991). This TAC was maintained from 1994-1998 based on conclusions from a series of stock status reports, which indicated that stock conditions were not expected to decline in coming years (Branton and Halliday 1994, Branton 1995, 1996, 1997, 1998). In 1999, the TAC was reduced to 9,000 t due to lower catch rates in 4W and a shift in fishing effort from 4W to 4X (Branton 1999), and has remained at this level ever since. Conservation measures for Unit 3 Redfish currently include protocols for protecting small fish below the minimum size of 22 cm fork length (FL) (i.e. closure areas; small fish amounts not to exceed 15% of catch/trip), 100% dockside monitoring and electronic Vessel Monitoring System (VMS), mandatory hail out and hail in, and a target level of 10-20% at-sea observer coverage.

Information on the status of Unit 3 Redfish (i.e. distribution, abundance, biomass) from 1999-2002 was provided through a series of Canadian Science Advisory Secretariat (CSAS) Research Documents, which included a synopsis of the Fisheries and Oceans Canada (DFO) Summer Research Vessel (RV) Survey trends back to 1970 for selected groundfish stocks (e.g. Branton and Black 2002). Since 2009, the status of Unit 3 Redfish has been updated based on Maritimes Region research vessel survey trends in biomass and abundance, in a series of CSAS Science Responses (e.g. DFO 2017a). Following the development of biological reference points consistent with the precautionary approach (DFO 2012), the DFO Summer RV Survey Trends Science Responses from 2014 to 2017 have included plots of the mature biomass index for redfish > 22 cm FL relative to the Upper Stock Reference (USR; 80% of Biomass at Maximum Sustainable Yield [B_{msy}] proxy) and the Limit Reference Point (LRP; 40% of B_{msy} proxy) (DFO 2017a). In 2015, a zonal peer review of the assessment framework for Units 1-3 Redfish (DFO 2017b) included a detailed review of Unit 3 Redfish stock status; however, this information has not yet been published, and there has been no new information available on the fishery for several years.

Resource management asked Science to review biological and fishery information on Unit 3 Redfish, to evaluate the current status of the stock relative to adopted reference points (DFO 2012), and report on bycatch of non-target species in the Unit 3 Redfish Fishery.

This Science Response Report results from the Science Response Process of December 6, 2018, on the Stock Status Update of Unit 3 Redfish.

Background

Biology

Redfish, known commercially as Ocean Perch, occur on both sides of the Atlantic Ocean. They are found along the slopes of fishing banks, in deep channels and off the edge of the continental shelf at depths ranging from 100-700 m. In the northwest Atlantic, Redfish range from Baffin

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Island in the north to the coast of New Jersey in the south. Two species of Redfish are found on the Scotian Shelf: Acadian Redfish (*Sebastes fasciatus*), which occur in the deep basins and at the edge of the continental shelf, and Deepwater Redfish (*Sebastes mentella*), which occur in deeper waters off the continental shelf and in the Laurentian Channel. These two species are difficult to distinguish visually and, as a result, both commercial and research survey catches are not separated.

Redfish are ovoviviparous as fertilization is internal and young are born live. Mating occurs in the fall (September-December) and females carry the developing young until release during spring and early summer (April-July). Larvae develop in surface waters and move to deeper waters as development progresses. Redfish are sexually dimorphic with females growing faster than males after Age 10. The average length at which 50% of redfish on Scotian Shelf are mature is 24-26 cm FL for females and 16-17 cm FL for males. They are slow growing (8-10 years to reach a size of 25 cm FL), long-lived, and characterized by a late age of sexual maturation (7-9 years to reach sexual maturity). This means that they are sensitive to overfishing and slow to recover from depletion (as evidenced by northern stocks). Recruitment success varies significantly, with long periods of low recruitment coupled with sporadic occurrences of strong year classes occurring at unpredictable and irregular intervals. Redfish are semi-pelagic and exhibit diel movement patterns rising off bottom at night to feed. Food consists primarily of pelagic crustaceans such as amphipods, copepods and euphausiids; fish become an important part of the diet as redfish increase in size.

Description of the Fishery

Redfish on the Scotian Shelf were historically managed as a Northwest Atlantic Fisheries Organization (NAFO) Division 4VWX stock. In response to a new understanding of stock structure (Atkinson and Power 1991), a new management area for Unit 3 Redfish was implemented in the 1993 Groundfish Management Plan, which consists of Statistical Unit Areas 4X and 4Wdehkl (Figure 1). Genetic research has shown that redfish in Unit 3 are almost exclusively *S. fasciatus* and belong to a separate stock from *S. fasciatus* in Unit 1 (Gulf of St. Lawrence/northern Laurentian Channel) and Unit 2 (southern Laurentian Channel/Western Grand Bank) (Morin et al. 2004). Unit 3 Redfish are also considered to be separate from the Gulf of Maine/Georges Bank stock.

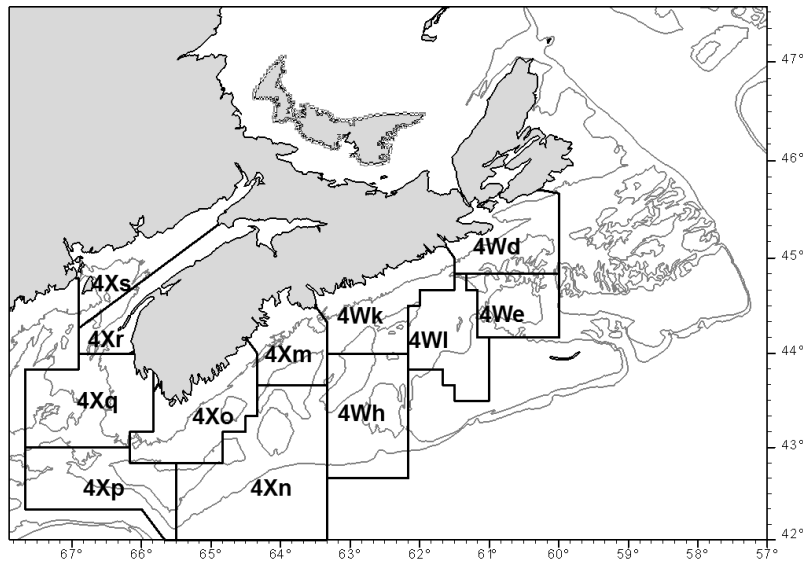


Figure 1. Unit 3 Redfish Management Area 4X+4Wdehkl.

Within the Unit 3 management area, the main geographic areas fished over the past 5 years include Crowell and Jordan basins (4Xpq), the Scotian Shelf slope (4Xn, 4Wh), the Sambro Bank area (4Xm, 4Wk), and the northern edge of La Have Basin (4Xm). In some years, fishing activity has also occurred on Browns and Baccaro banks, La Have Bank and in Emerald Basin. Redfish are fished primarily using bottom trawls with small mesh cod ends (110-115 mm diamond mesh) and are sold as fillets or used for lobster bait.

Two areas in 4X have been closed to small mesh gear due to persistent catches of undersized redfish, one in 4Xo (“Bowtie Closure”, implemented in 1995) and the other in 4Xmn (“Second Closure”, implemented in 2013). Redfish ≤ 22 cm FL are considered immature and there are restrictions on the proportion of these small fish in the landed catch per trip (i.e. no more than 15%).

Total landings of Unit 3 Redfish reached 18,000 t in the early 1970s when foreign fleets (mostly from the USA) fished on the Scotian Shelf (Table 1; Figure 2). Catches by foreign fleets declined after implementation of the 200 mile limit in 1977 and dropped off entirely by the early 1990s. Canadian landings have averaged 4,000 t since 1970, peaking at 9,000 in 1974 and more recently at 8,000 t in 2012. During the 1970s, landings were dominated by catches in 4W, but after 1980 they shifted to 4X, which has accounted for about 86% of landings from 1980 to 2018. Within 4X, there was a shift in landings from 4Xmno to 4Xpq in the late 1990s, probably to reduce capture of small fish. The TAC has been 9,000 t since 2000; landings have not exceeded this amount and were 4,571 t in 2017 and as of December 14th are currently at 3,587 t (Fishing Year Landings for 2018/2019 = 3,405 t). Quarter 2 accounts for most landings (47%), followed by quarter 3 (28%), quarter 4 (14%) and quarter 1 (11%).

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Table 1. Total reported Canadian and foreign landings (metric tonnes) of Unit 3 Redfish from 1970-2018. Ten-year annual average landings represent 1970 to 2009. Dash (-) = not applicable.

| | Year(s) | Canada | | USA | | USSR | Other | Total | TAC | FY ¹ |
|-----------------|-------------------|--------|---------|------|---------|------|-------|-------|------|-----------------|
| | | 4X | 4Wdehkl | 4X | 4Wdehkl | | | | | |
| Decadal Average | 1970-79 | 2042 | 2036 | 2966 | 2254 | 394 | 92 | - | - | - |
| Decadal Average | 1980-89 | 3229 | 1175 | 510 | 0 | 1.8 | 2.3 | - | - | - |
| Decadal Average | 1990-99 | 3932 | 393 | 5 | 0 | 26 | 28 | - | - | - |
| Decadal Average | 2000-09 | 3595 | 100 | 0 | 0 | 0 | 3 | - | - | - |
| Annual | 2010 | 4807 | 608 | 0 | 0 | 0 | 0 | 5415 | 9000 | 5246 |
| Annual | 2011 | 6052 | 685 | 0 | 0 | 0 | 0 | 6736 | 9000 | 7268 |
| Annual | 2012 | 7245 | 562 | 0 | 0 | 0 | 0 | 7807 | 9000 | 6510 |
| Annual | 2013 | 2914 | 1108 | 0 | 0 | 0 | 0 | 4022 | 9000 | 4240 |
| Annual | 2014 | 2524 | 1356 | 0 | 0 | 0 | 0 | 3880 | 9000 | 3579 |
| Annual | 2015 | 2591 | 593 | 0 | 0 | 0 | 0 | 3184 | 9000 | 3516 |
| Annual | 2016 | 3767 | 384 | 0 | 0 | 0 | 0 | 4151 | 9000 | 3948 |
| Annual | 2017 | 4173 | 398 | 0 | 0 | 0 | 0 | 4571 | 9000 | 4533 |
| Annual | 2018 ² | 3390 | 197 | 0 | 0 | 0 | 0 | 3587 | 9000 | 3405 |

¹ Fishing Year Landings (April 1st - March 31st)

² Landings for 2018 are preliminary, from the Maritimes Fisheries Information System (MARFIS) as of December 14th.

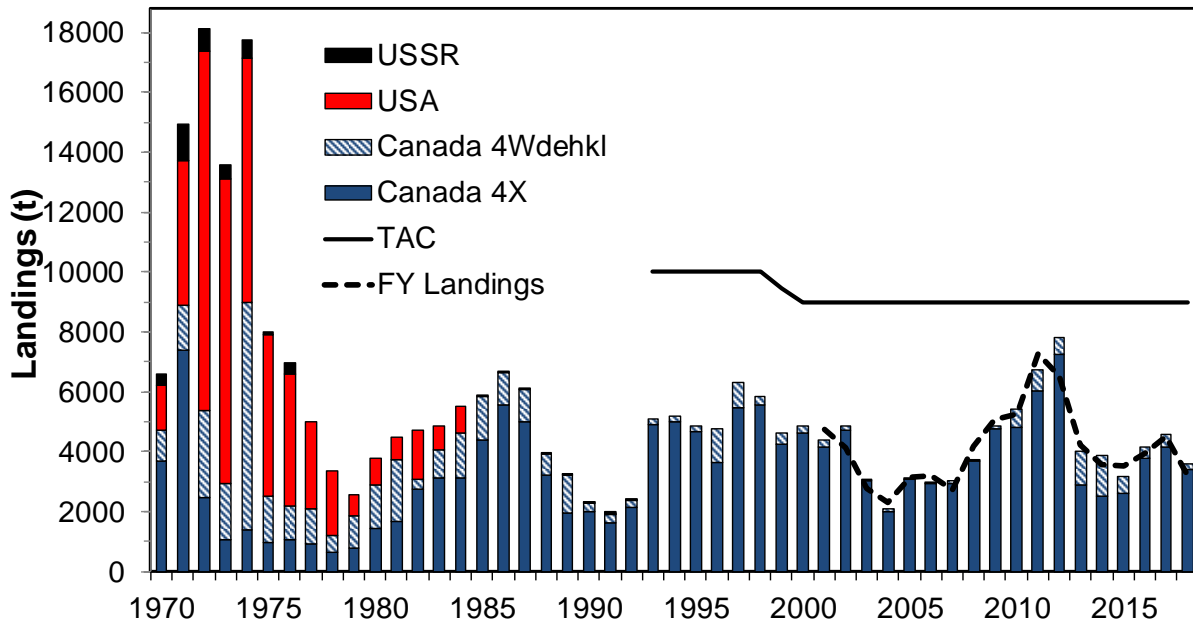


Figure 2. Unit 3 (4X+4Wdehkl) Redfish landings (metric tonnes) from 1970-2018 (histograms = calendar year; dashed black line = fishing Year). The solid black line is the Canadian Total Allowable Catch (TAC).

Assessment Framework

While no formal modelling approach has been developed to determine stock status, empirically determined reference points have been calculated for Unit 3 Redfish using DFO Summer RV Survey data for mature biomass (> 22 cm FL) (DFO 2012). A proxy for B_{msy} (73,000 t) was calculated as the survey mean mature biomass from 1970-2010. Forty percent (40%) of the

B_{msy} proxy was presented as the LRP (29,000 t) and 80% as the USR (58,000 t). The mature biomass index from the DFO Summer RV Survey (smoothed using 5-year arithmetic moving average) is used to determine current stock biomass in relation to biological reference points. In addition, a target Removal Reference (RR=0.068) was proposed based on the maximum Relative Fishing Mortality (Relative F) that would not result in a reduction in population biomass. This value, also known as the replacement ratio, was determined using an “index based” assessment methodology (NEFSC 2002) using a 3-year smoothed moving average for the DFO Summer RV Survey mature biomass index based on data for 1970-2010 (DFO 2012). The RR was updated to include data from 1970-2018 for comparison with the original value.

Analysis and Response

DFO Summer Research Vessel Survey

A stratified-random bottom trawl survey of the Scotian Shelf/Bay of Fundy has been conducted in July and August since 1970 and, with the exception of 2018, has provided complete coverage of the entire Unit 3 stock area (defined as strata 456, 458-495 in Branton and Halliday 1994). Reduced coverage in 2018 represented about 75% of the Unit 3 survey area (i.e. strata 460, 461, 465 and 470-495 were sampled). Mature redfish biomass was calculated using stratified total abundance at size (for lengths > 22 cm FL) and the length-weight relationship for combined sexes calculated using length and weight data from 1992-2017 (time period for electronic balances).

Total and mature biomass declined from the late 1970s to the early 1990s, was low but variable through to the mid-2000s, then increased to higher levels from 2007-2016 (Figure 3, upper panel). Much of the total biomass in 2008-2009 (44-55%) and 2011-2012 (36-40%) was comprised of immature fish (≤ 22 cm FL), which may indicate earlier periods of strong recruitment.

Not all strata in 4W were sampled during the 2018 DFO Summer RV Survey; therefore, the biomass index time series for 1970-2018 was recalculated using only the strata covered in the 2018 survey (460, 461, 465, 470-495) (Figure 3, lower panel). Since most of the Unit 3 Redfish biomass occurs in the NAFO Area 4X (Strata 470-495), the trajectories for total and mature biomass indices are almost identical for all of the Unit 3 strata compared to the strata sampled in 2018. Including the 2018 survey results indicates that total and mature biomass has declined since 2016 and is currently at a level comparable to the 1990s.

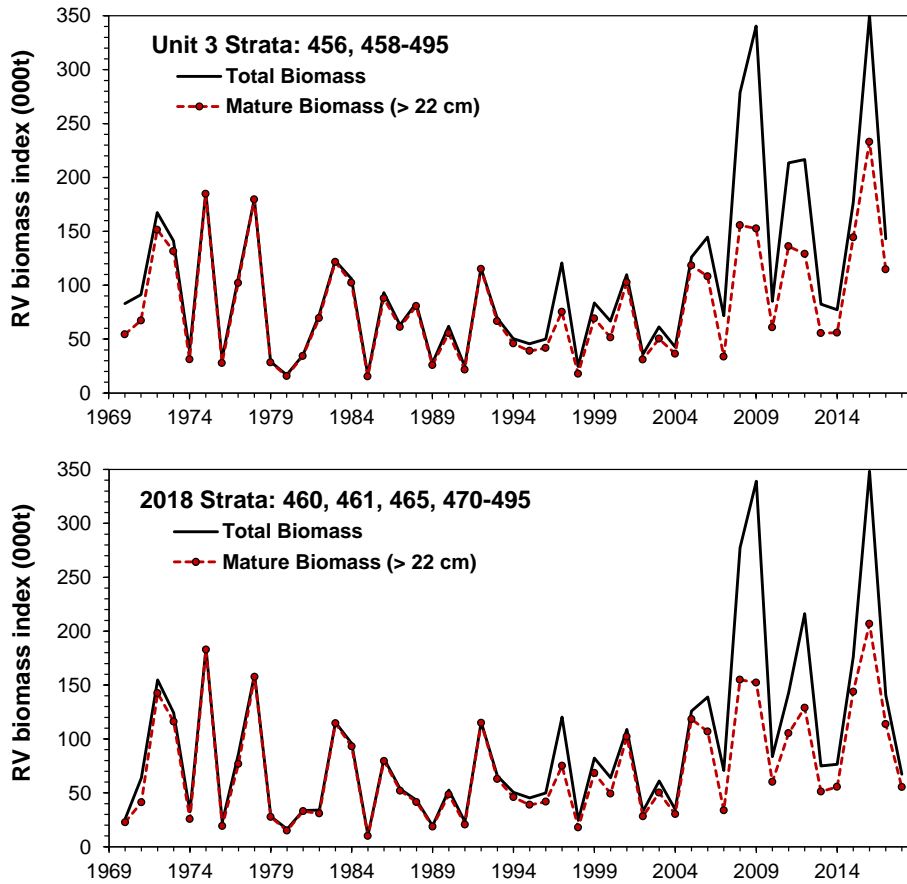


Figure 3. The DFO Summer RV survey total biomass and mature (> 22 cm FL) biomass indices ($t \times 10^3$) for Unit 3 Redfish Strata (456, 458-495) from 1970-2017 (top panel), and recalculated using only the strata sampled in 2018 (460, 461, 465, 470-495) for 1970-2018.

There was a decline in the DFO Summer RV Survey total abundance at length from 2017 to 2018 (Figure 4). The short-term median abundance index (2007-2016) was higher than the long-term median abundance index (1970-2016) but peaked at smaller size (i.e. 22 cm versus 25 cm FL), indicating higher abundance of smaller fish during the short-term period. The 2018 abundance at length was higher for most sizes compared to long term-median but was below the short-term median for sizes < 26 mm FL, reflecting the recent drop in abundance.

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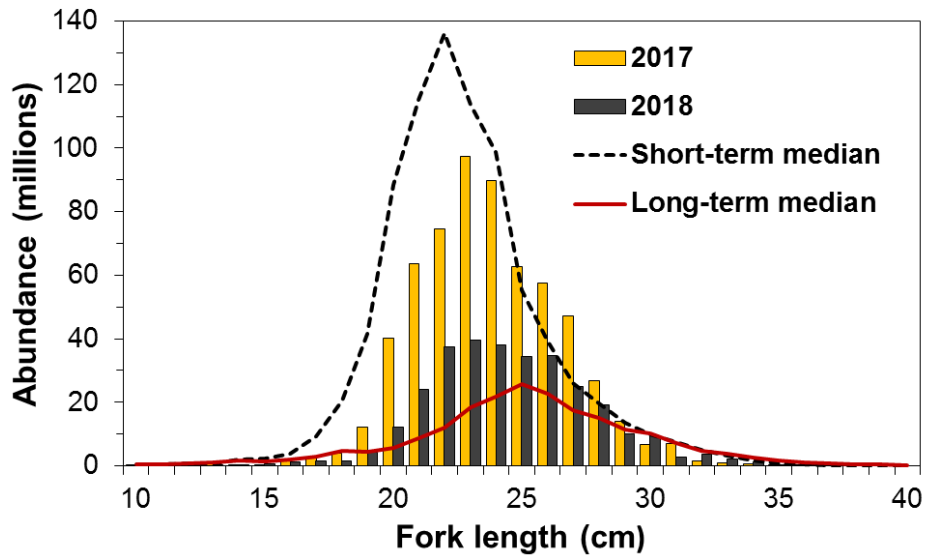


Figure 4. Length frequency indices for Unit 3 Redfish from DFO Summer RV surveys, 1970-2018. Black bars represent the numbers in millions at length from the 2018 survey; yellow bars represent numbers in millions at length from the 2017 survey. The red line represents the long term median abundance at length (1970-2016) and the dashed black line is the short-term median abundance at length (2007-2016).

Condition

Fulton’s K (weight/length³) was calculated separately for males 23-40 cm FL and females 23-45 cm FL. During the 1970s and 1980s, K was higher for both sexes, but because spring balances were used during this period it is not clear how precise this data is (Figure 5). For 1992-2018 (the time period for electronic balances), K has generally been above or below the 1992-2018 average for males, but it has shown a declining trend since 2009 for females. The reason for this is unclear, but warmer water temperatures in recent years may result in more spawning before the survey takes place. Similar declines in condition have been observed for other Scotian Shelf species such as Silver Hake (Stone et al. 2013), Pollock (Stone 2010) and Haddock (Stone and Hanson 2014).

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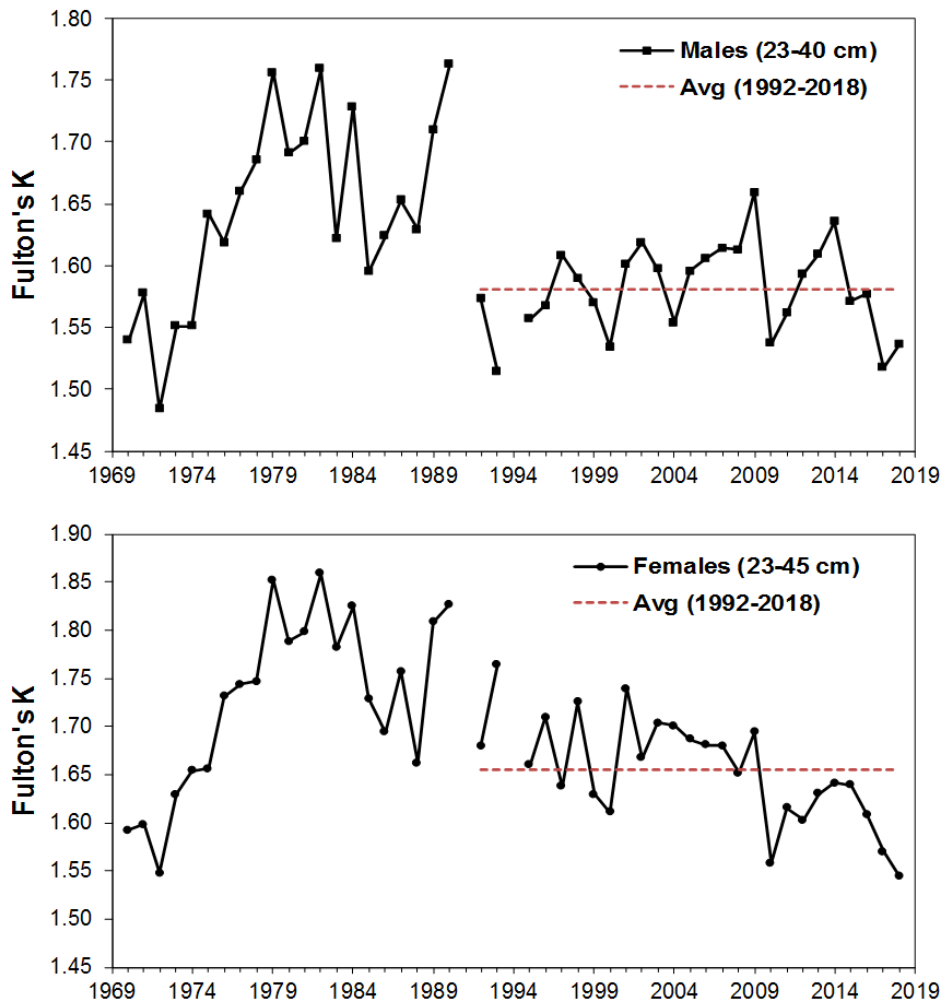


Figure 5. Fulton's Condition factor ($\text{weight(g)/length(cm)}^3$) for male (23-40 cm FL; upper panel) and female (23-45 cm FL; lower panel) redfish from DFO Summer RV Survey length and weight data for 1970-2018.

Fishery Average Size and Percent ≤ 22 cm FL

The average size of redfish (weighted mean length calculated from the fishery catch at size) declined from the mid-1970s to the late 2000s but has been increasing since 2011 (Figure 6). The percentage of small fish in the catch exceeded the 15% tolerance level from 1990-2002 and more recently from 2007-2014. Implementation of the "Second Closure" area (4Xmn) in 2013 may have helped to reduce the catch of small redfish (≤ 22 cm FL) in recent years, leading to an increase in average size since 2011 along with growth of cohorts in the fishery.

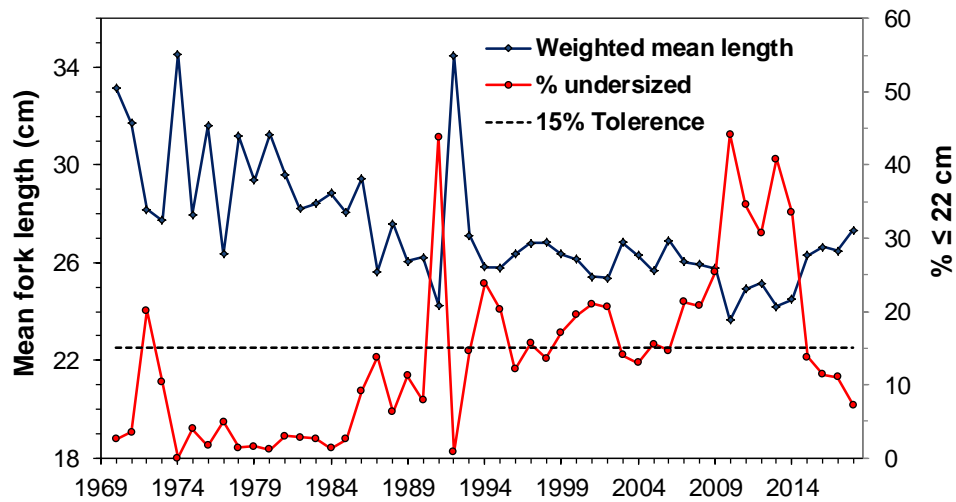


Figure 6. Weighted mean length (cm) of Redfish from the commercial fishery catch at size and percentage of catch at size ≤ 22 cm FL for 1970-2018. The dashed line indicates the 15% tolerance level.

Reported Landings of Redfish and Bycatch Species

The 4X component of the Unit 3 management unit is more of a mixed species fishery than 4W, so bycatch landings are presented separately for both areas (Figure 7). Bycatch landings for 2009-2018 from the MARFIS commercial landings database averaged 23% of total landed catch in the 4X fishery compared to 10% in 4W. The most common landed bycatch species in 4X is Pollock (9%), followed by Haddock (7%), White Hake (3%) and Atlantic Cod (1%). Pollock is also the main bycatch in 4Wdehkl but at a lower level (6%), followed by Monkfish (2%), non-specified skates (1%) and White Hake (1%).

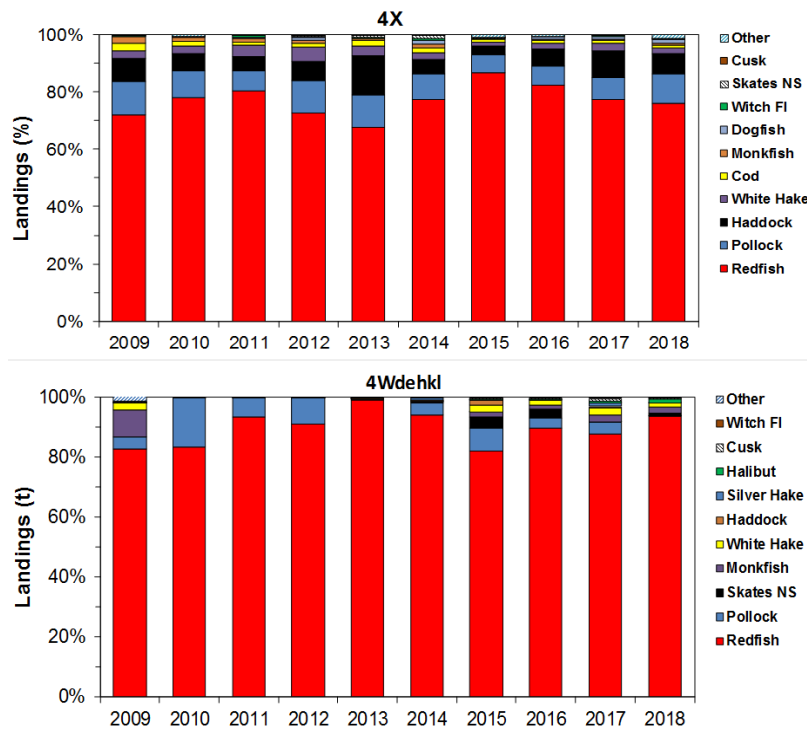


Figure 7. Percentage of landings by species from the Unit 3 Redfish fisheries in 4X (upper panel) and 4Wdehkl (lower panel), 2009-2018.

Observer Coverage and Bycatch

Estimates of at-sea observer coverage levels for the redfish fishery use data from the Observer Program Database and the MARFIS Commercial Landings Database for mobile gear with 110-115 mm diamond mesh cod ends (89% of total landings). On average, about 7% of Redfish landings and trips have been observed over the past 5 years (Table 2). With the exception of 2015, coverage has been below the 10-20% target level proposed by Resource Management.

Table 2. Percent observer coverage (observed redfish catch/total redfish landings; observed redfish trips/total redfish trips) for the directed mobile gear redfish fishery in Unit 3, 2014-2018.

| Year | Total Landings (t) | Total Trips | Observed Redfish Catch (t) | Observed Redfish Trips | Observed Redfish Land (%) | Observed Redfish Trips (%) |
|------------------------|--------------------|-------------|----------------------------|------------------------|---------------------------|----------------------------|
| 2014 | 3312.6 | 133 | 91.8 | 3 | 2.8 | 2.3 |
| 2015 | 2832.8 | 106 | 302.8 | 12 | 10.7 | 11.3 |
| 2016 | 3534.9 | 165 | 207.9 | 10 | 5.9 | 6.1 |
| 2017 | 3775.7 | 214 | 342.7 | 20 | 9.1 | 9.3 |
| 2018 | 2927.5 | 144 | 120.7 | 7 | 4.1 | 4.9 |
| Avg (2015-2018) | | | | | 6.5 | 6.8 |

Observer data from 2000-2018 (342 trips in 4X and 72 trips in 4Wdehkl) indicates that 92% and 97% of the total observed catch (kept + discarded) from Unit 3 Redfish trips is retained in 4X and 4Wdehkl, respectively. At-sea observers recorded similar proportions of retained bycatch as reported in the commercial landings database. Redfish (75%), Pollock (9%), Haddock (4%),

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White Hake (2%) and Atlantic Cod (1%) are reported as the main species retained in 4X compared to Redfish (82%), Pollock (10%) and Haddock (2%) in 4Wdehkl. Total discard amounts are low and represent 8% of observed catches in 4X and 3% in 4Wdehkl for 2000-2018. Discarded species in 4X include Spiny Dogfish (6%), American Lobster (0.4%) and Basking Shark (0.1%), and in 4Wdehkl include small Redfish (0.7%), Spiny Dogfish (0.6%), small Pollock (0.5%) and Barndoor Skate (0.4%).

Harvest Control Rule

The smoothed (5-year moving average) mature biomass index from the DFO Summer RV Survey is used to determine the current stock biomass in relation to biological reference points. Management Strategies for Unit 3 Redfish outlined in the 2017 Groundfish Integrated Fisheries Management Plan (IFMP) for the Maritimes Region indicate that a TAC may be set to achieve a maximum 9% exploitation rate based on the index when it is above the USR. When mature biomass is below the LRP, the TAC is reduced so that the exploitation rate does not exceed 3% of the index.

Since not all Unit 3 strata in 4W were sampled during the 2018 DFO Summer RV Survey, the mature biomass index time series for 1970-2017 was calculated for all of the Unit 3 strata (456, 458-495) and then recalculated for the entire time series (1970-2018) using only the strata covered in the 2018 survey (460, 461, 465, 470-495) (Figure 8). Both smoothed mature biomass indices have similar trajectories and have never fallen below the LRP. The stock has been above the USR (58,000 t) since 2004 and above B_{msy} (73,000 t) since 2007, and it is currently in the Healthy Zone.

Relative F is calculated as Fishery Landings/DFO Summer RV Survey mature biomass index (smoothed with 3-year moving average) (Figure 9). The highest values occurred in early-1970s, mid-1980s and late-1990s when landings were high relative to the mature biomass index. With increasing mature biomass, Relative F has been at or below the 1970-2010 RR (0.068) since 2003 and was estimated at 0.027 for 2017 and 0.024 for 2018, indicating that current exploitation is low. When the RR is recalculated using landings and the mature biomass index updated for the entire DFO Summer RV Survey time series (1970-2018), RR=0.056 and Relative F has been below this level since 2012.

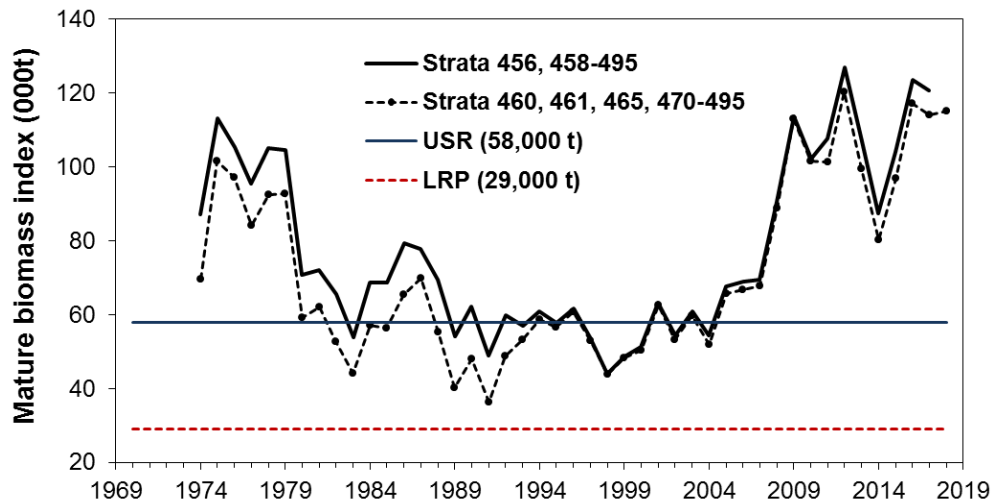


Figure 8. Mature biomass index (5-year smoothed moving average) calculated for Unit 3 Redfish strata (456, 458-495; 1970-2017) and a reduced number of strata covered in 2018 (460, 461, 470-495; 1970-2018). Solid blue line = Upper Stock Reference (58,000 t). Dashed red line = Limit Reference Point (28,000 t).

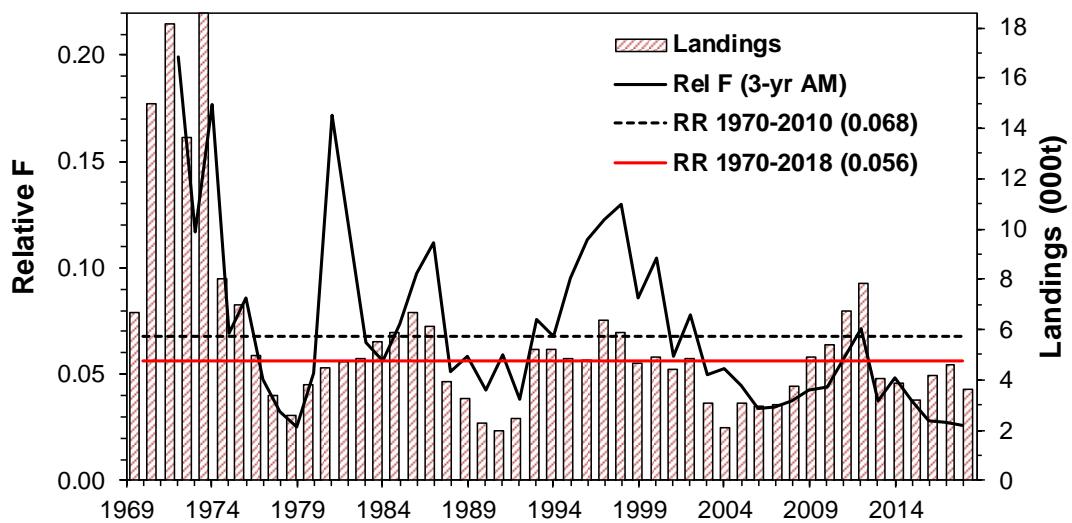


Figure 9. Relative Fishing Mortality (Fishery Landings/Survey Mature Biomass Index with 3-year smooth; black line) and total landings (000 t; red histograms) for Unit 3 Redfish, 1970-2018. The Removal Reference (RR) calculated using the index method is shown for 1970-2010 (dashed black line) and 1970-2018 (solid red line).

Conclusions

The TAC for Unit 3 Redfish has been 9,000 t since 2000 and total landings have generally been less than half this amount over the past 18 years. The average size of redfish in the fishery catch at length has been increasing since 2011 and the percentage of immature fish (≤ 22 cm FL) in the catch at length has declined to $< 15\%$ over the past four years.

The 4X component of the Unit 3 management unit is more of a mixed species fishery than 4Wdehkl, with bycatch landings for 2009-2018 averaging 23% of total landed catch in 4X

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compared to 10% in 4Wdehkl. Pollock is the most commonly landed bycatch species in both areas. About 7% of redfish landings and trips have been observed over the past 5 years, with observers recording similar proportions of retained bycatch as reported in the commercial landings database. Discard amounts are low and estimated to be 8% of total observed catches in 4X and 3% in 4Wdehkl for 2000-2018. The main discarded species are Spiny Dogfish, American Lobster, Basking Shark and Barndoor Skate, all at low levels.

Although mechanical problems with the survey vessel in 2018 led to incomplete coverage of Unit 3 strata for the first time since 1970, the mature biomass index calculated for the entire time series (1970-2018) based on reduced Unit 3 strata coverage in 2018 indicates that the index has never fallen below the LRP and that the stock has been above the USR since 2004. Relative F has been below the 1970-2010 RR (0.068) since 2002 and the updated 1970-2018 RR (0.056) since 2012. In 2017 and 2018, Relative F is estimated to be 0.027 and 0.024, respectively, indicating that the current exploitation rate is low. The status of Unit 3 Redfish is determined solely by the mature biomass index generated from the DFO Summer RV Survey and requires complete annual coverage of the Unit 3 stock area strata in order to be reliable.

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