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Assessment of St. Mary's Bay Longhorn Sculpin (*Myoxocephalus octodecemspinosus*), 1999–2019

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Foreword

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

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ABSTRACT

A directed fishery for Longhorn Sculpin in St. Mary's Bay began in 1999 and has continued through to 2019, with the exception of 2007 and 2008 when the fishery was closed. Four license holders are permitted to direct for Longhorn Sculpin using otter trawls with 90–100 mm diamond mesh cod ends. The fishery occurs over a 6-week period during April and May, and the Sculpin catch is sold for Lobster bait. Longhorn Sculpin landings from St. Mary's Bay peaked at 235 t and 229 t in 2011 and 2012, but declined to 29 t in 2019. At the same time, landings of Winter Flounder bycatch increased from 1% of total landings in 2011 (3 t) to 58% in 2019 (51 t) and currently exceed those of Longhorn Sculpin. The average size of Longhorn Sculpin and percentage > 23 cm (size at 50% maturity) in fishery catches has been below the long-term average since 2015. At-sea-observer coverage levels for the 2009–2019 directed Longhorn Sculpin fishery averaged 15% of landings and trips per year, which is lower than the earlier period of the fishery (1999–2006). Crustaceans represent 74% of all discarded bycatch (1999–2019 average) and include American Lobster (46%), Jonah Crab (16%), and Rock Crab (12%). Since 2015, there has been an increase in the percentage of Winter Flounder discards, which represent 40% of all discards in 2018 and 2019. The overall spatial distribution of Longhorn Sculpin from the DFO Summer Research Vessel (RV) Survey does not appear to have changed; however, there has been a notable decrease in survey catches on the Eastern Scotian Shelf and the outer Bay of Fundy since 2000. Biomass indices for DFO Summer RV Survey strata in 4X and stratum 490 (adjacent to St. Mary's Bay) have been below the long-term mean (1970–2019) since 2010. The average size of Longhorn Sculpin and percentage > 23 cm in survey catches show a declining trend in 4X strata and stratum 490 from 1970–2019, but the decline is steeper for stratum 490, especially since 2000. The directed Longhorn Sculpin fishery Catch Per Unit Effort (CPUE) index shows a pattern of “fishing up” and “fishing down” the stock before and after the 2007–2008 closure. The median of the CPUE time series was used as a proxy for Biomass at Maximum Sustainable Yield (B_{MSY}). A Limit Reference Point (LRP) was calculated as 40% of B_{MSY} . The 3-year median CPUE was used for determining stock status. CPUE declined rapidly to levels approaching 40% of the time series median (LRP proxy) in 2006 and 2019, in close proximity to the Cautious/Critical Zone boundary. In-season exploitation was above 30% in 2006 and from 2009–2015 and potentially as high as 75–76% in 2011 and 2012, when landings were highest. At the same time, catch rates of Winter Flounder increased steadily since 2009, but it is unclear if this was due to an increase in Winter Flounder abundance or to targeting of this species by the directed Longhorn Sculpin fishery license holders. The current prognosis for the Sculpin fishery in St. Mary's Bay appears to be poor and this species has clearly undergone periods of localized depletion at a time when the overall population biomass appears to be lower than average.

INTRODUCTION

A directed fishery for Longhorn Sculpin (*Myoxocephalus octodecemspinosus*) in St. Mary's Bay began in 1999 and has continued through to 2019, with the exception of 2007 and 2008 when the directed fishery was closed (Figure 1). Four license holders are permitted to direct for Longhorn Sculpin using otter trawls with 90–100 mm diamond mesh cod ends deployed by “Generalist” mobile gear vessels under 65 feet in length. Small mesh gear is used in this fishery to reduce entanglement damage to American Lobster bycatch. The fishery occurs over a 6 week period in April and May during daylight hours (0600–1800), and the Sculpin catch is sold for Lobster bait.

There have been no annual Total Allowable Catches (TACs) established for this fishery. Conservation measures include 100% dockside monitoring, mandatory hail out/hail in, and a target observer coverage level of 25%. The main bycatch species include American Lobster, most of which are released alive, and Winter Flounder, which can be retained and landed.

A previous stock assessment was completed in July 2008 (DFO 2008, Comeau et al. 2009). The assessment evaluated the impact of the directed fishery on Sculpin and Lobster populations within the bay, as well as on the benthic habitat over which the directed fishery occurs (Comeau et al. 2009). The main conclusions from the assessment were:

- Sculpin catch rates declined during the first years of the 1999–2006 directed fishery then stabilized at low levels,
- The abundance of larger (> 23 cm) Sculpin declined during this period, as well as the size of Sculpin in the adjacent Fisheries and Oceans Canada (DFO) Research Vessel (RV) Survey stratum (490),
- Within season exploitation rates were considered to be high (> 30%) but insufficient information was available at the time to determine what level would be sustainable,
- The most abundant bycatch species caught were American Lobster, Winter Flounder, crabs, and Sea Raven,
- While Lobster bycatch was high, all animals were released and less than 1% were reported as damaged or dead; however, there was a poor understanding of any sub-lethal effects on Lobsters after they were released,
- The habitat over which the directed Sculpin fishery occurred was considered to be highly energetic and of low bottom complexity; the impact of the Sculpin fishery on the sea floor was expected to be low.

Industry participants in the directed St. Mary's Bay Sculpin fishery have recently expressed concern about the sustainability of this fishery and the decreasing size of Sculpin in their catches. Consequently, DFO Resource Management asked DFO Science to review all information available for evaluating the sustainability of this fishery, including commercial fishery and RV survey size composition, commercial fishery catch rates, in-season exploitation rates, bycatch of non-target species, and the identification of indices for future monitoring.

LONGHORN SCULPIN BIOLOGY

The Longhorn Sculpin is a bottom dwelling fish found in coastal waters of the western North Atlantic ranging from the Strait of Belle Isle, Newfoundland, south to the coast of northern Virginia (Collette and Klein-MacPhee 2002). Off Nova Scotia, they are found on Banquereau and Sable Island Bank and are also common throughout the Bay of Fundy and St. Mary's Bay. Their preferred depth range on the Scotian Shelf is < 90 m (Scott 1982), but they have been

found at depths of up to 192 m (Collette and Klein-MacPhee 2002). They can also undertake seasonal movements, occupying shallow coastal waters in summer and deeper waters offshore during winter.

Longhorn Sculpin can reach a length of 46 cm; however, they rarely grow larger than 35 cm (Scott and Scott 1988). Little work has been conducted on the age and growth of this species with the exception of a study based on otoliths from Longhorn Sculpin collected in southern New England waters (Morrow 1951). This work suggested that sculpin were 5.5 cm at Age 1, 18 cm at Age 2, 21 cm at Age 3, 25 cm at Age 4, 27 cm at Age 5, and 30 cm at Age 6.

In southern New England, spawning occurs during winter months (November–January) in inshore areas (Collette and Klein-MacPhee 2002); however, the exact timing of spawning is uncertain for St. Mary’s Bay. Spawning occurs inshore on rocky bottoms (Scott and Scott 1988) where the average female deposits approximately 8,000 eggs (Collette and Klein-MacPhee 2002). The eggs are demersal, adhesive, and deposited in clusters on sponges or cavities on hard bottom (Scott and Scott 1988). The size of Longhorn Sculpin at 50% maturity in the Maritimes area of the northwest Atlantic is reported to be 23 cm for females and 24 cm for males (Beacham 1982), which roughly corresponds to ages 3–4.

Longhorn Sculpin are opportunistic feeders and consume fish (Haddock, Sand Lance), shrimp, and crabs. Predators include Atlantic Cod, Spiny Dogfish, Little Skate, Winter Skate, Sea Raven, Monkfish, White Hake, and other sculpins. Other attributes of Longhorn Sculpin biology are provided in Comeau et al. (2009).

COMMERCIAL FISHERY

SCULPIN LANDINGS

Sculpin landings first appear in the Maritimes regional landing statistics in 1990, likely as a result of the implementation of the Dockside Monitoring Program (Table 1; Figure 2). The Northwest Atlantic Fisheries Organization (NAFO) Division 4X accounts for 98% of total reported landings from 1990–2019, with the remaining 2% from Divisions 4VW, 5Y, and 5ZE. Total landings were < 50 t/year in 4VWX5 up to 1998 when Sculpin were reported as bycatch in other fisheries. Landings increased in 1999, when the directed Longhorn Sculpin fishery began in St. Mary’s Bay (Figure 2). The period of highest landings in 4VWX5 occurred from 2009–2016 when reported catches ranged from 260–434 t (Table 1).

Sculpin landings by gear type (bottom trawl, gillnet, longline, and trap) in 4VWX5 for 2002–2019 are summarized in Table 3. The majority of landings (94% of 2002–2019 total) are from bottom trawl fisheries (average = 234 t/yr for 2002–2019) followed by groundfish gillnet (4% of total; average = 8 t/yr for 2002–2019). Over 98% of Sculpin bottom trawl and gillnet landings were from 4X. Incidental Sculpin catches have also been reported from 4X groundfish longline fisheries, but the amounts were small (< 1% of total; average = 1 t/yr for 2002–2019). In 2018 and 2019, incidental Longhorn Sculpin landings were reported for Lobster trap fisheries in 4X (2018: 9 t; 2019: 29 t) and 4W (2019: 9 t).

Reported landings and positional data from the Maritimes Region Commercial Landings Database (MARFIS) were examined to illustrate the spatial distribution of Sculpin catches in 4X bottom trawl and gillnet fisheries over the past four years (2016–2019) (Figure 3). For bottom trawl, the main areas of Sculpin catches included St. Mary’s Bay (4Xr), the outer Bay of Fundy (4Xrs), the inner Bay of Fundy (4Xr), north of Browns Bank (4Xo), and in the western Gulf of Maine (4Xq) (Figure 3). Sculpin landings from outside St. Mary’s Bay were likely bycatch from Haddock or Winter Flounder directed fisheries. Reported landings from 4X5Y gillnet fisheries occurred in the outer reaches of St. Mary’s (4Xr) Bay and St. Margaret’s Bay (4Xm), as well as

on German Bank (4Xq) (Figure 4). Incidental catches for longline fisheries in 4X were not plotted since amounts were so small. Also, no positional information was available for the incidental catches from Lobster trap fisheries so these could not be plotted.

Sculpin landings from the directed fishery in St. Mary's Bay for 2002–2019 were extracted from MARFIS for the four license holders permitted to direct for Longhorn Sculpin in April and May within a defined rectangle of latitude and longitude (i.e., > 44°19' N and < 44°30' N; > 66°00' W and < 66°20' W). This was done because the commercial landings database does not differentiate between Sculpin landings from directed or bycatch fisheries. Landings for 1999–2001 were available from the Observer Program Database (ISDB) when coverage was 100%.

Sculpin landings from the directed fishery averaged 94 t/year from 1999–2006 (63% of 4X landings) and 143 t/year from 2009–2019 (44% of 4X landings) (Table 1; Figure 2). Although there was no directed fishery in 2007 and 2008, Sculpin bycatch landings in 4X were 141 t and 147 t, respectively. Landings from the directed fishery peaked at 235 t and 229 t in 2011 and 2012, but they have been steadily declining since 2014, with greater contributions from outside of St. Mary's Bay in unit areas 4Xoqrs as bycatch in other fisheries (Table 2). In 2019, reported landings from the directed fishery were 29 t, the lowest amount reported for the 1999–2006 and 2009–2019 time series; however, only three of the four licensed vessels were fishing in 2019.

LANDINGS OF BYCATCH SPECIES

Several bycatch species are landed from the directed Longhorn Sculpin fishery in St. Mary's Bay and have been reported in the MARFIS Commercial Landings Database from 2002–2019 (Table 4). Since 2011, Winter Flounder landings increased steadily and exceeded Sculpin landings in 2019 (i.e., 51 t of Winter Flounder compared to 29 t of Longhorn Sculpin). Other landed species included skates (< 1.0 t – 5.0 t), Haddock (< 1.0 t – 3.6 t), and Halibut (< 1.0 t). Winter Flounder bycatch increased from 1% of total landings in 2011 to 58% in 2019 (Figure 5). It is unclear if this reflects a change in fishing patterns with more targeting of Winter Flounder or an increase in Winter Flounder abundance. Skate landings had similar trend increasing from 1% of total landings in 2014 to 6% in 2019.

FISHERY CATCH-AT-SIZE, WEIGHTED MEAN LENGTH AND PERCENTAGE < 23 CM

The directed Longhorn Sculpin fishery catch-at-size was calculated using annual length frequency samples obtained from at-sea observers. These were expanded to the fishery level using annual commercial landings and a length-weight relationship for Longhorn Sculpin derived from DFO Summer RV Survey length and weight measurements (i.e., weight (kg) = $a \cdot \text{Length}(\text{cm})^b$; where $a = 0.00000732$ and $b = 3.105$).

The catch-at-size in numbers was calculated for the early (1999–2006; Table 5) and recent (2009–2019; Table 6) time periods of the fishery and then converted to percentage-at-size to allow for comparisons between years (Figure 6). This analysis revealed a recruitment pulse of small fish in 2005 (mean = 11 cm Total Length), many of which were retained by the small mesh gear, as well as smaller modal sizes in 2016–2019 (< 24 cm) compared to earlier years (≥ 24 cm).

The average size of Longhorn Sculpin (weighted mean length calculated from the annual fishery catch-at-size) declined during the early (1999–2006) and more recent (2009–2019) period of the fishery, with annual means falling below the time series mean of 24.2 cm in 2005 and from 2016–2019 (Figure 7). In 2005, the weighted mean length was influenced by a recruitment pulse of small Sculpin (mean = 11 cm total length), which reduced the overall mean to 21 cm.

The percentage of Longhorn Sculpin > 23 cm (size at 50% maturity) in the fishery catch-at-size declined from 80% to 60% during the early years of fishery (1999–2006) (Figure 7). Only 36% of the catch was > 23 cm when the fishery resumed in 2009, then increased to 60–85% from 2011–2015 (Figure 7). Since 2015, the percentage of Longhorn Sculpin > 23 cm has been below the time series mean of 62%, averaging 45% for 2016–2019.

OBSERVER COVERAGE, ESTIMATED KEPT AND DISCARDED CATCH

Estimates of at-sea observer coverage levels for the St. Mary's Bay Longhorn Sculpin directed fishery uses data from the Observer Program database (ISDB) and the MARFIS database. Percent at-sea observer coverage was calculated as: observed catch (t)/total catch (t) and observed trips/total trips. Coverage from 1999–2001 was 100% of trips and landings; from 2002–2006, coverage ranged from 30–70%, and from 2009–2019 coverage declined to 10–19% of trips and landings (2009–2019 average = 15%) (Table 7), less than the target coverage level of 25%.

A discard:kept ratio estimator was used to estimate the kept and discarded catch (t) from the St. Mary's Bay Longhorn Sculpin fishery. The ratio estimator was used to calculate the total kept and discarded amounts for the fishery (i.e., expanded to total landings) for years when observer coverage was < 100% (i.e., 2002–2006 and 2009–2019).

Similar to MARFIS landings, Winter Flounder is the primary kept species after Longhorn Sculpin and represent an increasing amount of total kept catch since 2011, followed by Sea Raven, skates (Little, Winter, Thorny), and Atlantic Halibut (Table 8; Figure 8, upper panel). Sea Raven is recognized by at-sea observers as a separate species; however, this species is not separated in the MARFIS database and is included in the "Sculpin" category along with grubbies and Shorthorn Sculpin (approximately 3% kept sculpin catch). No adjustments to the landings data were made to account for this in this assessment.

Over 90 species were reported by at-sea observers as discards from the St. Mary's Bay Longhorn Sculpin fishery. The pro-rated discard amounts by year (1999–2019) for the main discarded species are summarized in Table 9 and Figure 8 (lower panel). Crustaceans represent most of the discarded bycatch and include American Lobster (average = 23 t/yr), Jonah Crab (average = 13 t/yr), and Rock Crab (average = 7 t/yr). Winter Flounder discards averaged 6 t/yr but increased to 33 t and 29 t in 2018 and 2019, respectively, which represent 40% of all discards for these years. Additional discarded species include sturgeon (2.5 t/yr), skates (1.8 t/yr), Ocean Pout (1 t/yr), and Windowpane Flounder (1 t/yr).

SCULPIN BYCATCH IN OTHER FISHERIES

Longhorn Sculpin occurs as bycatch in other fisheries in NAFO Divisions 4X and 5Y. The main fisheries examined for this analysis include the mobile gear fleets for 4X5Y Haddock, Unit 3 Redfish, 4X Winter Flounder, and Scallop Fishing Area 29 (SFA 29) Scallop. At-sea observer estimates of retained and discarded Longhorn Sculpin bycatch were calculated as a percentage of the retained catch of the directed species for all observed sets over the past 10 years (2010–2019). These fisheries have observer coverage levels ranging from 4–10% of trips. The highest percentage of Longhorn Sculpin was retained in the 4X Winter Flounder fishery, followed by the 4X5Y Haddock fishery. No Longhorn Sculpin were retained during observed trips from the Unit 3 Redfish and SFA 29 Scallop fisheries (Table 10). Discarding occurred at low levels in all three groundfish fisheries examined, as well as the SFA 29 Scallop fishery.

Starting in the 2018/2019 Lobster fishing season, observer coverage (1% of trips) was initiated in Lobster Fishing Areas (LFAs) 33, 34, and 35. Longhorn Sculpin bycatch occurred in all three

LFAs; however, only small percentages were retained (Table 10). Similarly, small amounts were discarded from all three LFAs, with the highest percentage being in LFA 35.

DFO SUMMER RESEARCH VESSEL SURVEYS

TRENDS IN TOTAL BIOMASS

Fisheries and Oceans Canada has conducted an annual stratified random bottom trawl survey of the Scotian Shelf and Bay of Fundy area since 1970. The DFO Summer RV Survey does not provide coverage of St. Mary's Bay; therefore, no fishery independent abundance index for Longhorn Sculpin is currently available for this area. The closest DFO Summer RV Survey stratum (490) is located adjacent to and west of St. Mary's Bay and, for most of the time series, has been assigned four tows per year (Figure 9). This stratum is used for comparing trends in Longhorn Sculpin biomass and abundance with those from NAFO Divisions 4X (strata 470–495) and 4VW (strata 440–466). Over the 49-year time series, there have been persistent aggregations of Longhorn Sculpin on the Scotian Shelf, the main areas being offshore on Sable Island Bank and Banquereau, Browns Bank, and the outer Bay of Fundy (Figure 10). Although the overall spatial distribution does not appear to have changed, there has been a notable decrease in survey catches on the Eastern Scotian Shelf and the outer Bay of Fundy over the past two decades (i.e., 2000–2009 and 2010–2019).

Annual DFO Summer RV Survey minimum trawlable biomass estimates for stratum 490, the 4X strata, and the 4VW strata tend to be quite variable over the 49-year time series (Figure 11). Applying a three-year geometric mean (GM; 3-year moving average) to the annual biomass estimates provides a clearer indication of long-term trends by smoothing some of the variability. For the 4X strata and stratum 490, the smoothed biomass index was below the long-term GM (1970–2019) from the early 1970s to the mid-1980s, followed by a period of higher biomass during 1990s. After 2000, a steeper biomass decline occurs in stratum 490 compared to the 4X strata, which coincides with start of the St. Mary's Bay directed Longhorn Sculpin fishery. Both series have been below the long-term GM since 2010.

Biomass trends in the 4VW strata differ from those in 4X and stratum 490 (Figure 11). The smoothed biomass index for the 4VW strata was above long-term GM in the 1970s, then variable up to the mid-2000s, but has been below the time series GM since 2008. Overall, Longhorn Sculpin biomass has declined across the Scotian Shelf/Bay of Fundy area since the late 2000s. In 2018, there was no DFO Summer RV Survey coverage of the 4VW strata due to mechanical problems with the vessel.

TRENDS IN ABUNDANCE-AT-LENGTH, WEIGHTED MEAN LENGTH AND PERCENTAGE > 23 CM

In the 4X strata, there was an increase in the DFO Summer RV Survey total abundance-at-length from 2018 to 2019 for lengths 20–27 cm (Figure 12; upper panel). For both years, the total abundance for lengths ≥ 25 cm was below the short-term (2008–2017) and long-term (1970–2017) median abundance indices. In stratum 490, there was a decrease in total abundance-at-length from 2018 to 2019 for all lengths > 24 cm (Figure 12; lower panel). Similar to the 4X strata, total abundance for lengths ≥ 23 cm in 2018 and 2019 was below both the short- and long-term medians. These patterns indicate a decrease in the abundance of larger fish in both areas over the past two years.

Similar to the commercial fishery, the weighted mean length (cm) of Longhorn Sculpin from the DFO Summer RV Survey catch-at-size and percentage of catch-at-size > 23 cm (mature fish) for stratum 490 and strata 470–495 (4X) showed a decline over the survey time series from

1970–2019 (Figure 13). The rate of decline (linear trend) in average length and percentage > 23 cm is steeper for stratum 490 compared to the 4X strata, with the greatest divergence between the two series occurring after 2000 (i.e., lower for stratum 490). Although the St. Mary's Bay fishery began in 1999, it is unclear if the start of the fishery influenced the steeper declines in weighted mean length and percentage > 23 cm in stratum 490 after 2000.

Throughout the directed fishery (1999–2019), the average size of Longhorn Sculpin from the 4X strata and stratum 490 was generally smaller than the average size of Longhorn Sculpin from the St. Mary's Bay fishery (Figure 14). This could be attributed to differences in gear configuration and selectivity. For example, the DFO Summer RV Survey uses a Western IIA bottom trawl with a 19 mm mesh cod end liner, while the commercial fishery uses a 260 "Balloon" otter trawl with 90–100 mm diamond mesh cod ends. The survey trawl retains a higher proportion of small Sculpin compared to the commercial trawl (Figure 15). This results in a smaller mean size for Longhorn Sculpin from the DFO Summer RV Survey, even though the modal size from the survey can be greater than (i.e., 2016, 2017), less than (i.e., 2018) or equal to (i.e., 2019) the modal size in the fishery. Consequently, size comparisons of Longhorn Sculpin catches from the DFO Summer RV Survey and the directed commercial fishery are likely confounded by gear selectivity.

CONDITION FACTOR

Fulton's K (weight/length³), a measure of fish condition, was calculated separately for mature (> 23 cm TL) and immature (10–23 cm TL) Longhorn Sculpin using DFO Summer RV Survey length and weight data from strata 470–495 (4X) for 1995–2019. During this period, weights were consistently recorded using electronic balances. Up to 2015, K has fluctuated above and below the long-term average (1995–2019) for mature Longhorn Sculpin, but has fallen below the long-term average from 2016–2019 (Figure 16; upper panel). The reasons for this are unclear. For immature Longhorn Sculpin, K has fluctuated both above and below the long-term average without any real trend (Figure 16; lower panel).

INDICATORS OF STOCK STATUS

COMMERCIAL FISHERY CATCH RATES

Nominal catch rates (t/hr) for the St. Mary's Bay directed Longhorn Sculpin fishery were calculated using landings and effort data from MARFIS for 2002–2019 and the ISDB for 1999–2001, when there was 100% at-sea observer coverage. From 1999–2006, fishing effort (hrs towed) was variable but peaked in 2006 even though landings did not increase at that time (Figure 17). Fishing effort from 2009–2014 showed a modest increase with increasing landings and remained high after 2014, despite a steady decline in landings.

The CPUE index showed a pattern of "fishing up" then "fishing down" the stock before and after the 2-year closure in 2007 and 2008, with peaks in 2000 and 2011, respectively (Figure 18). Assuming the CPUE index is proportional to population abundance, this would indicate a decline in relative abundance from 2001–2006 and from 2012–2019.

The median of the 1999–2019 CPUE time series (0.132 t/hr) was used as a proxy for biomass-at-maximum sustainable yield (B_{MSY}). A Limit Reference Point (LRP) was calculated as 40% of B_{MSY} (i.e., $0.132 \times 0.4 = 0.053$ t/hr). A LRP based solely on the recent fishery CPUE time period (2009–2019) was also evaluated, but this time period was considered too short to provide a meaningful reference point.

A smoothed CPUE index, calculated using a 3-yr moving median to reduce variability in the time series, was used to assess current stock status in relation to the LRP (Figure 18). In 2006 and

2019, the smoothed index was just above 40% of the time series median at 0.081 and 0.061 t/hr respectively, placing the relative abundance of the St. Mary's Bay Longhorn Sculpin stock at the Cautious/Critical Zone boundary.

IN SEASON EXPLOITATION RATES

A depletion model known as the “Leslie Method” (Leslie and Davis 1939) was used to estimate the initial Longhorn Sculpin population size (N_0) available for each year of the St. Mary's Bay fishery using catch and effort data from MARFIS for 2002–2019 and the ISDB for 1999–2001. This approach involves regressing the daily CPUE index of abundance (t/hr) against cumulative daily catch (t). The X-intercept of the regression line is a proxy for the initial population size (N_0) available at the beginning of the fishing season. The ratio of annual catch to initial population size provides an estimate of “in season” exploitation rate (similar to Relative F).

For this method to work, the fishery has to occur over a short time period (6 weeks for the St. Mary's Bay fishery) to limit the potential effects of immigration/emigration, and the stock has to be depleted by fishery removals over time (i.e., regression of daily CPUE to cumulative catch has negative slope). For most years, the relationship between CPUE and cumulative catch had a negative slope (Figures 19–21), but three years (1999, 2002, 2004) had increasing CPUE with cumulative catch (Figure 19) and were not included in this analysis. The relationships between CPUE and cumulative catch in 2013, 2018, and 2019 had slightly negative slopes and were included in the analysis. The initial population size for these years is likely an overestimate, resulting in exploitation levels that appear to be lower than would be expected in comparison with the CPUE time series (Figures 20 and 21).

Results from the Leslie Depletion Model are summarized in Table 11. From 2000–2006, “in-season” exploitation increased from 12% to 36%, after which the directed fishery was closed in 2007 and 2008 (Figure 22). When the fishery resumed in 2009, exploitation was above 30% from 2009–2015 and potentially reached 75–76% in 2011 and 2012, when landings were highest (note: 30% is considered to be very high for groundfish stocks). In 2016 and 2017, exploitation declined to approximately 30%. The low estimates of exploitation for 2018 (23%) and 2019 (18%) are inconsistent with the low catch rates observed for these years and are caused by the lack of contrast between CPUE and cumulative catch, which results in a slope that is only slightly negative (Figure 21). In season exploitation levels were likely very high on the St. Mary's Bay Longhorn Sculpin stock from 2009–2016.

WINTER FLOUNDER CATCH RATES AND AVERAGE SIZE

Winter Flounder catch rates (t/hr) declined from 0.015t/hr in 1999 to < 0.001 t/hr in 2006 (Figure 23). After the resumption of the Longhorn Sculpin directed fishery in 2009, catch rates increased from < 0.001 t/hr to 0.07 t/hr, an increase of more than a factor of 7. It is unclear if this increase in catch rates was due to an increase in Winter Flounder abundance in St. Mary's Bay or to the targeting of this species by the directed Longhorn Sculpin fishery license holders, but it coincides with declining Longhorn Sculpin catch rates.

The size composition of the Winter Flounder bycatch has been recorded consistently by at-sea observers since 2009, with the total number of length measurements ranging from 700–3500 individual lengths/year from 2009–2019. Over the time series, the average size of Winter Flounder ranged from 24–37 cm, with a long-term mean of 31 cm (Figure 24). The percentage of immature fish (i.e., < 23 cm, based on DFO Summer RV Survey data) averaged approximately 5% and ranged from 0–41% over the time series. Currently, there is no small fish protocol in place for Winter Flounder captured in the St. Mary's Bay Longhorn Sculpin fishery.

SUMMARY AND CONCLUSIONS

Landings of St. Mary's Bay Sculpin peaked at 235 t and 229 t in 2011 and 2012, respectively, but declined to 29 t in 2019. At the same time, landings of Winter Flounder bycatch increased from 1% of total landings in 2011 (3 t) to 58% in 2019 (51 t) and currently exceed those of Sculpin. The average size of Longhorn Sculpin and the percentage of fish > 23 cm (size at 50% maturity) in fishery catches has been below the long-term average since 2015.

At-sea observer coverage levels for the 2009–2019 directed fishery have averaged 15% of landings and trips, which is lower than the earlier period of the fishery (1999–2006) and below the 25% target coverage level. Crustaceans represent 74% of all discarded bycatch (1999–2019 average) and include American Lobster, Jonah Crab, and Rock Crab. Since 2015, there has been an increase in the percentage of Winter Flounder discards, which represent 40% of all discards in 2018 and 2019.

The overall spatial distribution of Longhorn Sculpin does not appear to have changed across the Scotian Shelf/Bay of Fundy area; however, catches of Sculpin from the DFO Summer RV Survey have declined since 2000. Biomass indices for 4X strata and stratum 490 (adjacent to St. Mary's Bay) have been below the long-term mean (1970–2019) since 2010. The average size of Longhorn Sculpin and percentage > 23 cm in survey catches show a declining trend in 4X strata and stratum 490 from 1970–2019, but the decline is steeper for stratum 490, especially since 2000. It is unclear if the trends observed in stratum 490 are influenced by the St. Mary's Bay Longhorn Sculpin fishery, but this stratum provides the only time series of data currently available from an area closest to the directed fishery. To interpret these trends, tagging studies could be used to determine the amount of movement and mixing between the St. Mary's Bay and stratum 490.

The directed fishery CPUE index shows a pattern of “fishing up” and “fishing down” the stock before and after the 2007–2008 closure. In both periods, relative abundance declined rapidly to levels approaching 40% of the time series median (LRP proxy) in 2006 and 2019. The two-year closure (2007–2008) may have allowed the St. Mary's Bay Longhorn Sculpin stock to rebuild but the stock declined rapidly after the fishery resumed in 2009.

In season exploitation rates were above 30% from 2009–2015 and may have reached levels of 75–76% in 2011 and 2012, when landings were highest. Since 2016, the Longhorn Sculpin fishery exploitation rate has declined. At the same time, catch rates of Winter Flounder have increased steadily since 2009. It is unclear if this increase is due to an increase in Winter Flounder abundance or to targeting of this species by the directed Longhorn Sculpin fishery license holders.

The primary indicator used to assess stock status is an LRP based on 40% of the 1999–2019 CPUE time series median (a proxy for B_{MSY}). A smoothed CPUE index, calculated using a 3-year moving median, was used to determine the current level of relative abundance in relation to the LRP. In 2006 and 2019, the smoothed index was just above 40% of the time series median at 0.081 and 0.061 t/hr respectively, placing the relative abundance of the St. Mary's Bay Longhorn Sculpin stock at the Cautious/Critical Zone boundary.

The current prognosis for the directed Sculpin fishery in St. Mary's Bay appears to be poor and this species has undergone periods of localized depletion at a time when the overall population biomass appears to be lower than average. Limiting removals to the lowest possible level may promote future stock growth, which appears to have occurred after the fishery resumed in 2009.

Since a full analytical assessment is not possible for the St. Mary's Bay Longhorn Sculpin fishery, average length and percentage of mature fish in the fishery and survey catches, total biomass and abundance in survey catches, and in season exploitation rates could also be used

as indices to evaluate stock status in future assessments. Currently, these indicators support the conclusion that the stock is now approaching the Cautious/Critical Zone boundary and that exploitation needs to be reduced.

Future monitoring of the St. Mary's Bay Longhorn Sculpin fishery could include port sampling to collect length measurements of Longhorn Sculpin and Winter Flounder bycatch. In addition, a DFO Science/industry bottom trawl survey of LFA 34 has been conducted using a chartered commercial vessel and a version of the USA Northeast Fisheries Science Centre bottom trawl since 2016. Unlike the DFO Summer RV Survey, which does not provide coverage of nearshore areas off southwestern Nova Scotia, the LFA 34 survey samples 6 stations within the St. Mary's Bay area (Figure 25). Data from several groundfish species are recorded during this survey, including information on Longhorn Sculpin. Over time, a fisheries independent index of abundance/biomass for Longhorn Sculpin could be developed using data from the 6 stations sampled within St. Mary's Bay.

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TABLES

Table 1. Reported annual landings (t) of sculpins (all species) by NAFO Division, 1990–2019. Cells with dashes have no data available; cells with 0 have landings < 1 t. SMB = St. Mary's Bay directed Longhorn Sculpin fishery.

YEAR	4V	4W	4X	5Y	5ZE	4VWX5	SMB
1990	-	-	0.8	-	-	0.8	-
1991	-	-	13.8	0	-	13.8	-
1992	-	1.4	38.6	-	-	40.0	-
1993	-	-	17.5	0.3	-	17.8	-
1994	-	-	43.4	0.1	-	43.5	-
1995	-	-	34	0.2	0	34.2	-
1996	0.6	0.1	23.8	0.1	0.1	24.7	-
1997	-	-	18.3	0	0.9	19.2	-
1998	-	0	21	0		21.0	-
1999	-	0	82.8	0	1.3	84.1	62.0
2000	-	-	165.5	0	0.5	166.0	141.0
2001	-	0.2	172.9	0.1	4.2	177.4	152.0
2002	-	0.1	142.8	0.1	0.2	143.3	100.6
2003	-	0.1	121.5	0.7	0.0	122.3	74.2
2004	-	0.4	106.7	0.4	0.6	108.1	42.3
2005	-	0.1	181.4	0.7	1.6	183.7	87.5
2006	8.6	0.6	188.7	0.4	6.1	204.4	88.5
2007	3.5	0.1	141.3	0.3	1.5	146.7	-
2008	-	0.4	143.9	0.5	1.3	146.1	-
2009	-	0.5	339.1	8.0		347.7	156.0
2010	-	0.1	363.1	0.3	0.0	363.5	208.3
2011	-	0.1	430.5	3.7	0.0	434.2	235.1
2012	11.7	0.3	382.7	5.3	0.6	400.6	228.5
2013	4.5	1.7	315.4	3.2	0.7	325.5	172.1
2014	0.4	0.2	408.2	0.1	0.9	409.7	195.1
2015	0.5	0.3	343.8	0.2		344.7	127.5
2016	0.1	2.1	257.9	0.0	0.3	260.4	92.8
2017	4.2	1.6	176.9	0.1	0.1	182.9	74.3
2018	1.0	0.3	145.6	0.1	1.5	148.5	55.7
2019	1.5	10.0	139.6	0.1	0.2	151.4	29.0

Table 2. Reported annual landings (t) of sculpins (all species) by NAFO Division, 1990–2019. Cells with dashes have no data available, cells with 0 have landings < 1 t. Percentage of landings from unit area 4Xr are also shown.

Year	4XM	4XN	4XO	4XP	4XQ	4XR	4XS	4XU	Total	% 4Xr
1990	-	-	-	-	-	-	-	0.8	0.8	0.0
1991	-	-	-	-	0	7.6	-	6.2	13.8	55.1
1992	-	0.2	-	-	4.4	30.2	3.9	-	38.7	78.0
1993	-	0	1.0	-	1.5	14	0.8	0.2	17.5	80.0
1994	-	-	0.3	-	1.8	29.7	3.1	8.4	43.3	68.6
1995	0	0.3	2.1	0.1	2.7	24.1	4.6	0.2	34.1	70.7
1996	0	0.6	1.7	0.1	1.0	16.1	4.3	0.1	23.9	67.4
1997	0.4	0.1	0.9	0.1	1.8	12.7	2.2	0.1	18.3	69.4
1998	0.3	0	1.6	0.4	3.1	9.4	2.8	3.4	21.0	44.8
1999	0.3	0.6	3.9	0.1	7.4	55.6	1.0	13.9	82.8	67.1
2000	0.1	0.7	3.6	0.1	5.3	150.9	2.2	2.6	165.5	91.2
2001	0.3	0.2	3.6	0.4	7.0	157.3	2.1	2.1	173.0	90.9
2002	0.3	0.4	2.9	0.1	7.9	124.5	5.0	1.7	142.8	87.2
2003	0.7	0.6	4.4	0.1	6.7	95.4	12.7	1.0	121.5	78.5
2004	0.5	0.4	5.8	1.0	10.4	69.7	13.5	5.3	106.7	65.4
2005	1.2	0.4	15.1	0.4	12.8	125.6	23.8	2.0	181.3	69.3
2006	1.9	0.5	20.6	6.7	21.3	114.9	21.5	1.5	188.7	60.9
2007	2.1	0.7	32.2	2.4	11.2	71.1	19.4	2.3	141.3	50.3
2008	3.0	0.6	19.5	2.3	15.8	57.6	37.3	7.9	143.9	40.0
2009	2.7	0.8	48.3	0.3	30.9	218.9	31.9	5.2	339.0	64.6
2010	2.9	0.8	45.4	3.8	32.4	242.1	29.0	6.7	363.1	66.7
2011	2.1	0.4	43.7	1.0	13.3	322.1	46.6	0.9	430.1	74.9
2012	1.7	0.3	21.8	0.3	26.3	293.4	36.2	2.6	382.7	76.7
2013	0.7	0.6	11.0	0.3	11.8	244.4	44.5	2.1	315.4	77.5
2014	0.9	0.7	28.2	0.2	10.1	312.9	51.4	4.0	408.2	76.6
2015	0.6	0.5	26.6	0.0	8.1	229.0	72.1	7.1	343.8	66.6
2016	0.9	0.1	21.6	0.3	6.5	167.6	54.7	2.9	254.4	65.9
2017	1.3	0.2	9.7	0.1	4.9	134.1	19.0	3.3	172.6	77.7
2018	5.0	0.1	12.5	0.0	4.1	88.8	30.1	2.9	143.6	61.8
2019	6.3	0.0	27.5	0.1	9.8	66.9	21.5	7.6	139.6	47.9

Table 3. Reported annual landings (t) of sculpins (all species) by gear type in 4VWX5, 2002–2019. Cells with dashes indicate no sculpin landings for that year, cells with 0 have landings < 1 t.

Year	Bottom Trawl	Gillnet	Longline	Trap
2002	133.9	8.7	0.6	0.1
2003	113.3	8.6	0.2	0.2
2004	101.3	6.6	0.2	-
2005	179.2	4.0	0.5	0.0
2006	200.2	3.9	0.4	-
2007	140.4	5.7	0.7	-
2008	131.8	11.0	6.7	-
2009	339.0	8.2	0.5	-
2010	351.3	10.2	0.3	-
2011	424.0	9.5	0.8	-
2012	392.8	7.0	0.9	-
2013	320.8	4.7	0.6	-
2014	401.1	8.2	0.4	-
2015	333.4	10.7	0.7	-
2016	250.4	8.9	1.7	-
2017	171.3	10.7	1.4	-
2018	128.0	6.2	0.9	13.3
2019	92.8	10.4	0.9	39.3

Table 4. Reported annual landings (t) of bycatch species from the St. Mary's Bay Longhorn Sculpin directed fishery, 2002–2006 and 2009–2019. LH = Longhorn; FL = Flounder; NS = Non-Specified. The directed fishery was closed in 2007 and 2008.

Year	LH Sculpin	Winter Fl	Flounder NS	Halibut	Haddock	Skates NS	Total
2002	100.6	1.4	1.7	0.1	3.6	0.3	107.8
2003	74.2	1.4	0.2	0.0	1.4	0.0	77.3
2004	42.3	0.7	0.3	0.1	0.0	0.0	43.3
2005	87.5	2.5	2.4	0.0	0.1	0.2	92.6
2006	88.5	0.1	2.8	0.0	0.0	0.0	91.4
2007	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-
2009	156.0	0.3	6.9	0.2	0.0	0.0	163.4
2010	208.3	5.5	2.4	0.1	0.0	0.0	216.2
2011	235.1	2.8	4.1	0.1	0.0	0.0	242.1
2012	228.5	17.4	0.2	0.2	0.0	0.1	246.5
2013	172.1	16.9	0.7	0.4	0.0	0.4	190.4
2014	195.1	17.4	3.4	0.4	0.0	2.2	218.6
2015	127.5	33.0	0.0	0.5	0.0	2.2	163.1
2016	92.8	37.9	0.0	0.0	0.0	4.3	135.0
2017	74.3	30.6	0.0	0.3	0.2	2.9	108.3
2018	55.7	39.6	0.0	0.5	0.2	4.1	100.0
2019	29.0	50.6	0.0	0.5	2.6	5.0	87.8

Table 5. Catch-at-size (numbers) of Longhorn Sculpin from the St. Mary's Bay fishery, 1999–2006. Cells with dashes indicate no catches of Sculpin at that length.

Length (cm)	1999	2000	2001	2002	2003	2004	2005	2006
7	-	-	-	-	-	36	-	-
8	-	-	-	-	-	0	-	-
9	-	-	-	-	-	75	-	-
10	-	-	-	-	-	73	-	72
11	-	-	-	-	-	125	-	84
12	-	-	-	-	-	117	-	221
13	-	-	-	-	-	158	-	579
14	-	-	-	444	-	247	60	1,035
15	-	-	-	232	-	543	174	1,854
16	-	63	-	790	804	643	483	3,127
17	49	125	125	1,256	1,277	1,052	1,029	5,637
18	810	545	47	2,599	5,361	1,437	2,126	12,237
19	1,377	1,193	978	4,875	4,966	1,867	3,509	19,407
20	3,846	4,781	3,049	7,840	14,960	2,982	10,404	31,954
21	8,625	12,833	7,759	15,990	34,058	6,942	35,250	43,117
22	27,614	27,861	23,542	39,219	53,839	11,064	51,887	51,987
23	48,501	59,103	62,415	57,406	80,430	20,816	73,544	62,204
24	70,982	120,173	142,837	83,264	92,061	30,749	92,405	75,231
25	74,903	142,116	229,566	96,438	81,186	40,229	97,579	86,634
26	61,212	142,603	200,088	109,409	59,913	38,113	69,986	73,811
27	43,667	126,416	109,794	73,464	31,623	29,458	46,267	52,718
28	22,437	76,706	50,662	46,147	19,134	23,185	23,851	33,726
29	11,282	43,284	27,522	30,156	9,469	14,207	12,840	15,685
30	3,136	15,946	12,730	13,037	5,926	7,701	4,304	7,158
31	1,014	8,732	4,240	4,084	2,741	3,895	2,717	5,203
32	421	1,944	2,347	1,956	634	1,715	1,125	2,458
33	50	819	701	1,212	795	1,127	323	1,501
34	-	530	103	681	278	438	812	909
35	-	127	35	-	102	217	1,379	553
36	-	190	-	104	-	55	1,272	-
37	-	-	-	-	-	-	1,317	-
38	-	-	-	-	-	-	865	-
39	-	63	-	-	-	-	832	-
40	-	-	-	-	-	-	200	-
41	-	-	-	-	-	-	133	-
42	-	-	-	-	-	-	-	-
43	-	-	-	-	-	-	67	-
44	-	-	-	-	-	-	-	-
45	-	-	-	-	-	-	-	-
46	-	-	-	-	-	-	-	-
47	-	-	-	-	-	-	-	-
48	-	-	-	-	-	-	-	-
Total	379,925	786,156	878,541	590,602	499,556	239,267	536,673	589,100

Table 6. Catch-at-size (numbers) of Longhorn Sculpin from the St. Mary's Bay fishery, 2009–2019. Cells with dashes indicate no catches of Sculpin at that length.

Length (cm)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
7	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	769	-
10	-	-	-	-	-	-	-	119	-	-	173
11	-	-	-	116	134	-	-	-	-	-	729
12	255	-	-	-	-	-	-	-	-	-	290
13	-	-	-	-	-	-	-	-	295	-	828
14	-	-	-	546	467	189	-	334	1,844	-	1,324
15	346	-	-	1,333	467	528	362	2,245	6,996	-	1,992
16	1,083	169	-	2,786	1,594	165	181	4,716	9,413	250	3,471
17	3,888	-	1,117	8,607	1,614	3,106	997	6,936	15,853	480	5,464
18	8,277	2,418	2,762	12,490	6,211	9,279	2,408	13,425	21,248	2,105	7,784
19	12,195	13,005	5,016	30,328	13,771	19,271	2,710	26,512	29,397	3,392	11,723
20	49,724	39,989	10,609	63,332	37,858	34,484	5,277	68,148	37,755	17,696	15,906
21	115,298	138,867	47,441	103,505	49,878	70,615	17,804	90,074	58,967	36,943	20,486
22	282,505	284,597	130,386	169,227	99,669	161,169	29,431	93,328	74,499	58,784	24,451
23	312,461	341,453	283,010	217,082	126,527	272,533	35,800	93,104	79,609	67,525	27,216
24	225,352	270,715	388,809	234,812	158,446	300,858	45,541	71,272	75,801	72,494	26,713
25	133,530	197,638	322,855	242,361	168,198	257,565	58,413	61,355	57,508	54,948	23,392
26	53,042	95,560	186,061	157,558	151,194	127,557	75,541	50,593	42,605	34,428	17,840
27	25,063	74,081	91,281	119,222	116,103	59,047	83,692	37,647	27,974	23,688	12,166
28	8,298	27,345	43,546	74,585	67,240	32,841	82,608	23,244	18,697	11,186	6,930
29	1,529	19,705	15,552	33,475	37,511	14,419	68,542	13,778	11,081	4,941	3,539
30	704	11,004	13,462	20,099	17,161	6,577	47,158	5,139	5,084	2,448	2,033
31	255	2,305	6,092	13,679	9,841	687	30,965	3,342	2,052	768	1,259
32	196	530	3,641	8,186	4,280	835	12,512	1,870	184	1,294	524
33	-	610	720	2,236	1,726	-	6,898	4,867	613	125	521
34	-	760	31	2,665	834	181	3,964	4,217	-	119	196
35	-	-	41	-	516	-	2,286	2,566	-	-	116
36	-	-	7	-	375	-	1,590	539	-	250	51
37	-	-	-	-	-	-	806	-	-	-	74
38	-	-	55	-	232	-	-	217	-	-	-
39	-	-	19	-	-	-	-	132	-	-	-
40	-	-	14	-	-	-	-	-	-	-	-
41	-	-	-	-	-	-	-	-	-	-	-
42	-	-	-	-	-	-	-	-	-	-	-
43	-	-	-	-	-	-	-	-	-	-	-
44	-	-	-	-	-	-	-	-	-	-	-
45	-	-	-	-	-	-	-	-	-	-	-
46	-	-	-	-	-	-	-	-	-	-	-
47	-	-	-	-	116	-	-	-	-	-	-
48	-	-	-	-	116	-	-	-	-	-	-
Total	1,234,003	1,520,747	1,552,530	1,518,232	1,072,078	1,371,906	615,488	679,719	577,474	394,634	217,189

Table 7. Percent observer coverage for the St. Mary's Bay Longhorn Sculpin fishery (LHS) calculated as observed Sculpin catch/total Sculpin landings and observed Sculpin trips/total Sculpin trips, 1999–2006 and 2009–2019. The directed fishery was closed in 2007 and 2008.

Year	Total Landings (t)	Total Trips	Obs LHS Catch (t)	Obs LHS Trips	Obs LHS Land (%)	Obs LHS Trips (%)
1999	61	33	63	33	100.0	100.0
2000	141	62	143	62	100.0	100.0
2001	152	120	152	120	99.7	100.0
2002	101	93	31	30	30.8	32.3
2003	74	79	23	23	30.7	29.1
2004	42	67	28	36	66.0	53.7
2005	85	81	44	41	51.5	50.6
2006	88	66	42	48	47.6	72.7
2007	-	-	-	-	-	-
2008	-	-	-	-	-	-
2009	156	125	30	23	18.9	18.4
2010	208	148	31	23	14.8	15.5
2011	235	140	40	24	16.9	17.1
2012	228	138	32	23	14.0	16.7
2013	172	138	32	23	18.6	16.7
2014	195	138	32	24	16.6	17.4
2015	127	136	14	21	10.9	15.4
2016	93	127	9	15	10.0	11.8
2017	74	131	11	18	15.4	13.7
2018	55	135	6	15	10.3	11.1
2019	28	104	4	11	13.2	10.6

Table 8. Pro-rated kept amounts (t) by year for the main kept species reported by at sea-observers from the St. Mary's Bay Longhorn Sculpin fishery, 1999–2019. The directed fishery was closed in 2007 and 2008.

Year	Sculpin	Winter Flounder	Sea Raven	Halibut	Skates
1999	63.4	5.2	0.7	0.0	0.1
2000	135.7	6.6	1.0	0.1	0.4
2001	147.6	2.8	0.6	0.0	0.1
2002	100.6	2.3	1.3	0.0	0.0
2003	74.2	0.9	3.0	0.0	0.0
2004	42.3	0.8	1.8	0.0	0.0
2005	87.5	4.9	3.7	0.0	0.1
2006	88.5	4.5	7.3	0.0	0.0
2007	-	-	-	-	-
2008	-	-	-	-	-
2009	156.0	7.3	0.0	0.1	0.0
2010	208.3	9.7	10.0	0.0	0.0
2011	235.1	8.3	7.6	0.0	0.0
2012	228.5	22.1	7.9	0.2	0.3
2013	172.1	17.8	5.8	0.4	1.0
2014	195.1	23.0	3.2	0.4	2.0
2015	127.5	72.9	9.6	0.5	4.5
2016	92.8	46.9	7.5	0.0	3.2
2017	74.3	32.2	0.4	0.3	2.0
2018	55.7	37.1	5.8	0.3	2.9
2019	29.0	36.2	5.2	0.8	4.9
Average	110.2	16.3	3.9	0.2	1.0
Min	0.0	0.0	0.0	0.0	0.0
Max	235.1	72.9	10.0	0.8	4.9

Table 9. Pro-rated discard amounts (t) by year for the main discarded species reported by at-sea observers from the St. Mary's Bay Longhorn Sculpin fishery, 1999–2019. The directed fishery was closed in 2007 and 2008.

Year	Lobster	Rock Crab	Jonah Crab	Winter Flounder	Ocean Pout	Sturgeons	Skates	Windowpane Flounder
1999	2.9	0.1	0.2	0.1	2.3	0.0	0.0	0.0
2000	8.9	0.4	0.8	0.0	1.3	0.1	0.0	0.0
2001	6.6	0.6	4.4	0.6	0.6	0.2	0.0	0.0
2002	12.4	0.0	16.1	0.3	0.6	0.6	0.0	0.0
2003	13.1	4.6	6.4	0.9	0.1	0.0	0.0	0.0
2004	7.0	1.6	3.8	1.2	0.1	0.0	0.0	0.4
2005	13.2	8.1	5.1	1.1	0.2	0.5	3.6	0.6
2006	20.1	6.6	4.9	1.3	0.3	0.1	6.2	0.6
2007	-	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-	-
2009	22.5	35.2	0.0	0.0	0.0	0.6	0.1	0.0
2010	32.3	7.2	0.0	0.3	0.1	0.3	0.0	0.3
2011	28.3	4.2	0.0	0.1	0.0	0.0	0.0	1.1
2012	65.5	6.6	0.0	10.0	1.0	3.5	2.3	1.7
2013	23.9	4.4	0.0	2.6	0.2	3.9	1.2	1.1
2014	29.0	2.4	132.9	1.6	0.0	9.6	1.4	1.7
2015	49.0	18.0	51.7	11.5	0.8	4.4	1.9	5.9
2016	27.7	29.3	0.0	16.3	0.5	16.5	1.7	5.8
2017	19.1	3.3	0.3	7.0	0.4	0.5	1.6	0.0
2018	30.9	3.7	7.2	33.0	0.2	6.5	0.6	0.7
2019	28.5	0.0	12.1	29.2	3.7	0.0	0.0	0.0
Average	23.2	7.2	12.9	6.2	0.7	2.5	1.1	1.0
min	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
max	65.5	35.2	132.9	33.0	3.7	16.5	6.2	5.9

Table 10. Percentage of kept and discarded bycatch of Longhorn Sculpin in Lobster Fishing Areas (LFAs) 33–35 (2018/2019 fishing season), Unit 3 Redfish, 4X5Y Haddock, 4X Winter Flounder and Scallop Fishing Area (SFA) 29 fisheries (2010–2019 combined) expressed as a percentage of the directed species kept catch.

Fishery	Year(s)	Percentage of Directed Species Catch	
		Kept Sculpin	Discarded Sculpin
LFA 33	2019	0.6	0.4
LFA 34	2019	0.1	0.3
LFA 35	2019	0.0	1.1
Unit 3 Redfish	2010–2019 all	0.0	0.0
4X5Y Haddock	2010–2019 all	0.1	0.1
4X Winter Flounder	2010–2019 all	2.1	0.1
SFA 29	2010–2019 all	0.0	0.1

Table 11. Results from the Leslie Depletion Model for the St. Mary's Bay (SMB) Longhorn Sculpin fishery, 1999–2019. Exploitation levels for 1999, 2002, and 2004 could not be calculated because the relationship between CPUE and cumulative catch had a positive slope. The directed fishery was closed in 2007 and 2008.

Year	Intercept	Catchability (q)	Initial Population Size (t)	SMB Fishery Landings (t)	Exploitation (%)
1999	0.13546	-0.00114	-118.5	63.4	-
2000	0.27823	0.00024	1180.5	142.9	12.07
2001	0.16377	0.00018	518.2	151.5	28.43
2002	0.09795	-0.00045	-219.4	100.6	-
2003	0.12622	0.00049	257.1	74.2	28.86
2004	0.07114	-0.00049	-145.4	42.3	-
2005	0.19376	0.00055	351.1	87.5	23.41
2006	0.07313	0.00031	238.0	88.5	36.23
2007	-	-	-	-	-
2008	-	-	-	-	-
2009	0.33951	0.00106	321.6	156.0	47.99
2010	0.41572	0.00104	400.4	208.3	52.03
2011	0.66933	0.00212	315.3	235.1	74.58
2012	0.62725	0.00210	298.6	228.5	76.49
2013	0.34278	0.00075	457.1	172.1	34.51
2014	0.32278	0.00076	422.0	195.1	46.22
2015	0.21123	0.00104	202.7	127.5	62.52
2016	0.11884	0.00037	319.0	92.8	28.90
2017	0.11238	0.00046	242.8	74.3	30.02
2018	0.06937	0.00029	238.0	55.7	23.30
2019	0.04744	0.00030	157.9	29.0	17.88

FIGURES

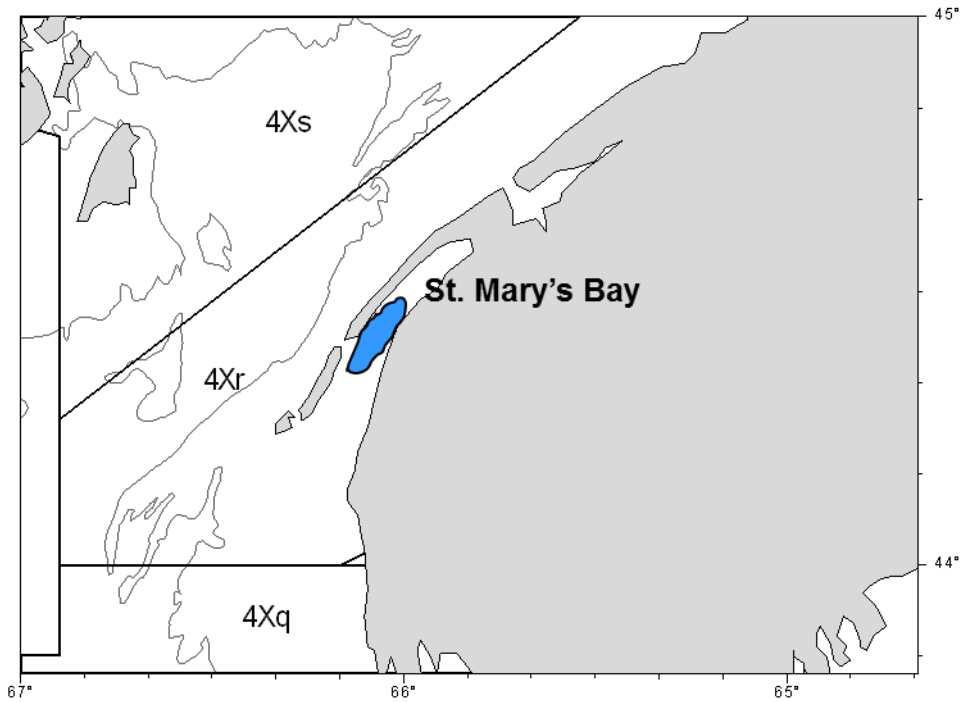


Figure 1. Location of directed Longhorn Sculpin fishery (blue polygon) in St. Mary's Bay Nova Scotia.

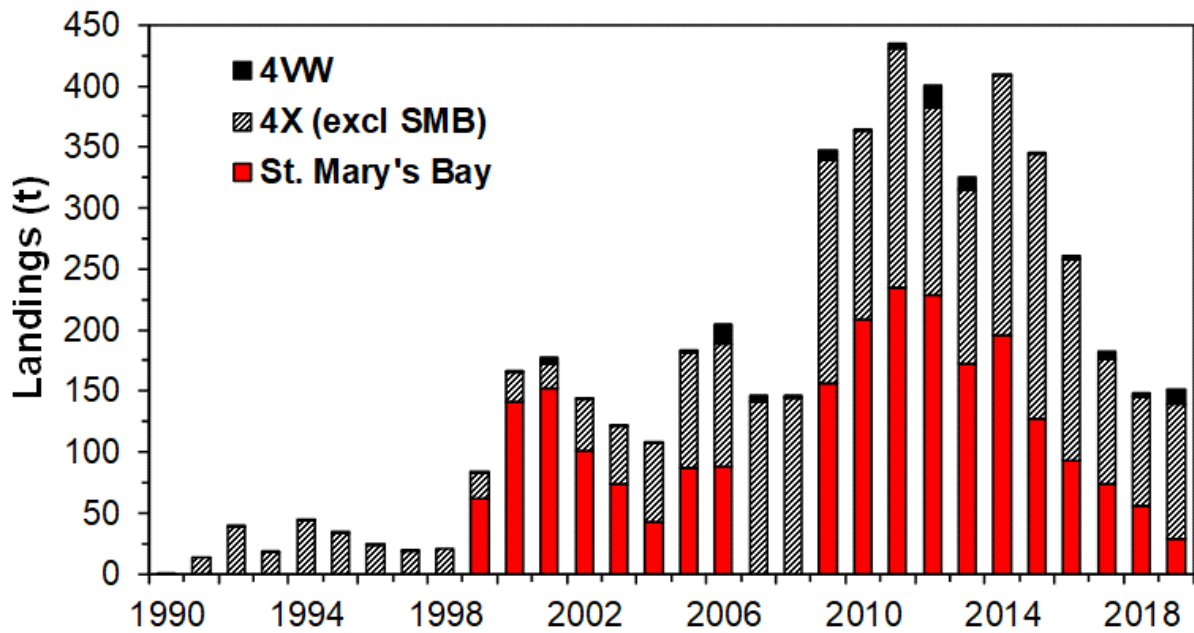


Figure 2. Landings of Sculpin (t) (all species) in NAFO areas 4X (excluding St. Mary's Bay) and 4W (1990–2019), and the St. Mary's Bay directed Longhorn Sculpin fishery (1999–2019). The directed fishery was closed in 2007 and 2008.

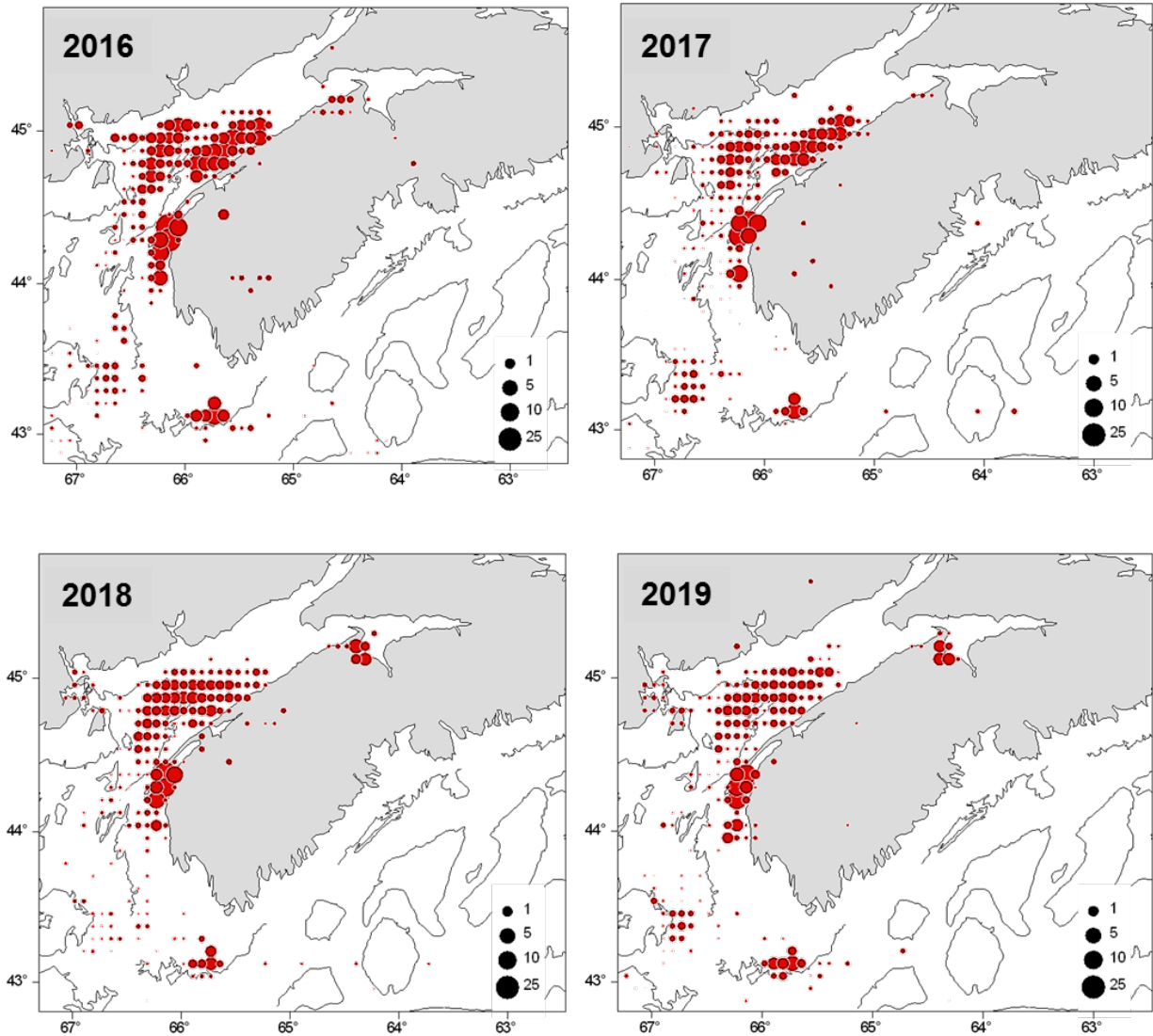


Figure 3. Distribution of Longhorn Sculpin catches (t aggregated by 1 minute rectangles of latitude and longitude) reported in the MARFIS Commercial Landings database for bottom trawl fisheries in 4X, 2016–2019.

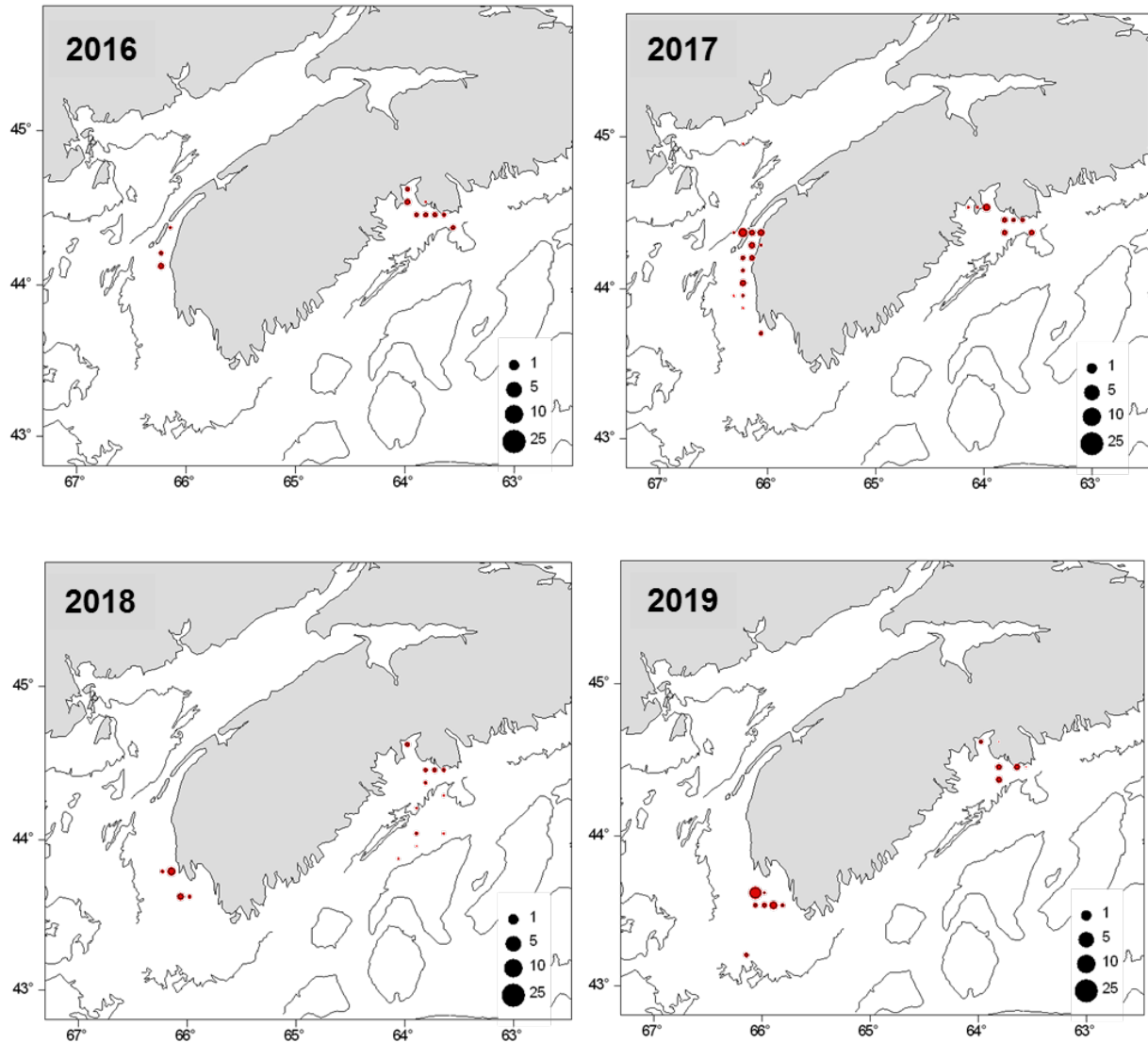


Figure 4. Distribution of Longhorn Sculpin catches (t aggregated by 1 minute rectangles of latitude and longitude) reported in the MARFIS Commercial Landings database for groundfish gillnet fisheries in 4X, 2016–2019.

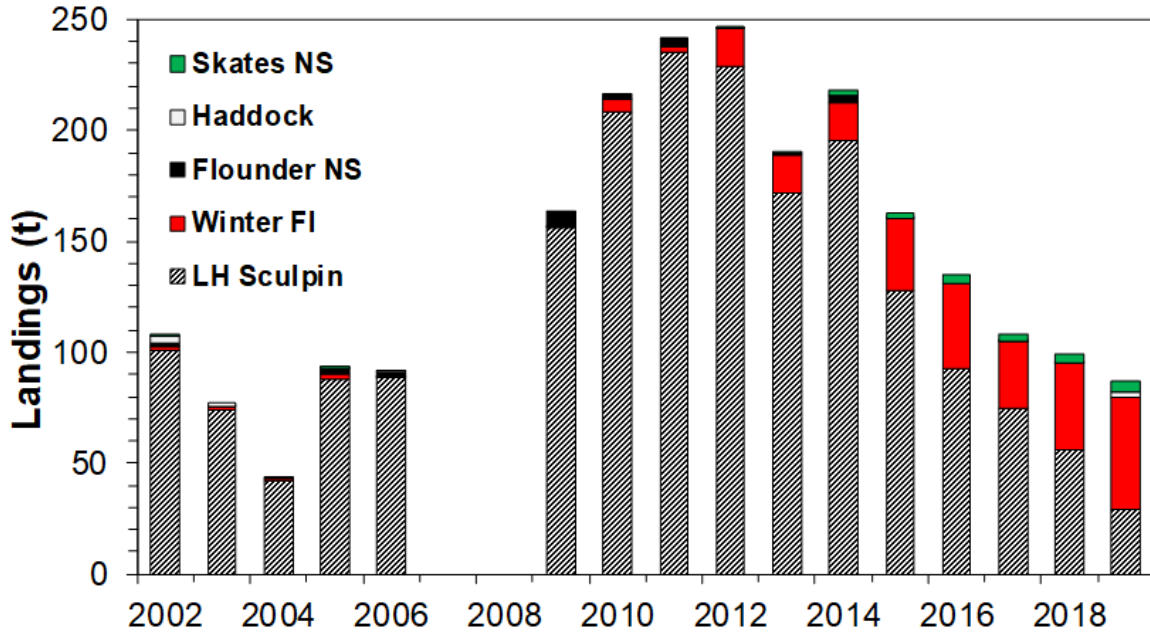


Figure 5. Reported annual landings (t) by species from the St. Mary's Bay Longhorn Sculpin directed fishery, 2002–2006 and 2009–2019. NS = Non-Specified; FI = Flounder; LH = Longhorn. The directed fishery was closed in 2007 and 2008.

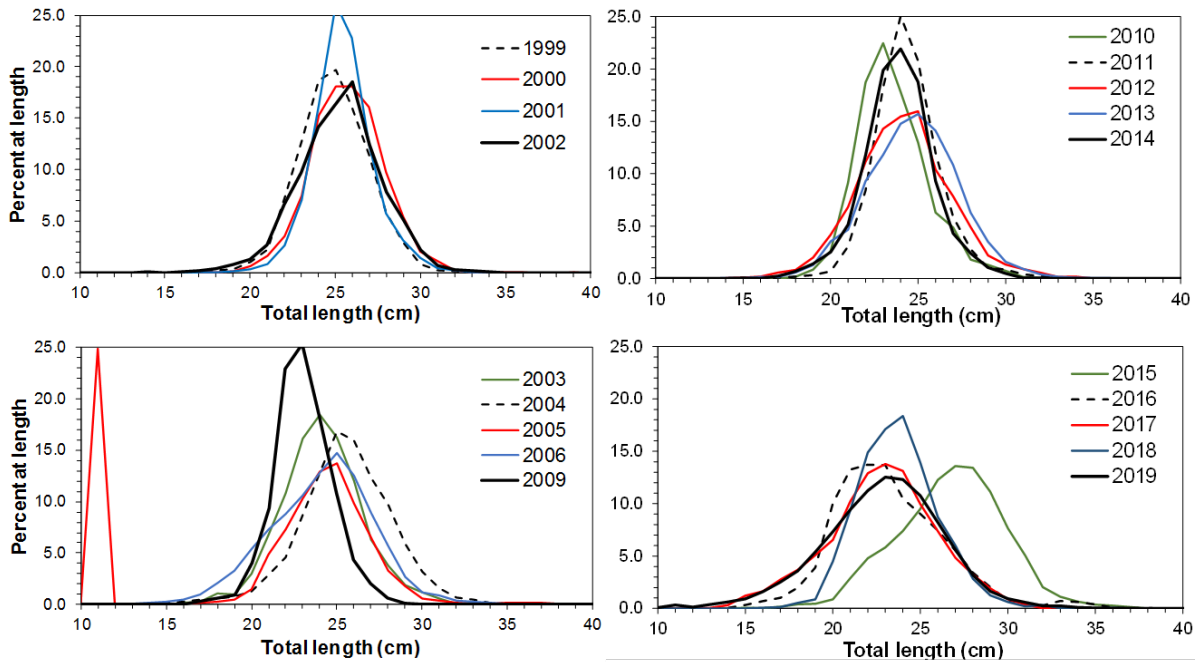


Figure 6. Percentage catch-at-size of Longhorn Sculpin from the directed fishery in St. Mary's Bay, 1999–2006 and 2009–2019.

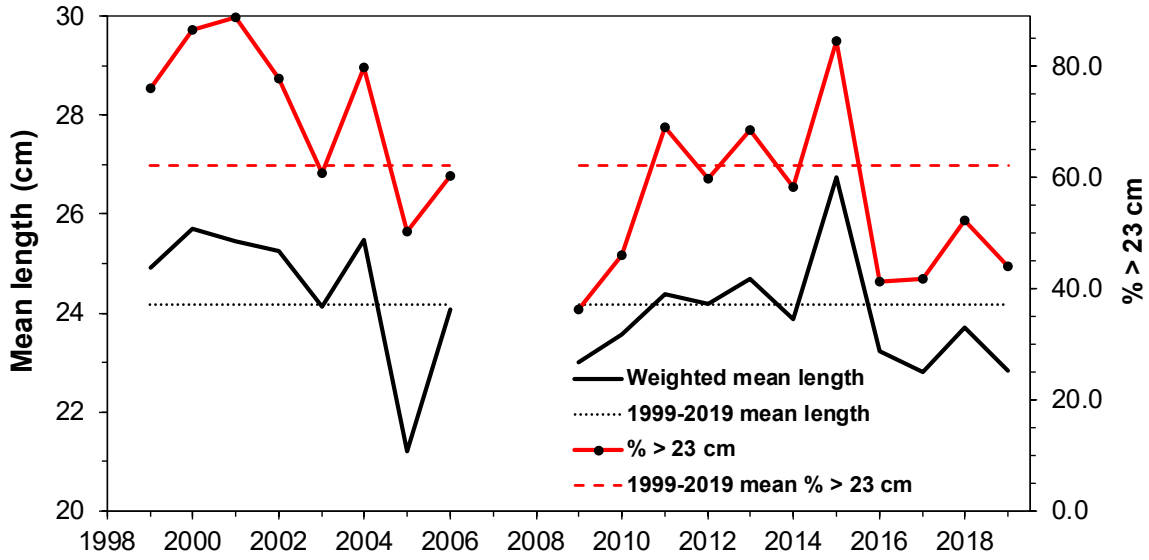


Figure 7. Weighted mean length (cm) of Longhorn Sculpin from the commercial fishery catch-at-size and the percentage of the catch-at-size > 23 cm (size at 50% maturity) for 1999–2019. Dashed lines are the 1999–2019 means for each series. The directed fishery was closed in 2007 and 2008.

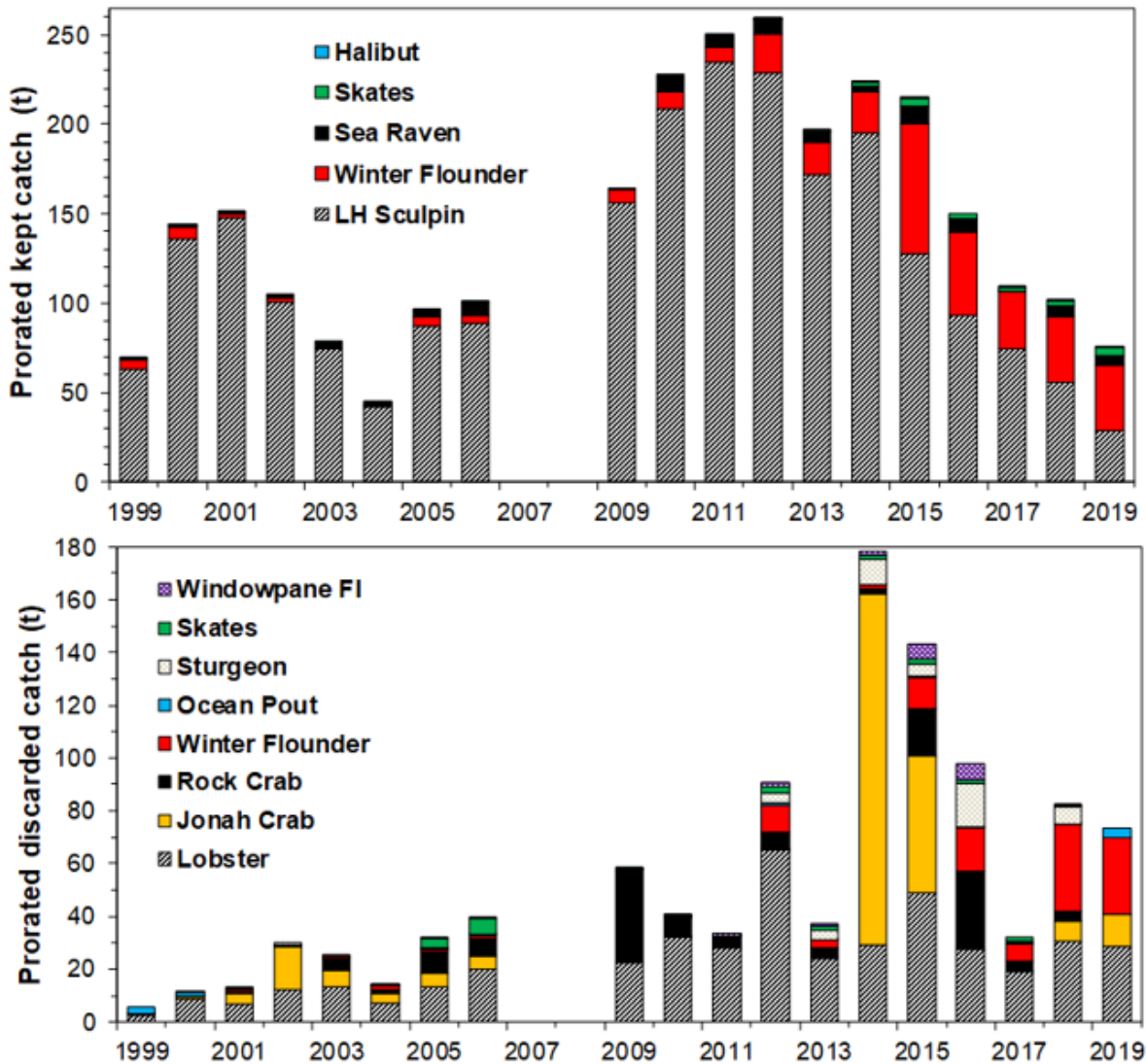


Figure 8. Prorated total kept catch (t, upper panel) and discarded catch (t, lower panel) by species from the St. Mary's Bay Longhorn Sculpin fishery, 1999–2019, based on at-sea observer data. The directed fishery was closed in 2007 and 2008. LH = Longhorn, FI = Flounder.

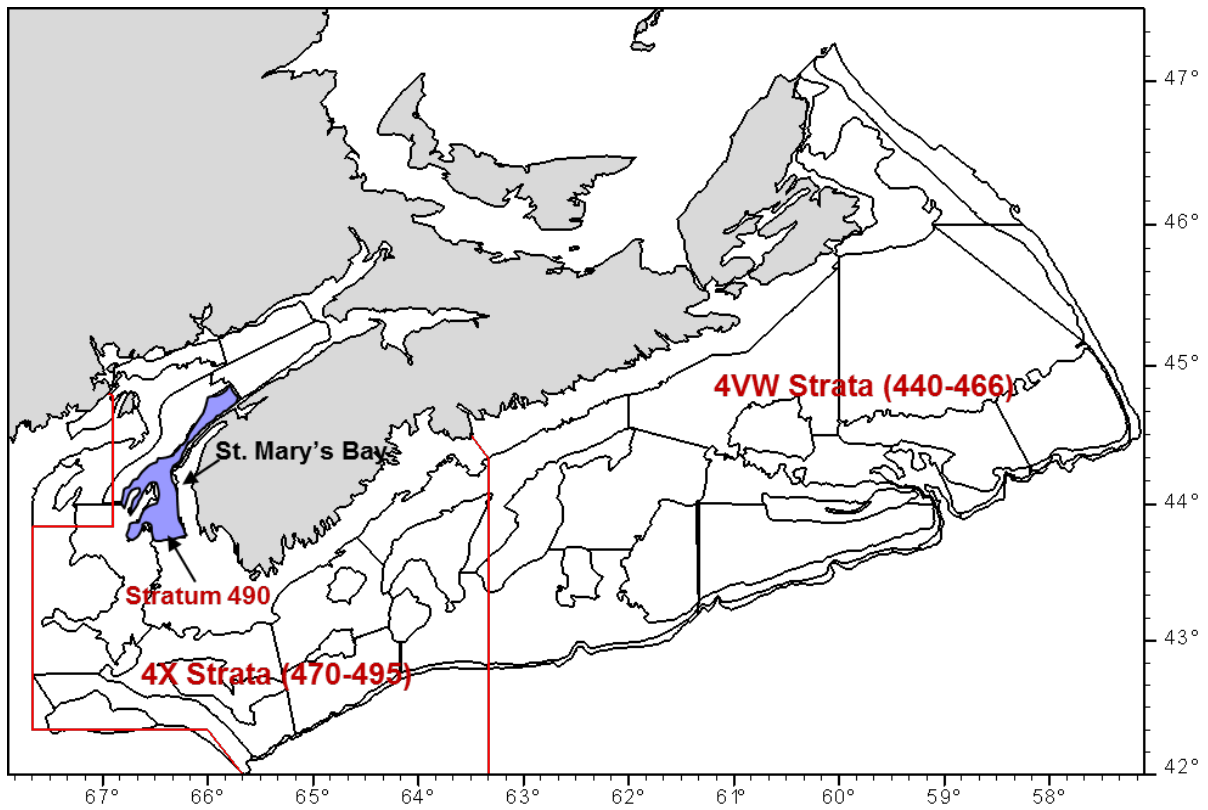


Figure 9. Location of DFO Summer Research Vessel Survey stratum 490 (adjacent to St. Mary's Bay, Nova Scotia), 4X strata (470–495), and 4VW strata (440–466).

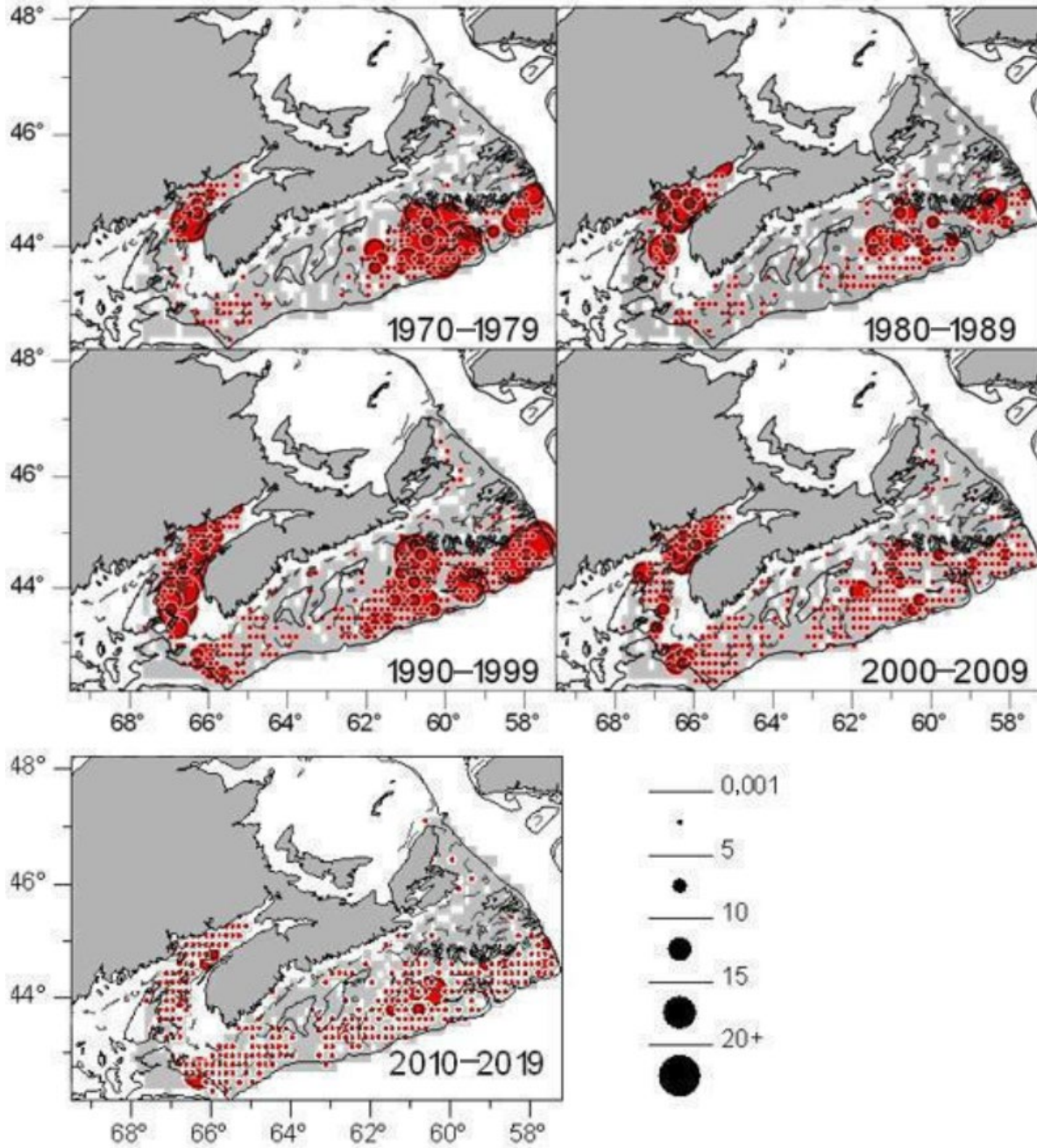


Figure 10. Distribution of Longhorn Sculpin catches (10-year average weight (kg)/tow aggregated by 10 minute squares) from DFO Summer Research Vessel Survey strata 440–495, 1970–2019. Grey shading indicates extent of area surveyed.

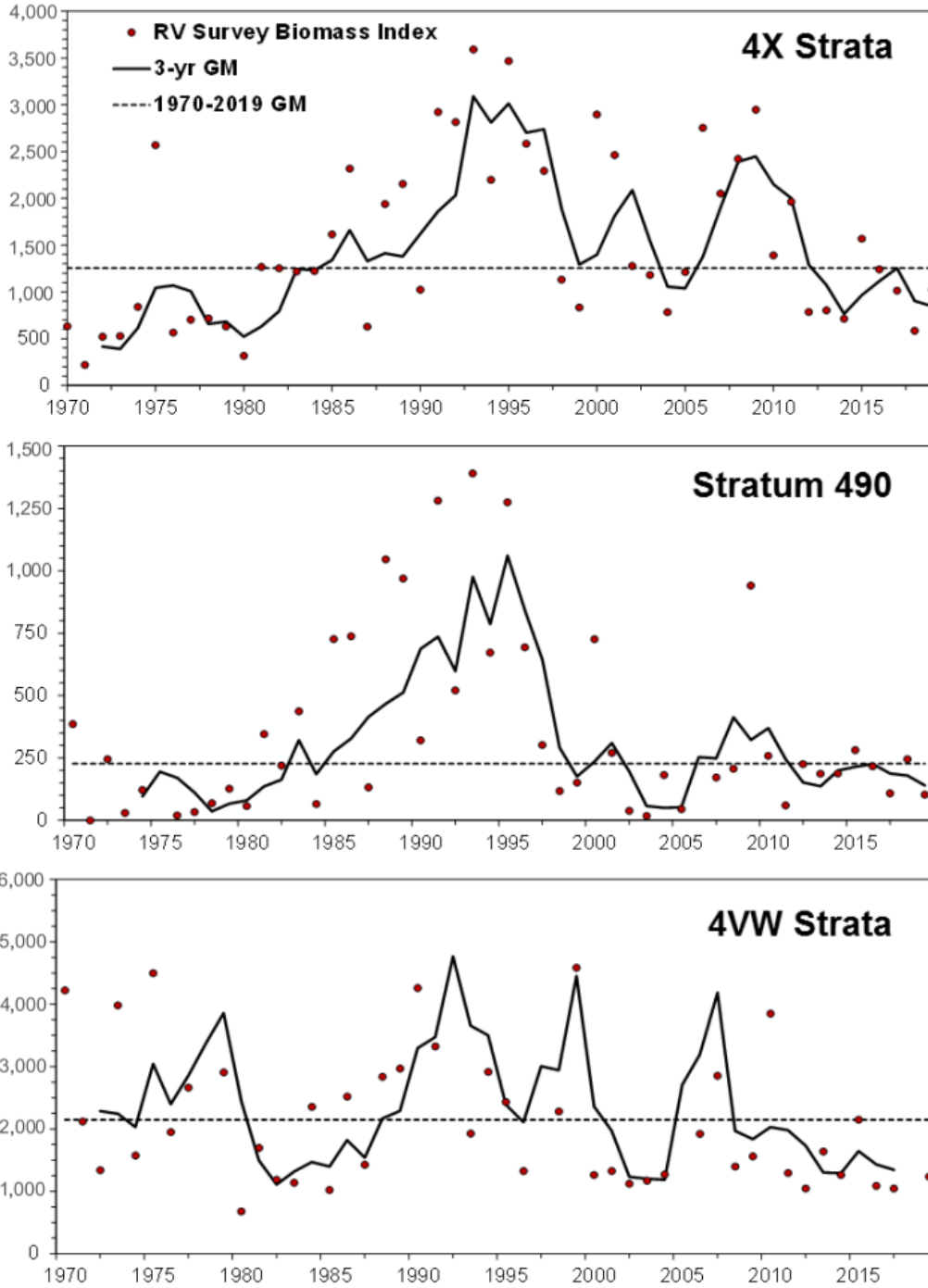


Figure 11. Trends in the Longhorn Sculpin total biomass index (t) from the DFO Summer Research Vessel (RV) Survey for 4X strata (470–495), stratum 490, and 4VW strata (440–466), 1970–2019. The red dots are the annual survey index values, the solid black line is the 3-year moving geometric mean, and the dashed line is the geometric mean for the 1970–2019 time series. There was no survey coverage for the 4VW strata in 2018.

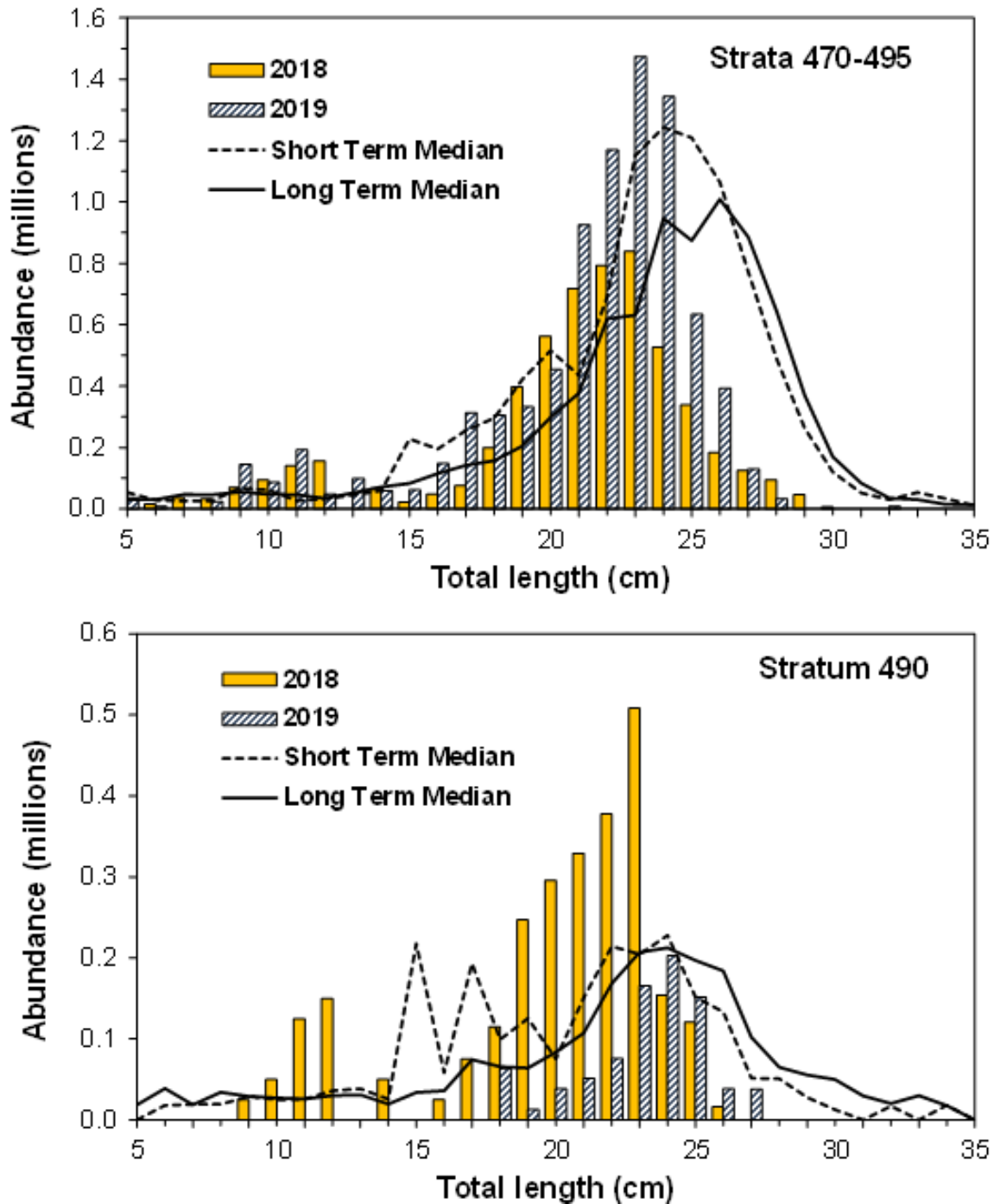


Figure 12. Length frequency indices for Longhorn Sculpin from DFO Summer Research Vessel Survey strata 470–495 (4X; upper panel) and stratum 490 (lower panel) 1970–2019. The black hatched bars represent the numbers in millions at length from the 2019 survey, yellow bars represent the number in millions at length from the 2018 survey. The solid black line represents the long-term median abundance-at-length (1970–2017) and the dashed black line is the short-term median abundance-at-length (2008–2017).

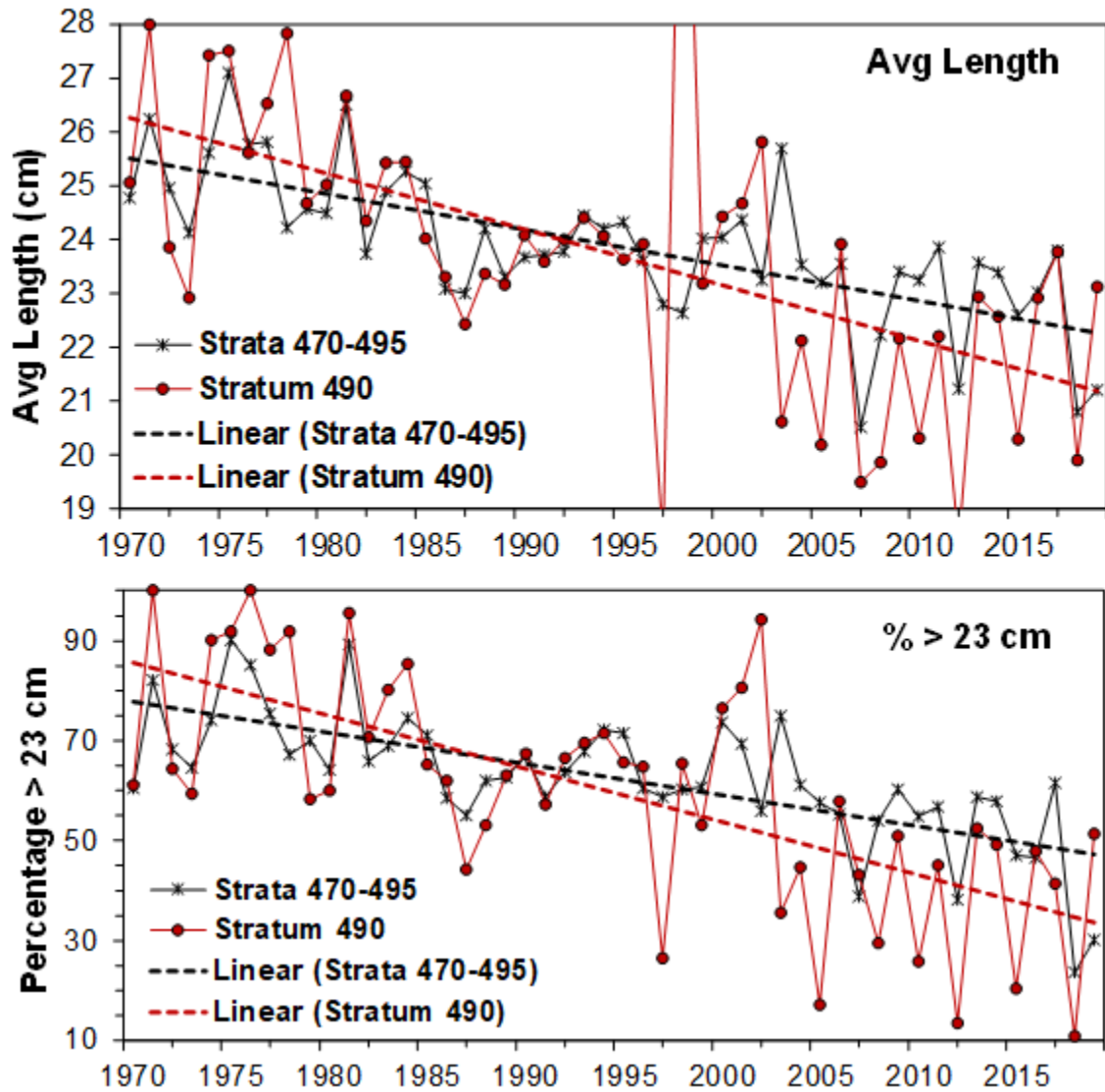


Figure 13. Weighted mean length (cm) of Longhorn Sculpin from the DFO Summer Research Vessel Survey catch-at-size (upper panel) and percentage of catch-at-size > 23 cm TL (lower panel) for stratum 490 and strata 470-495 (4X), 1970-2019. The dashed lines are linear trends for strata 490 (red) and strata 470-495 (black).

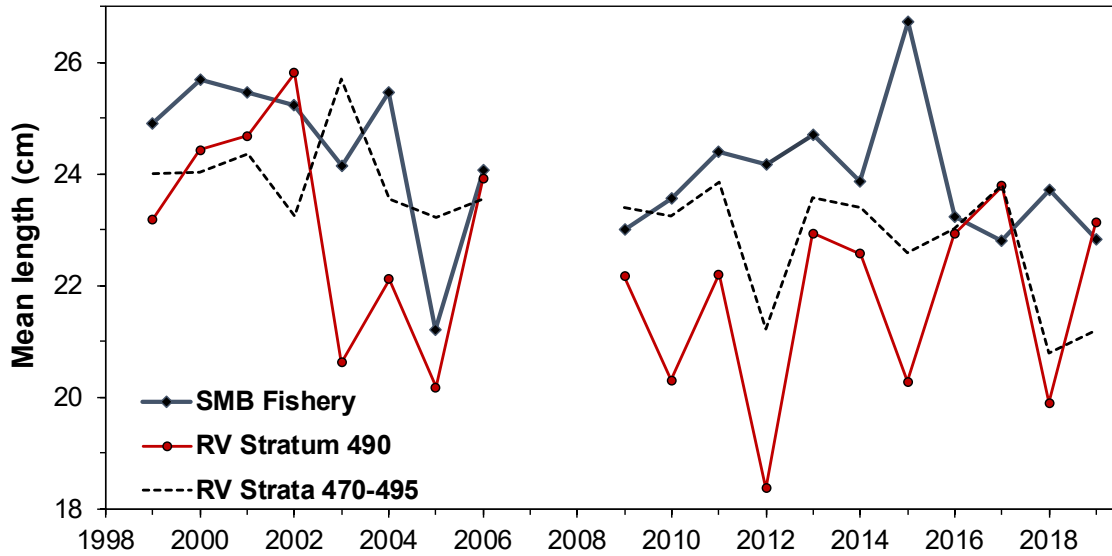


Figure 14. Comparisons of Longhorn Sculpin weighted mean length (cm) calculated from the commercial fishery catch-at-size and DFO Summer Research Vessel (RV) Survey catch-at-size for stratum 490 and strata 470–495 (4X), 1999–2019. There was no directed Sculpin fishery in 2007 and 2008.

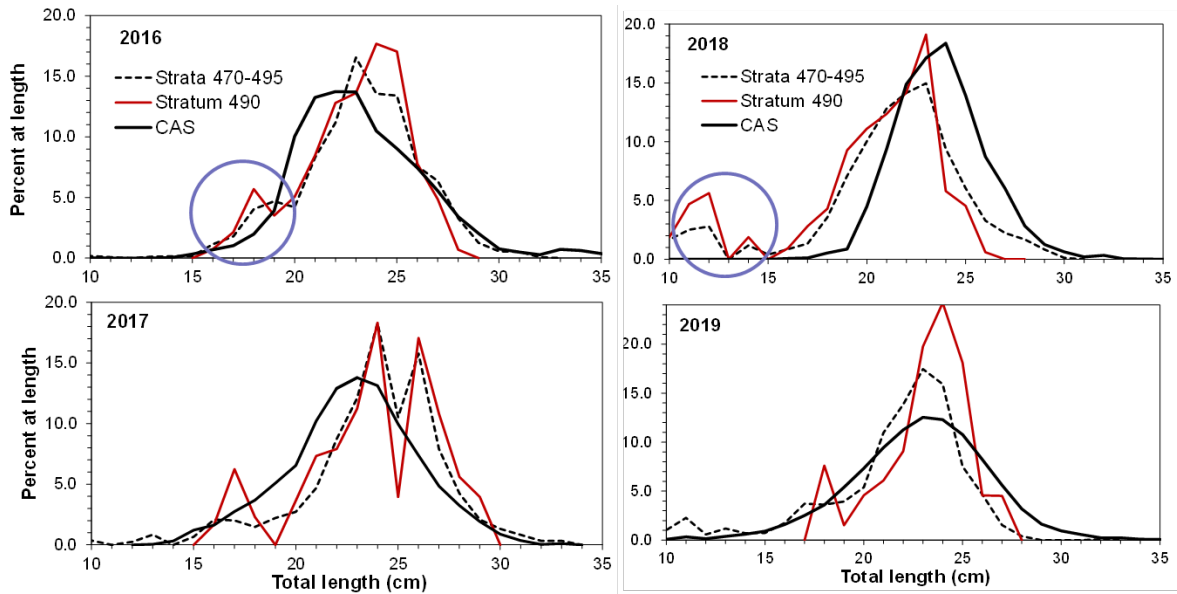


Figure 15. Percentage at length (cm) of Longhorn Sculpin in the commercial fishery Catch-At-Size (CAS) and DFO Summer Research Vessel (RV) Survey catch-at-size for stratum 490 and strata 470–495 (4X), 2016–2019. The blue circle indicates higher retention of smaller Longhorn Sculpin in DFO Summer RV Survey catches.

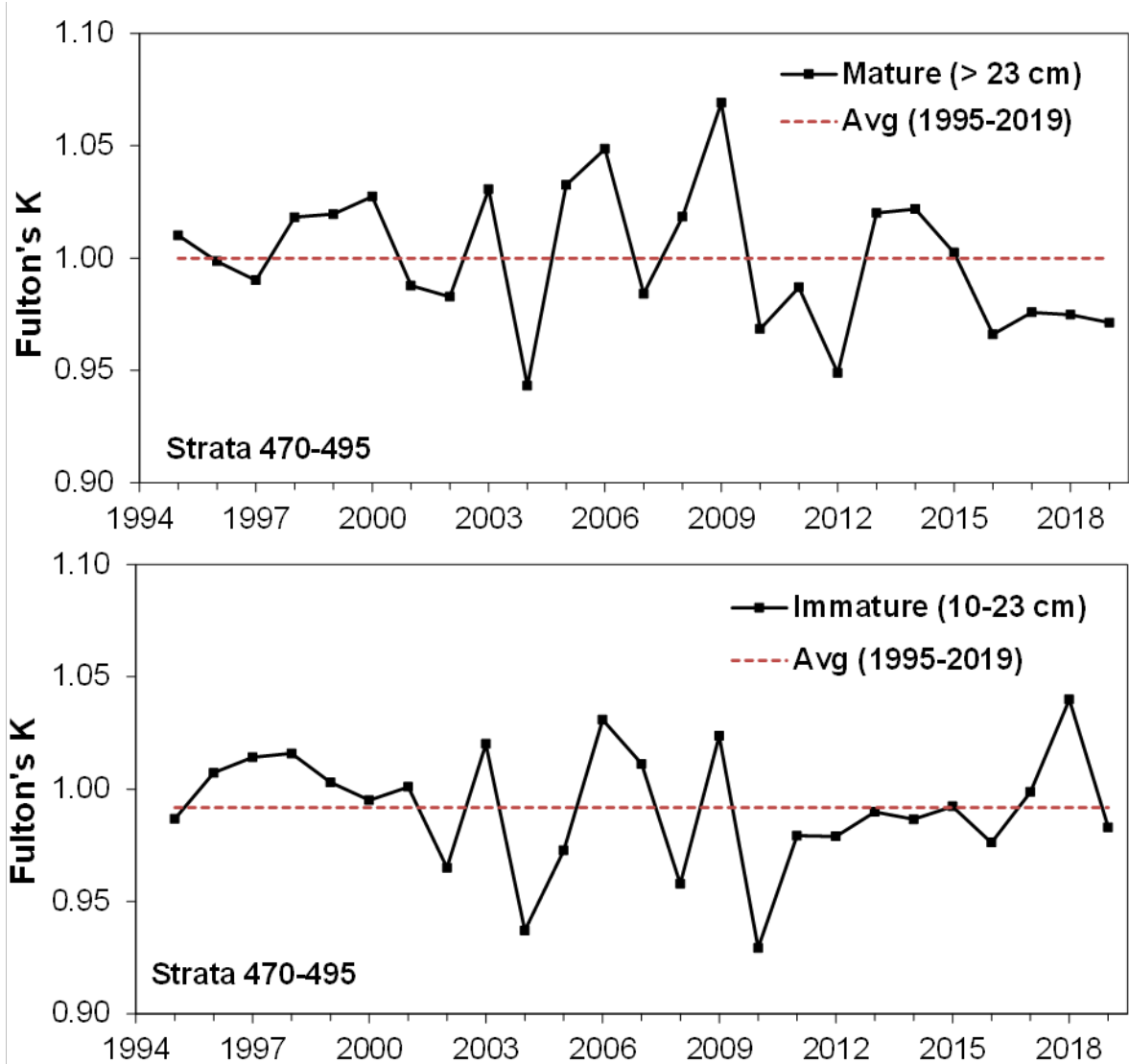


Figure 16. Fulton's condition factor (weight (g)/length (cm)³) for mature (> 23 cm; upper panel) and immature (10–23 cm; lower panel) Longhorn Sculpin based on DFO Summer Research Vessel Survey length and weight data from strata 470–495 (4X) for 1995–2019. The dashed red line is the time series average.

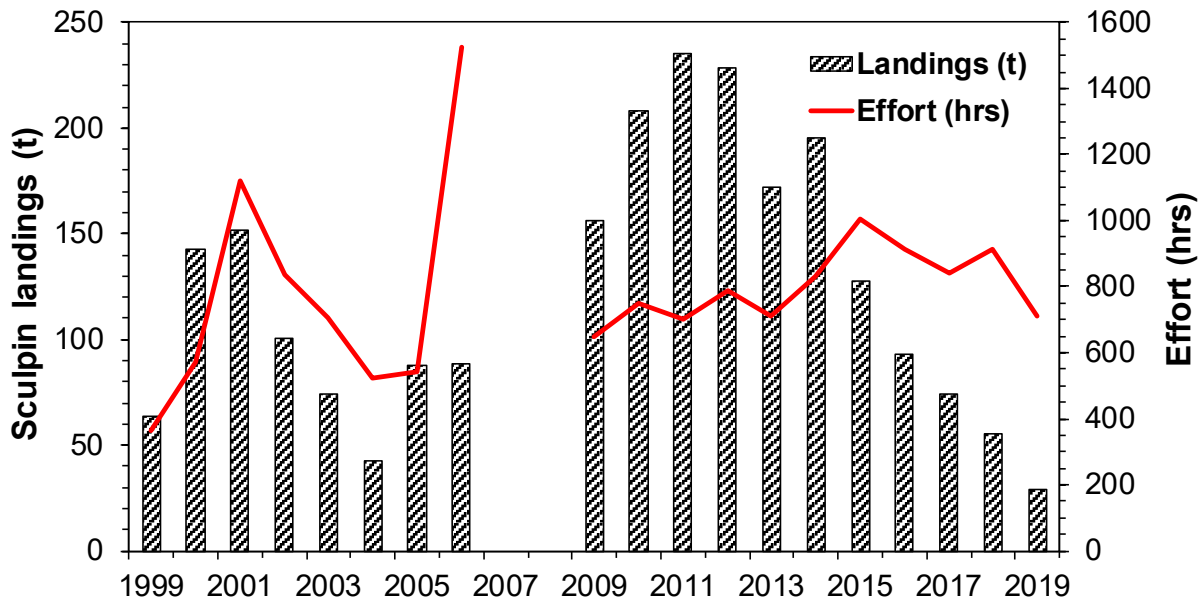


Figure 17. Fishing effort (hours towed; red line) and total Sculpin landings (black histograms) from the St. Mary's Bay directed fishery, 1999–2019. The directed fishery was closed in 2007 and 2008.

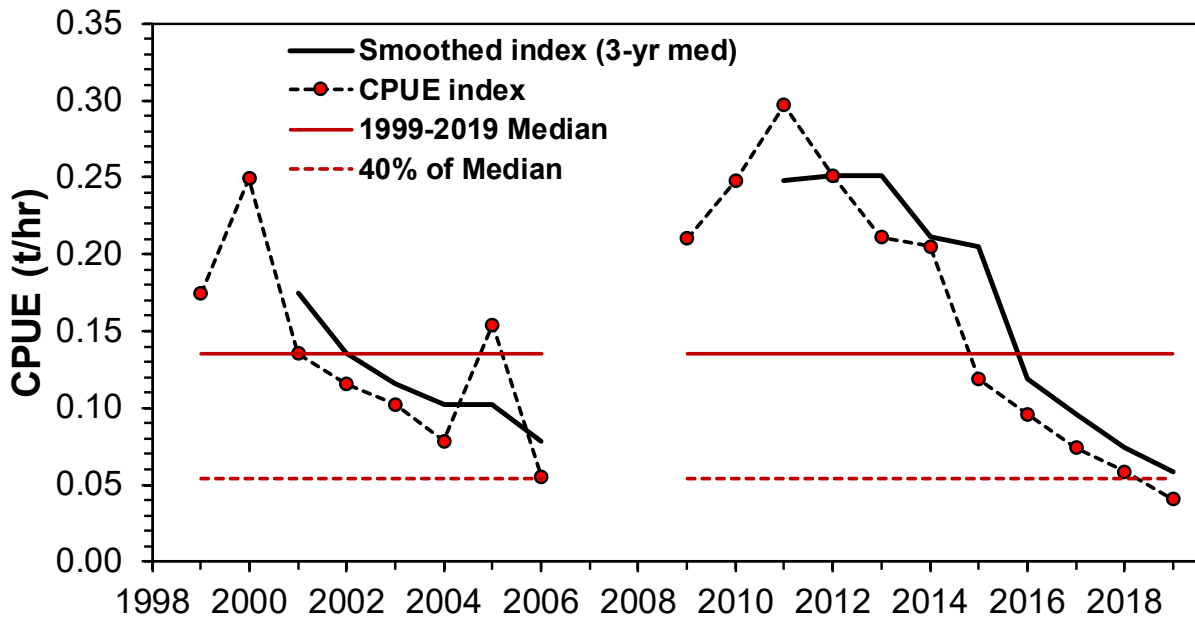


Figure 18. Catch Per Unit Effort (CPUE; t/hr) for the St. Mary's Bay directed Longhorn Sculpin fishery, 1999–2019. Nominal CPUE index is indicated by the dashed black line; the smoothed CPUE index (3-yr running median) is indicated by the solid black line. The solid red line is the time series median (0.132 t/hr); dashed red line is 40% of the time series median (0.053 t/hr). The directed fishery was closed in 2007 and 2008.

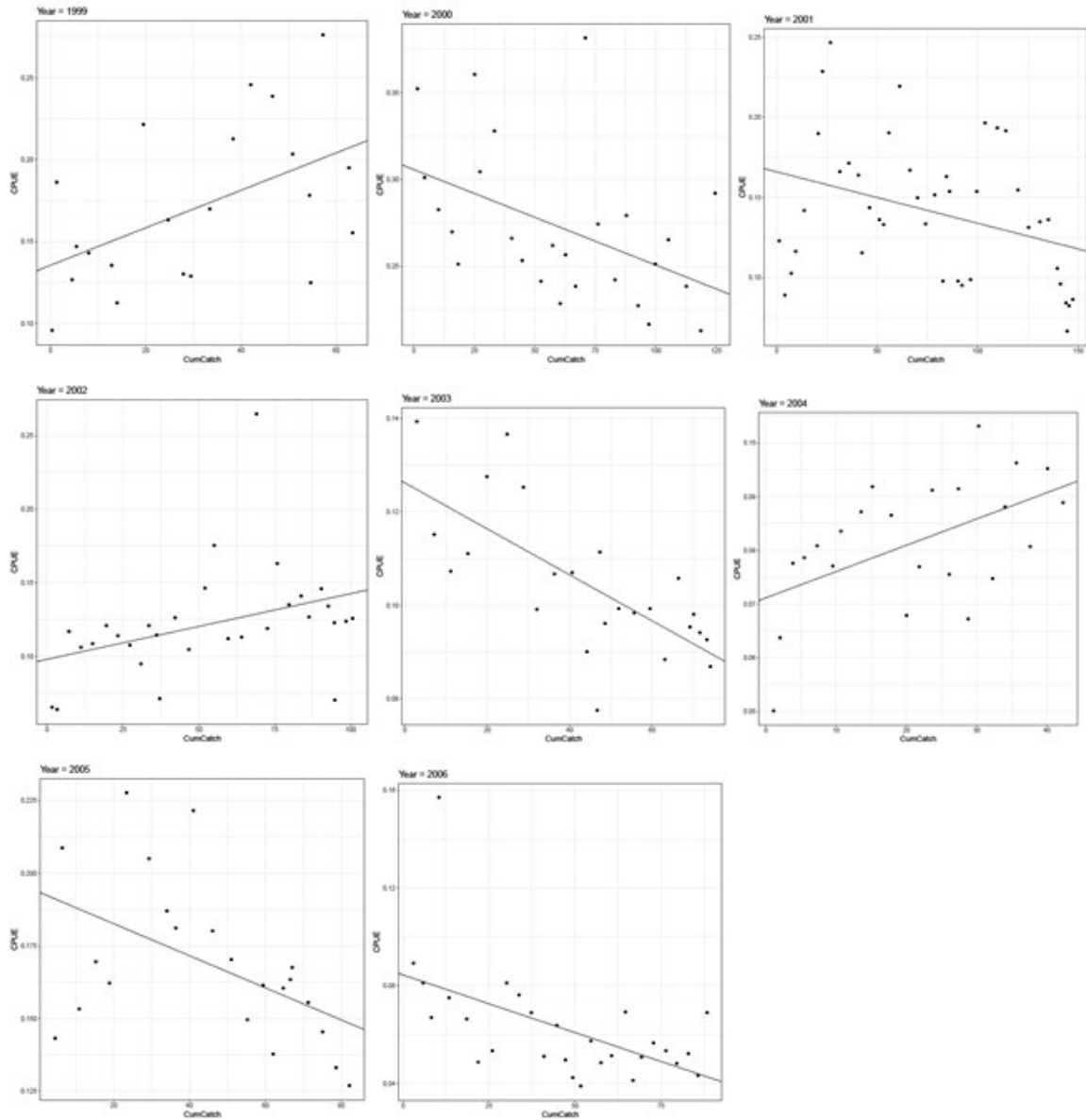


Figure 19. Plots of the relationship between daily Catch Per Unit Effort (CPUE) and cumulative catch for the St. Mary's Bay directed Longhorn Sculpin fishery, 1999–2006. Regressions with a pronounced negative slope (2000, 2001, 2003, 2005, 2006) were used for estimating initial population size while those with a positive slope (1999, 2002, 2004) could not be used.

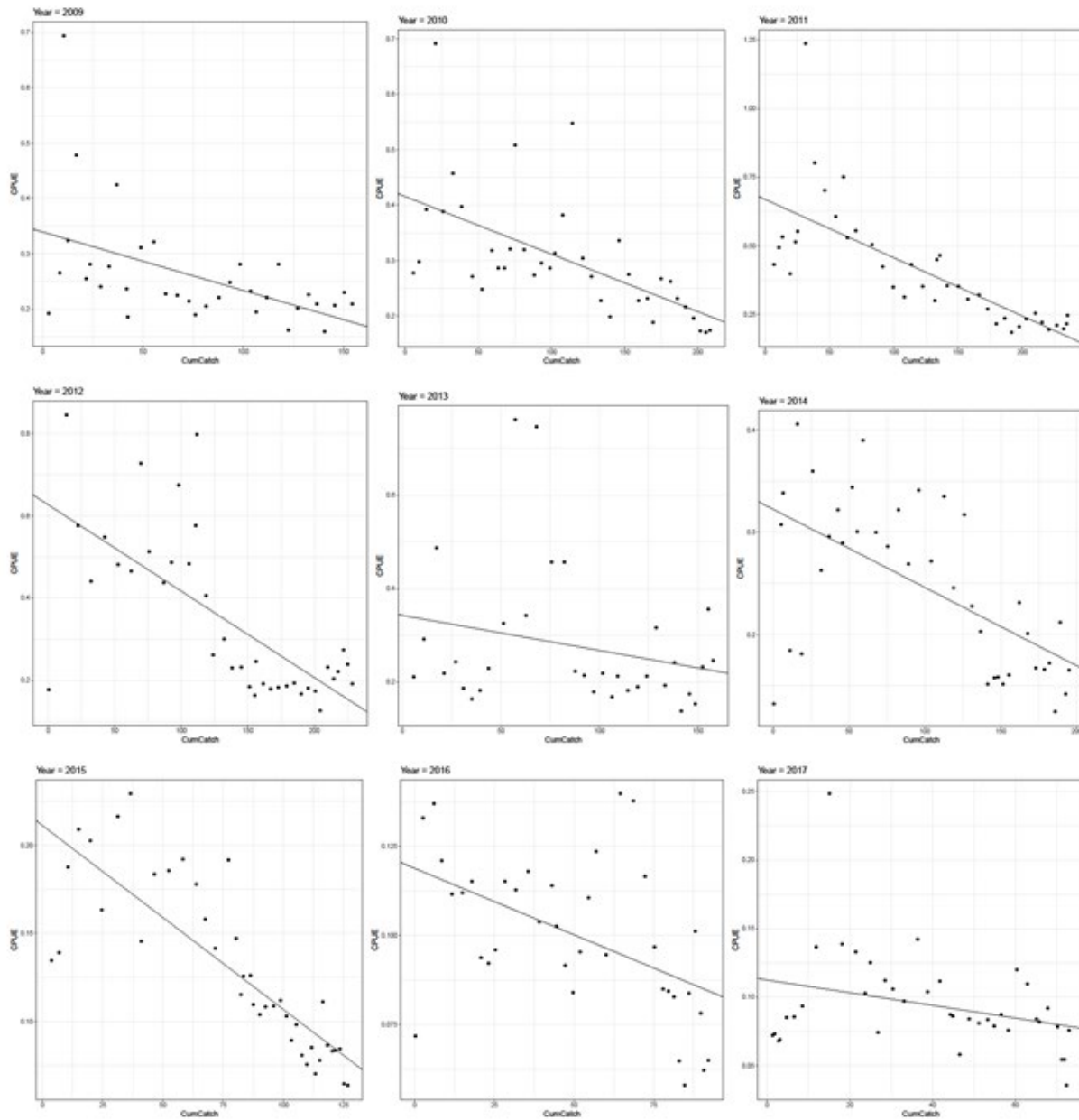


Figure 20. Plots of the relationship between daily Catch Per Unit Effort (CPUE) and cumulative catch for the St. Mary's Bay directed Longhorn Sculpin fishery, 2009–2017. Regressions with a negative slope (2009–2017) were used for estimating initial population size.

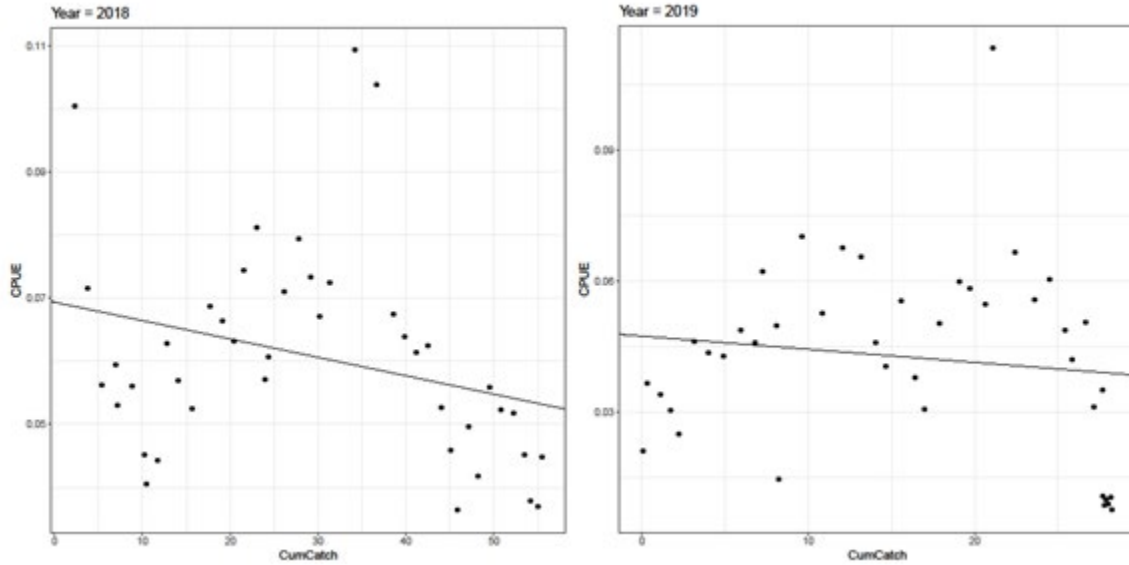


Figure 21. Plots of the relationship between daily Catch Per Unit Effort (CPUE) and cumulative catch for the St. Mary's Bay directed Longhorn Sculpin fishery, 2018–2019. Regressions with a negative slope (2018–2019) were used for estimating initial population size.

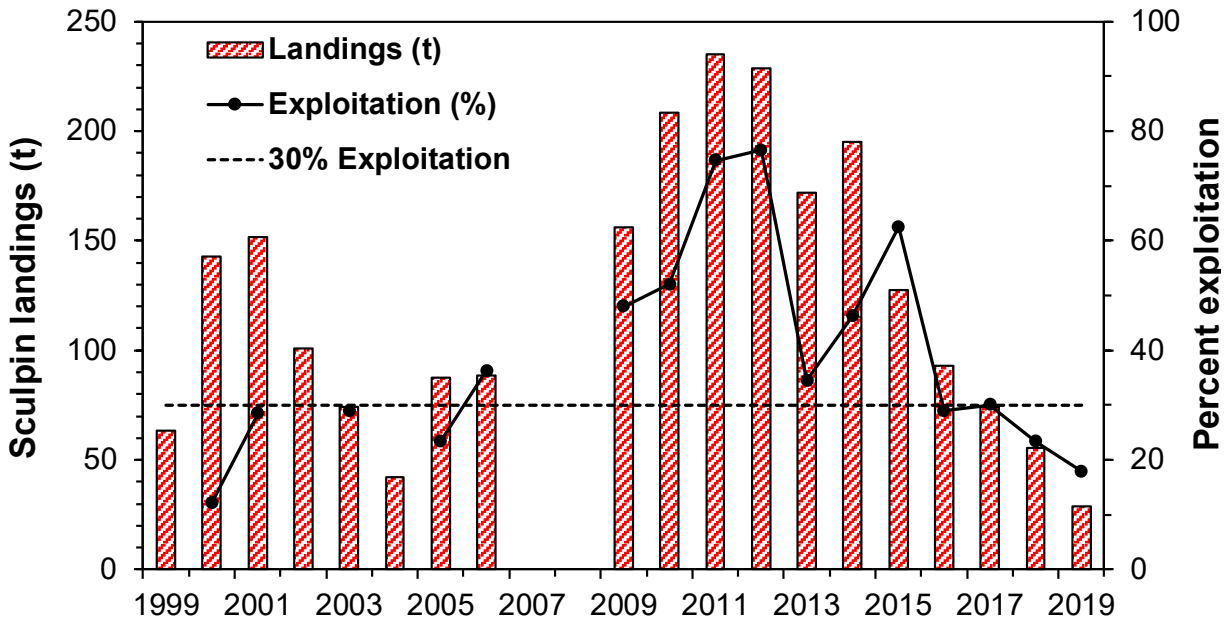


Figure 22. In season percent exploitation (black line) and total Longhorn Sculpin landings (red histograms) from the St. Mary's Bay directed fishery, 1999–2019. The black dashed line represents 30% level of exploitation, a level considered to be high for groundfish stocks. The directed fishery was closed in 2007 and 2008.

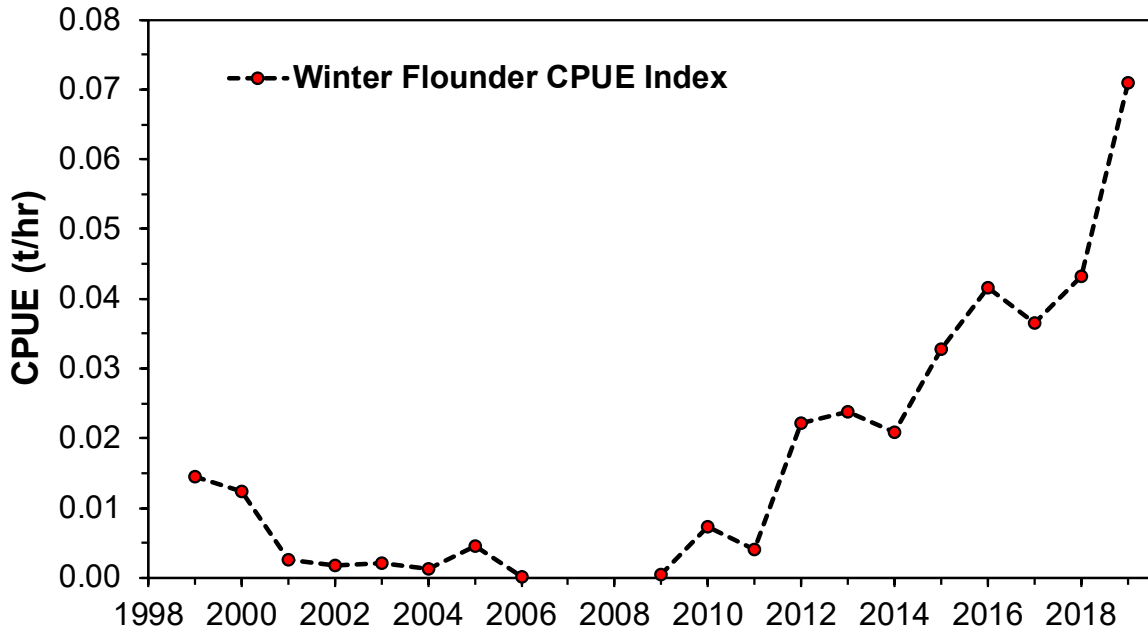


Figure 23. Trends in Catch Per Unit Effort (CPUE; t/hr) for Winter Flounder bycatch from the St. Mary's Bay directed Longhorn Sculpin fishery, 1999–2019. The directed fishery was closed in 2007 and 2008.

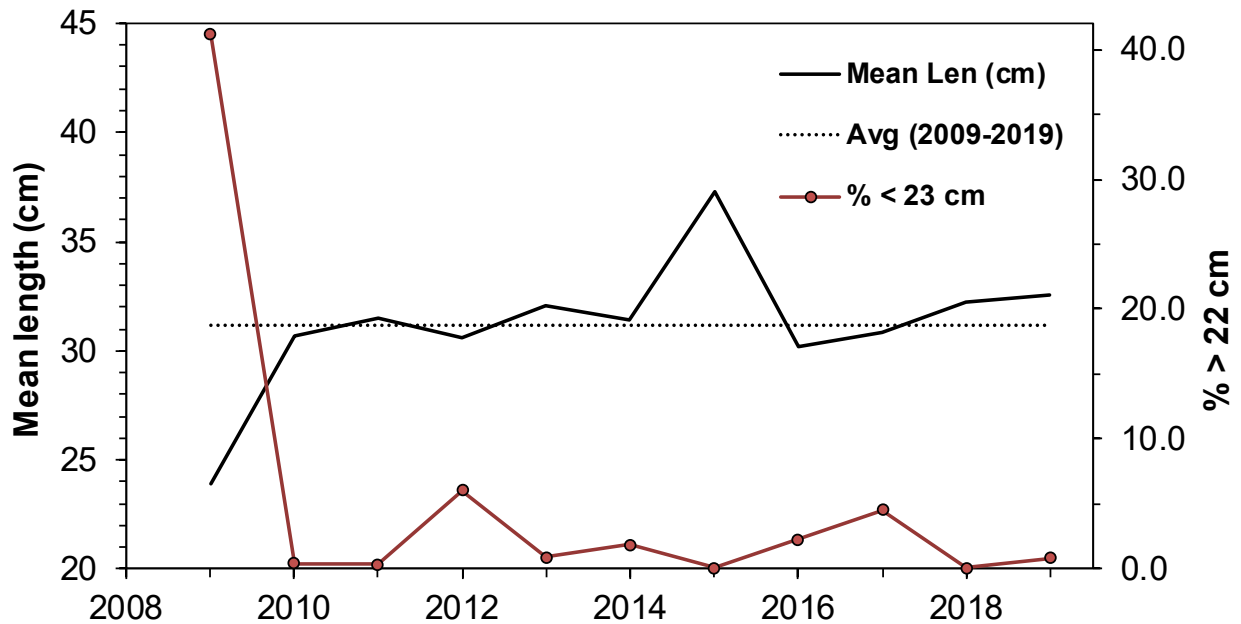


Figure 24. Mean length (cm) of Winter Flounder bycatch based on measurements recorded by at-sea observers deployed in the St. Mary's Bay Longhorn Sculpin fishery (black line) and percentage of fish < 23 cm (immature; red line), 2009–2019. The black dashed line is the time series mean length (31.2 cm).

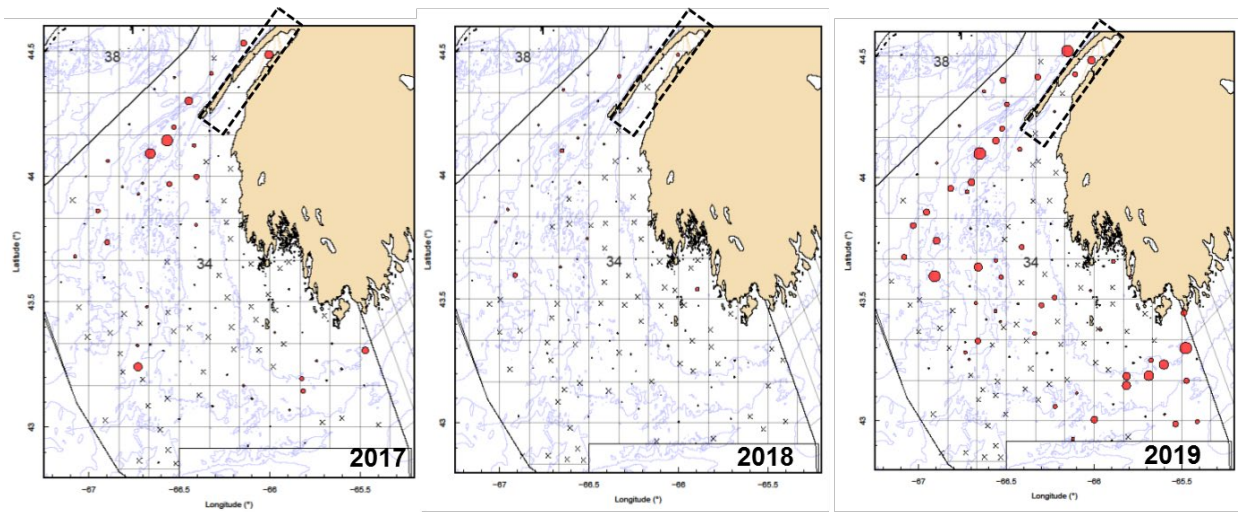


Figure 25. Longhorn Sculpin catch locations from the Lobster Fishing Area 34 Lobster survey, 2017–2019. The 6 stations sampled within St. Mary's Bay are delineated by the dashed black line rectangle.