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Sentinel Surveys 1995-2021 – Catch rates and biological information on Atlantic Cod *(Gadus morhua)* in NAFO Subdivision 3Ps

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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

Catch rates and biological information of Atlantic Cod (*Gadus morhua*) from the Sentinel survey in the Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps are updated for 2020, and preliminary results presented for 2021. Temporal trends in gillnet (small 3¼ inch mesh, large 5½ inch mesh) and linetrawl unstandardized catch rates were similar for all gears, with the highest values at the beginning of each time-series, followed by sharp declines after 1997, and oscillating around the series' mean catch rate thereafter. Age-disaggregated standardized catch rates for large mesh gillnet in recent year-classes were generally weaker than those in the past, but have increased for linetrawl in 2018–20. Age-aggregated catch rates were higher at the beginning of each time-series for both large mesh gillnets and linetrawl, declined over the mid-to-late 1990s, then remained at their lowest levels thereafter in the case of large mesh gillnet, but increased in the case of linetrawl in 2018–20.

Length frequencies of Atlantic Cod measured in Sentinel surveys indicated that the small mesh gillnet was the least selective gear (retaining small and large fish from multiple length-classes), whereas large mesh gillnet and linetrawl captured larger fish in specific size ranges and few overlapping length-classes. Fish lengths from small mesh gillnet showed several modes ranging between 37–43 cm and 53–60 cm throughout the time-series, while those of fish from large mesh gillnet and linetrawl ranged between 60–68 cm and 42–61 cm, respectively. Indices describing the physiological condition of Atlantic Cod varied at both seasonal and annual scales. Total annual removals of Atlantic Cod by Sentinel harvesters peaked at 38 t (2001), then declined to a minimum of 9.9 t (2016), prior to increasing to 15.4 t in 2020. At least 15 fish species have been recorded as Sentinel bycatch over 2005–20, with American Plaice (*Hippoglossoides platessoides*) and Redfish (*Sebastes sp.*) being the most common in gillnet and linetrawl, respectively.

INTRODUCTION

The Sentinel survey of Atlantic Cod (*Gadus morhua*) has been conducted in NAFO Subdivision 3Ps since 1995. The Sentinel Survey for 2021 was ongoing at the time of the present assessment, and its data will be reviewed in subsequent years.

Sentinel survey data were collected by trained fish harvesters at various inshore sites along the south coast of Newfoundland. The main goals of the Sentinel survey include: the development of indices of relative abundance (i.e. catch rates) for resource assessments; to incorporate knowledge of inshore fish harvesters in the resource assessment process; to evaluate inter-annual variability in resource distribution over inshore areas; and to collect information on key biological parameters used in the stock assessment (i.e. fish length, sex, maturity stage, and otoliths to determine fish age), as well as biological samples used for genetic, physiological, and toxicological analyses, and along with stomach contents for food and feeding studies.

MATERIALS AND METHODS

Fishing enterprises from St. Bride's to Burgeo have participated in the Sentinel survey of NAFO Subdivision 3Ps (Fig. 1). Participants in the Sentinel survey are trained in scientific sampling methods and equipment, computer use, and principles of resource assessment.

Sentinel harvesters fish one control and one experimental site: with the location of the control site being fixed, and based on historical fishing areas and gear-use patterns; whereas the experimental site changes only within a designated area. For each fishing day, up to half of the fishing gear is deployed at the control site, and the remaining gear is deployed at the experimental site at the discretion of Sentinel harvesters.

Sentinel surveys are usually conducted for 9–12 weeks, except in 1999 (6 weeks), and 2003–04 (8 weeks each). Since 2005, an average of 10 weeks has been maintained. Large mesh gillnet (5½ inch mesh size) crews deploy a maximum of six 50-fathom monofilament nets (rigged 2–3 to a fleet), and up to three fleets per fishing day. Linetrawl crews fish two tubs of bait hooks (approximately 500 hooks per tub) per fishing day. In addition, one small mesh gillnet (3¼ inch mesh size) is deployed at selected sites a minimum of one day per week.

Data recorded after each fishing set include: set location (Latitude, Longitude), set start and soak times, the number of Atlantic Cod, and of all bycatch fish and invertebrates species caught, and several environmental parameters (wind direction and speed, percent cloud cover, tidal conditions, in addition to water salinity and temperature at depth at selected sites). All fish (i.e., Atlantic Cod, as well bycatch species) caught by gillnets and linetrawl at control and experimental sites are kept separate and sampled on land. Each catch is sorted by species, and total number of individuals and total length (cm) by sex are recorded. Atlantic Cod otoliths are sampled using a length-stratified protocol, and up to 100 whole specimens are frozen bi-weekly and transported to the Northwest Atlantic Fisheries Center (NAFC) laboratory in St. John's, NL for detailed biological measurements, including total length (cm), gutted weight (g), and liver and gonad weights (g). Total annual removal (t) of Atlantic Cod from the Sentinel survey (control and experimental sites combined) are calculated by applying a standard weight-length relationship to the length data.

INDICES OF PHYSIOLOGICAL CONDITION

Body weight (gutted), liver and gonad weights are used to calculate three indices that reflect the physiological condition of individual Atlantic Cod (Lambert and Dutil 1997; Mello and Rose

2005): Fulton's condition factor (K); Hepatosomatic Index (HSI); and Gonadosomatic Index (GSI).

$K_i = (w_i / l_i^3)$

$HSI_i = ((h_i / w_i) \times 100)$

$GSI_i = ((g_i / w_i) \times 100)$

where w_i is gutted weight (g), l_i is total length (cm), h_i is liver weight (g), and g_i is gonad weight (g) of fish i.

SENTINEL CATCH RATES

Sentinel catch rate for gillnets and linetrawl are estimated for each fishing day and fishing community as the number of fish per gillnet, and number of fish per 1,000 hooks, respectively. Catch weight per unit effort was not estimated, because weigh scales were not available to all Sentinel harvesters over the years.

STANDARDIZED SENTINEL CATCH RATES

Age-aggregated and age-disaggregated standardized catch rates were estimated for large mesh gillnet and linetrawl, but data were insufficient to do so for small mesh gillnet. Moreover, the 2020 (as well as 2019) aging data associated with the detailed biological analysis were not available. Accordingly, the 2020 estimates of Sentinel standardized indices were calculated using a mixture of 2018 (i.e., aging data associated with the otolith and weight analyses) and 2020 aging data (i.e., aging data associated with the otolith analysis only).

Moreover, since the 2020 Fisheries and Oceans Canada (DFO) Peer Review Meeting on the stock assessment of Atlantic Cod in NAFO Subdivision 3Ps, two errors have been detected in the computer code used to compile, edit and analyze the Sentinel survey data. The first error resulted in the exclusion of a number of cod length measurements during the process of applying an age-length key to the Sentinel survey length frequency records. The error in the code removed 41,031 of 18,018,362 fish length measurements (0.23% of the records) used in the length-age analysis. The second error resulted in the exclusion of Sentinel survey data from 2 and 4 fishing sites used in the estimation of the standardized catch rate indices for large mesh gillnet and linetrawl, respectively. The Sentinel survey database have been updated to include all missing records, and the latest analysis of Sentinel indices indicated that the errors had minimal influence on previous results (see next Section).

Sentinel catch rates were standardized using Generalized Linear Models (GLM; McCullagh and Nelder 1989), in order to remove the effects of site selection and season. In addition, only Sentinel survey data recorded between June and November, and gillnets with soak times of 12–32 hours and linetrawls with soak times of 24 hours or less were used in this analysis. Zero catches were generated for ages not observed in a set, as sets with effort but no catch were considered valid input data to the model. Poisson models with a logarithmic link were fitted with the variables *Month* and *Age* as "nested effects": *Fishing Site* was nested within *Month*, and *Year* was nested within *Age*. The generic form of the age-disaggregated model is:

CPUE = Month (Fishing Site) x Age (Year) +Error

and the age-aggregated model:

CPUE = Month (Fishing Site) x Year + Error

Overall model fit was examined using the statistical significance of the effects included, and the distribution of residuals.

RESULTS

Sentinel survey data were gathered annually from between seven and seventeen fishing enterprises/locations since 1995 (Fig. 2); although the number of enterprises participating in this survey has decreased to twelve or less during the last decade. In 1995–2020, the annual number of fishing sets ranged from 2 to 80, 224 to 760, and 141 to 1,147 for small mesh gillnet, large mesh gillnet and linetrawl, respectively (Tables 1–3). In 2020, ten communities participated in the Sentinel survey in Subdivision 3Ps, predominantly fishing small mesh gillnet (3¼ inch mesh) in Lord's Cove and Little Paradise (Table 1), large mesh gillnet (5½ inch mesh) in Fox Harbour, St. Bride's and Lord's Cove (Table 2), and linetrawl in Rencontre East, Harbour Breton and Ramea (Table 3). Preliminary data from 133 sets in 2021 (all gears combined) indicate a similar pattern.

The number of sets conducted with large mesh gillnet declined from 760 in 1995 to 233 in 1999, and then fluctuated between 224 (the lowest value of the time-series) and 497 sets per year thereafter; for small mesh gillnet, the number of fishing sets was initially low, ranging between 2–29 sets annually (1995–99), increased to 40–80 sets annually between 2000–17 and then declined to 25 sets in 2020; the number of fishing sets for linetrawl was highest in 1995 (1,147 sets), declined from 498 to 194 sets annually between 1996–99, and then fluctuated between 141 and 407 sets annually in 2000–20 (Fig. 3, top panel).

Consistent with the reduction of fishing effort using large mesh gillnet, the number of fish measured for length declined by more than ten-fold: from approximately 31,000–45,000 annually in 1995–98 to 1,600–6,300 fish in 1999–2020; for small mesh gillnet, the number of fish measured was in general less variable, ranging between 460–2,544 annually, except in 1995, 1999, 2011 and 2020 (34–231 fish/year); similarly to large mesh gillnets, the substantial reduction in fishing effort by linetrawl harvesters at the start of the time-series was reflected in the total number of fish measured, declining from roughly 75,000 in 1995 to 9,500 fish in 1999, then fluctuating mostly between 9,300–21,200 fish during the 2000's and 4,400–9,600 fish during the last decade (Fig. 3, middle panel).

The percentage of sets with no cod catch ranged between 1–29% for large mesh gillnet; 0–19% for small mesh gillnet; and 0–10% for linetrawl (Fig. 3, bottom panel). No trend over time was observed for any of the gear types, however the percentage of sets with no cod catches increased substantially over the last decade for large mesh gillnet, ranging from 15 to 29% compared to < 16% between 1996–2008.

SENTINEL CATCH RATES

Mean annual catch rate for small and large mesh gillnet were similar and showed little variability between most fishing enterprises/communities, with a few exceptions in the case of small mesh gillnet (e.g., North Harbour, Little Harbour East), whereas catch rate for linetrawl tended to be more variable among enterprises/communities (Fig. 4). Mean catch rate for small mesh gillnet ranged mostly between 10–28 fish/net, but those from North Harbour and Little Harbour East were considerably higher, peaking at 169 fish/net (1998) and 160 fish/net (1997), respectively. Mean catch rate for large mesh gillnet fluctuated around 11 fish/net for most fishing enterprises/communities; however catch rates were highest once more for enterprises in Little Harbour East, and North Harbour, peaking at 92 fish/net (1996) and 100 fish/net (1997), respectively. Mean catch rate for linetrawl fluctuated around 120 fish per 1,000 hooks, with the largest ranges from Arnold's Cove, Little Paradise, Harbour Breton, François, and Burgeo (200–320 fish per 1,000 hooks); of note mean catch rates remained relatively higher in Burgeo, François, Ramea and Harbour Breton during the last 10–15 years, contrasting with the catch rates observed in the communities located further east, particularly in Placentia Bay.

Trends in mean annual catch rate in 1995–2020 (all enterprises/communities combined) were similar for all gears: the highest values were observed at the beginning of the time-series, followed by sharp declines after 1997; then values oscillated around or below the time-series mean catch rate of 28 fish/net for small mesh gillnet, 10 fish/net for large mesh gillnet, and 108 fish per 1,000 hooks for linetrawl (Fig. 5). Large mesh gillnet yielded the lowest mean annual catch rate: declining from 48 fish/net in 1997 to an average of 5 fish/net after 1999. Mean catch rate for small mesh gillnet was consistently higher than that of large mesh gillnet: peaking at 142 fish/net in 1996, then averaging 19 fish/net in 1998–2020. For linetrawl, mean catch rate peaked at 221 fish per 1,000 hooks in 1996, fluctuated around 110 fish per 1,000 hooks until 2012, then declined to its lowest value of 60 fish per 1,000 hooks in 2014. However, an increase in mean catch rate has been observed for linetrawl in 2019–20, averaging 94 fish per 1,000 hooks annually during this period. The variability of mean catch rate estimates (95% CIs) was generally small, with a few exceptions, notably for those associated with high catch rate values for small mesh gillnet at the beginning of the time-series.

STANDARDIZED SENTINEL CATCH RATES

Both age-disaggregated and age-aggregated models for standardized catch rate of Atlantic Cod from the large mesh gillnet and linetrawl surveys (control and experiments sites) provided a good fit to the data. The nested effects *Month (Fishing Site)* and *Age (Year)* in the age-disaggregated model were highly significant (P < 0.0001) in all cases. Likewise, the variable *Year*, and the nested effect of *Month (Fishing Site)* in the age-aggregated model were also highly significant in all cases. (Tables 4–5). No trends were apparent in the distribution of model residuals versus the estimated linear predictors *Year, Month, Fishing Sites*, or *Fishing Effort* (Figs. 6–9). These results suggest that overall model parameterization of standardized Sentinel survey catch rate was appropriate for both gears, and no systematic issues regarding model fit were detected. The age-disaggregated and age-aggregated models of the small mesh gillnet survey (both sites) failed the convergence diagnostics (Hessian convergence criterion), therefore the validity of the model fit was questionable and not considered in further analyses.

For large mesh gillnet, standardized annual catch rate at age (control sites) increased from 1995 to 1996, remained relatively high until 1998 (comprised mostly of 5–8 year-old fish), then declined rapidly and remained stable at low levels since 1999 (Fig. 10). Estimates for 2015–16 were the lowest for most age-groups; estimates for 2017–20 have improved slightly each year, notably for 6–9 year-old fish. Several year-classes were well-represented over 1995–98, but were replaced by mainly weaker year-classes since then; the 2010 year-class was well-represented as 3 year-old fish in 2013 but the same year-class was not tracked in catches during subsequent years. Catch rates and year-class composition for estimates from the experimental sites mirrored those from the control sites to a large extent (Fig. 11).

For linetrawl, standardized annual catch rate at age at the control sites was higher at the beginning of the time-series, and dominated by 4–8 year-old fish (Fig. 12). Catch rate declined by more than 50 % during the period 1995–99, and then increased in 2000–03 due to improved recruitment of 3 year-old fish, but overall those for older fish continued to decline until 2015; the index increased slightly in 2016–17 prior to declining once more in 2018; however catch rate increased steadily until 2020 (the highest estimate since 2006), resulting mainly from the increased contribution of 8–10 year-old fish to Sentinel linetrawl survey. Several year-classes were well-represented over 1995–98: the 1997 year-class, and especially the 1998 year-class, were consistently caught by linetrawls. In addition, the 1999 year-class also appeared relatively strong as 4–5 year-old fish, but was generally below average at older ages. Catch rates and age composition of catches from the experimental sites also followed the same patterns as observed at the control sites, but were in general higher at any given year (Fig. 13).

The effect of the computer code errors on the estimation of the standardized catch rate indices (both gears and sites) were in general small and limited to specific age-groups or time periods (Figs. 14–15). Overall the trend and the magnitude of change of the age-disaggregated indices were very similar over time, except for Atlantic cod ages 3–4 in 1996–2004 (large mesh gillnet) and ages 9–10 in 2015–20 (linetrawl). Furthermore, the age-aggregated indices for large mesh gillnet and linetrawl (both sites) indicate that the assessments not corrected for the computer code errors are within the 95% CIs of the current estimates, except for the 2020 estimate of the linetrawl survey from the control sites (Figs. 16–17). Age-aggregated standardized annual catch rate for large mesh gillnet from the control and experimental sites declined rapidly from 30 and 34 fish/net respectively in 1997 to 5 fish/net 1999, then remained stable at low levels (≤ 5 fish/net) in 2000–20. For linetrawl, catch rate from control and experimental sites decreased over 1995–99, from 190 and 216 fish per 1,000 hooks, respectively, to 92 fish per 1,000 hooks; the indices remained relatively stable until 2008, then declined to its lowest value in 2018 (48 and 61 fish per 1,000 hooks), prior to increasing in 2020 to 102 and 104 fish per 1,000 hooks (control and experimental sites, respectively). In most cases the variability of mean standardized catch rate (95% CIs) was small, with a few exceptions, notably for those associated with high catch rate values (large mesh gillnet).

BIOLOGICAL INFORMATION

Length

Length frequency distributions of Atlantic Cod from Sentinel surveys indicated that large mesh gillnet and linetrawl tended to capture larger fish from specific size ranges, whereas the small mesh gillnet was the least selective gear: retaining small and large fish from multiple length-classes (Fig. 18). Total length (TL) of fish retained in large mesh gillnet and linetrawl were 19–120 cm and 16–120 cm, respectively, with modal lengths for any particular year ranging between 60–68 cm (large mesh gillnet) and 42–61 cm (linetrawl). Atlantic Cod retained in small mesh gillnet were 20–115 cm (TL), with smaller bi-modal lengths ranging between 37–43 cm and 53–60 cm for the first and second modal-class, respectively. Of note, the length frequency distributions of fish retained by both small and large mesh gillnets in 2020 and 2021 are similar to the distribution from previous years, whereas in the case of linetrawl, modal length remained at 50 cm as in previous years but there was a noticeable increase in the frequency of larger fish (51–60 cm) from 2015 onwards.

Indices of physiological condition

All three indices (K, HSI, GSI) that reflect the physiological condition of Atlantic Cod varied seasonally and annually (Fig. 19). Fulton's K and HSI covaried: showing minimum values in April (HSI) and May (K) for females and May (HSI, K) for males; these indices remained high during the summer and fall and then peaked in December (K and HSI) for females, and October (K) and December (HSI) for males. The temporal trend in GSI contrasted with those of the other two indices: peaking in June for females and May for males, then reaching minimum values in October for females and September for males. Inter-annual trajectories in K and HSI also covaried: peaking in 2003 (K) and 2004 (HSI) for females, and 2004 (K and HSI) for males, then declining and reaching minimum values in 2012 (HSI) and 2013 (K) for females, and 2014 (K) and 2020 (HSI) for males. Female and male GSI fluctuated without any clear pattern over the time-series: their lowest GSI occurred in 2009 and 2003 for females and males, respectively; the GSI for females increased since 2010 and remained above the levels of previous decades, whereas for males the index has remained the same (i.e., no clear pattern) until 2017; the index increased in 2018–20 in the case of males and decreased in 2019–20 in the case of females. Of note, HSI decreased from 2017–20 for males, but increased for females during the same time

period, whereas K decreased for females (2018–20), and increase for males (2019–20). It should be noted that the data used for estimating the indices of physiological condition (as well length frequency distribution) were pooled from fish captured in all fishing communities/fishing enterprises, and that many of these enterprises participated in the Sentinel survey over different periods of time. Notwithstanding, confidence intervals for these three indices were usually small, suggesting that the impact of the unbalanced spatio-temporal design had a limited effect on the precision of the estimated indices.

SENTINEL SURVEY REMOVALS

Total removals (control plus experimental sites, all gears combined) of Atlantic Cod caught in Subdivision 3Ps Sentinel surveys over 2001–20 was highest in 2001–02 (38 t), declined by half during the period 2003–05 and then increased to 33 t in 2006; removals declined thereafter until 2011 and have since then fluctuated around 15 t annually (Fig. 20). At least 15 fish species have being recorded as Sentinel bycatch over 2005–20, and between 46–633 and 15–1593 individual fish have been recorded annually as bycatch by large mesh gillnet and linetrawl, respectively (Fig. 21). Bycatch species in the gillnet survey consisted of: American Plaice (*Hippoglossoides platessoides*) which was the most common, followed by Winter Flounder (*Pseudopleuronectes americanus*) and Redfish (*Sebastes* sp.). Bycatch species in the linetrawl survey consisted of: American Plaice, Redfish and Wolffish (*Anarhichas lupus and Anarhichas sp.*) which were the most common between 2002–11, with Redfish becoming the most common bycatch species thereafter. Other species reported infrequently as Sentinel bycatch were Haddock (*Melanogrammus aeglefinus*), Atlantic Halibut (*Hippoglossus hippoglossus*), Lumpfish (*Cyclopterus lumpus*), Pollock (*Pollachius virens*), Thorny Skate (*Amblyraja radiate*), Greenland Halibut (*Reinhardtius hippoglossoides*), White Hake (*Urophycis tenuis*), Witch Flounder (*Glyptocephalus cynoglossus*), and Yellowtail Flounder (*Limanda ferruginea*).

DISCUSSION

The most comprehensive Sentinel survey coverage in Subdivision 3Ps was conducted by linetrawl harvesters, including several sites in Placentia Bay, Fortune Bay, and the southwest coast. Sentinel survey coverage by small and large mesh gillnet was centered in Placentia Bay. Coverage by large mesh gillnet in Fortune Bay was limited to Grand Bank and Seal Cove (1999–2004).

The analysis of Sentinel catch rates aggregated by community and gear type indicated that the highest catch rates by gillnet harvesters were observed in Placentia Bay during the period 1995–98, whereas catch rates in Fortune Bay were considerably lower during the same period; catch rates declined by one order of magnitude in Placentia Bay since then and have remained unchanged. For linetrawl, trends in catch rate for communities in Placentia Bay were similar to those observed for gillnets, but for communities from Fortune Bay and along the southwest coast, catch rates remained relatively higher over the years.

The standardized age-disaggregated catch rate from large mesh gillnet was comprised mostly of 6–8 year-old fish during the period of high relative abundance; 5–6 year-old fish accounted for most of the large gillnet catch during the period of low relative abundance, except in 2018–20, when the proportion of 7–9 year-old fish increased. The same age-classes contributed to the catch rate from linetrawl during the periods of high and low relative abundance, in addition the contribution of 3–5 year-old fish was higher for linetrawl over the years. Of note, catch rates from linetrawl in 2019–20 were higher in relation to estimates from the previous 5–6 years, and were dominated by older age-classes, ranging between 6–9 years-old. Moreover, estimates from the experimental sites mirrored those from the control sites to a large extent (both gears),

suggesting that the trends observed in standardized catch rates are representative of this stock in inshore waters during the summer and fall.

Finally, while the number of enterprises participating in the Sentinel survey has decreased over the years, this program constitutes an independent source of information that can be readily incorporated in resource assessments of commercial fish stocks like the Subdivision 3Ps Atlantic Cod (Varkey et al. 2022, DFO 2022). It also engages stakeholders (e.g., inshore fish harvesters) to participate in the shared responsibilities of resource conservation and sustainable exploitation.

ACKNOWLEDGEMENTS

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APPENDIX I – TABLES

Table 1. Number of Sentinel survey sets (Gillnet 3¼ inch mesh) per fishing enterprise/community in Subdivision 3Ps, 1995–2021 (including sets with no catches). Data for 2021 are preliminary.

Community	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
St. Bride's	0	0	1	11	0	7	9	20	9	11	11	10	10	9
Little Hr. East	1	5	7	8	1	19	15	0	0	0	0	0	0	0
North Hr.	1	5	7	4	1	18	13	8	8	5	11	10	11	9
Garden Cove	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Paradise	0	0	0	0	0	0	6	6	6	6	6	8	10	6
Red Hr.	0	0	0	0	0	0	0	6	2	4	0	0	1	0
Lawn	0	0	7	6	4	4	19	20	10	18	16	18	11	10
Lord's Cove	0	0	0	0	0	0	0	20	12	16	16	15	20	20
Total	2	10	22	29	6	48	62	80	47	60	60	61	63	54

Table 1 continued

Community	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
St. Bride's	7	0	0	0	0	0	0	0	0	0	0	0	0
Little Hr. East	0	0	0	0	0	0	0	0	0	0	0	0	0
North Hr.	9	12	10	10	2	0	0	0	0	0	0	0	0
Garden Cove	0	0	0	0	7	9	10	9	10	9	12	11	1
Little Paradise	10	12	14	10	14	14	15	11	14	12	12	14	3
Red Hr.	0	8	5	2	0	0	2	0	0	0	0	0	0
Lawn	0	0	0	0	0	0	0	0	0	0	0	0	0
Lord's Cove	20	20	20	20	20	20	20	20	20	2	0	0	0
Total	46	52	49	42	43	43	47	40	44	23	24	25	4

Table 2. Number of Sentinel survey sets (Gillnet 5½ inch mesh) per fishing enterprise/community in Subdivision 3Ps, 1995–2021 (including sets with no catches). Data for 2021 are preliminary.

Community	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
St. Bride's	160	84	69	69	2	42	54	59	50	38	50	54	60	54
Fox Hr.	145	88	71	71	36	48	60	60	48	54	54	54	60	60
Little Hr. East	156	31	44	40	9	37	52	0	0	0	0	0	0	0
Arnold's Cove	4	0	8	21	2	20	0	0	0	0	0	0	0	0

Community	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
North Hr.	111	63	59	44	18	55	42	34	37	25	44	40	43	34
Garden Cove	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monkstown	145	69	72	72	36	57	60	60	0	0	0	0	0	0
Little Paradise	0	6	17	29	24	30	30	24	18	36	30	36	48	36
Red Hr.	0	0	12	24	15	21	16	23	6	18	24	18	23	11
Lawn	0	32	62	65	32	60	59	60	26	54	52	54	48	44
Lord's Cove	39	39	40	48	36	48	60	58	35	54	53	53	60	60
Grand Bank	0	0	0	0	0	0	24	23	18	24	23	18	18	18
Rencontre East	0	0	2	18	0	0	0	0	0	0	0	0	0	0
Seal Cove	0	0	3	24	23	6	40	27	8	0	0	0	0	0
Total	760	412	459	525	233	424	497	428	246	303	330	327	360	317

Table 2 continued

Community	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
St. Bride's	42	30	32	36	35	36	40	36	40	28	40	40	0
Fox Hr.	60	60	60	57	60	58	60	59	59	60	60	54	0
Little Hr. East	0	0	0	0	0	0	0	0	0	0	0	0	0
Arnold's Cove	0	0	0	0	0	0	0	0	0	0	0	0	0
North Hr.	37	49	42	39	8	0	0	0	0	0	0	0	0
Garden Cove	0	0	0	0	54	54	60	53	60	54	72	66	6
Monkstown	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Paradise	41	36	42	30	42	42	48	42	42	42	36	42	23
Red Hr.	16	16	14	10	4	8	8	4	24	20	20	20	20
Lawn	40	36	6	0	0	0	0	0	0	0	0	0	0
Lord's Cove	59	60	57	60	59	60	40	40	40	4	40	40	32
Grand Bank	18	30	12	31	16	14	26	14	0	16	12	12	24
Rencontre East	0	0	0	0	0	0	0	0	0	0	0	0	0
Seal Cove	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	313	317	265	263	278	272	282	248	265	224	280	274	105

Table 3. Number of Sentinel survey sets (Linetrawl) per fishing enterprise/community in Subdivision 3Ps, 1995–2021 (including sets with no catches). Data for 2021 are preliminary.

Community	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Arnold's Cove	147	63	61	6	5	22	0	0	0	0	0	0	0	0

Community	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Little Paradise	52	32	27	10	11	14	27	34	18	16	16	12	8	16
Red Hr.	31	30	17	7	5	8	14	28	14	11	12	16	17	23
Lord's Cove	8	9	0	0	0	0	0	4	0	0	0	0	0	0
Grand Bank	0	0	0	0	0	0	36	36	20	20	20	24	24	28
Rencontre East	174	96	64	56	36	90	71	60	20	32	40	36	36	36
Hr. Breton	154	39	27	28	31	45	31	53	34	30	33	40	30	38
Seal Cove	199	71	41	18	10	52	6	21	1	0	0	0	0	0
Ramea	201	46	96	60	38	88	92	82	46	36	44	44	49	50
Francois	181	66	74	68	30	52	35	22	25	10	42	38	28	32
Burgeo	0	46	60	62	28	36	64	45	36	24	28	44	40	36
Total	1147	498	467	315	194	407	376	385	214	179	235	254	232	259

Table 3 continued

Community	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Arnold's Cove	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Paradise	12	0	12	0	0	12	12	8	12	16	16	12	0
Red Hr.	16	16	18	18	28	17	30	8	24	20	20	20	4
Lord's Cove	0	0	0	0	0	0	0	0	0	0	0	0	0
Grand Bank	28	16	15	16	25	24	16	17	36	24	22	28	0
Rencontre East	36	36	36	40	40	40	40	40	40	40	40	36	8
Hr. Breton	34	37	36	36	32	40	38	32	44	40	43	43	0
Seal Cove	0	0	0	0	0	0	0	0	0	0	0	0	0
Ramea	48	48	48	48	46	48	48	0	0	0	0	0	0
Francois	22	27	0	0	0	0	0	0	0	0	0	0	0
Burgeo	41	40	40	24	34	32	32	36	40	34	26	36	12
Total	237	220	205	182	205	213	216	141	196	174	167	175	24

Table 4. Model information and results of fitting age-disaggregated and age-aggregated standardized Sentinel catch rates for large mesh (5½ inch) gillnets, using data from control and experimental sites in Subdivision 3Ps, 1995–2020.

Class	Level	Values
Fishing Site	18	61 61.5 63 63.5 64 65 66 66.5 67 68 69 69.5 70 71 71.5 73 75 76
Month	6	6 7 8 9 10 11
Year	26	1995–2020
Age	8	3 4 5 6 7 8 9 10

LR Statistics for Type 3 Analysis

Age-disaggregated - Control Sites

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	66	3974	81.82	<.0001	5399.90	<.0001
Age (Year)	207	3974	99.86	<.0001	20670.5	<.0001

Age-disaggregated - Experimental Sites

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	69	4003	71.77	<.0001	4952.39	<.0001
Age (Year)	207	4003	118.75	<.0001	24581.6	<.0001

Age-aggregated - Control Sites

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	66	439	12.03	<.0001	794.14	<.0001
Year	25	439	45.83	<.0001	1145.83	<.0001

Age-aggregated - Experimental Sites

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	69	440	10.87	<.0001	750.28	<.0001
Year	25	440	53.60	<.0001	1339.90	<.0001

Table 5. Model information and results of fitting age-disaggregated and age-aggregated standardized Sentinel catch rates for linetrawl, using data from control and experimental sites in Subdivision 3Ps, 1995–2020.

Class	Level	Values
Fishing Site	20	62 65 68 69 69.5 70 71 71.5 73 73.5 74 75 76 76.5 76.75 77 77.5 78 78.5 78.75
Month	6	6 7 8 9 10 11
Year	26	1995–2020
Age	8	3 4 5 6 7 8 9 10

LR Statistics for Type 3 Analysis

Age-disaggregated - Control Sites

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	88	3888	29.53	<.0001	2598.20	<.0001
Age (Year)	207	3888	47.22	<.0001	9775.16	<.0001

Age-disaggregated - Experimental Sites

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	87	3873	27.19	<.0001	2365.63	<.0001
Age (Year)	207	3873	50.28	<.0001	10407.1	<.0001

Age-aggregated - Control Sites

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	88	409	6.32	<.0001	556.25	<.0001
Year	25	409	8.96	<.0001	224.12	<.0001

Age-aggregated - Experimental Sites

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	87	408	5.91	<.0001	513.94	<.0001
Year	25	408	9.48	<.0001	236.88	<.0001
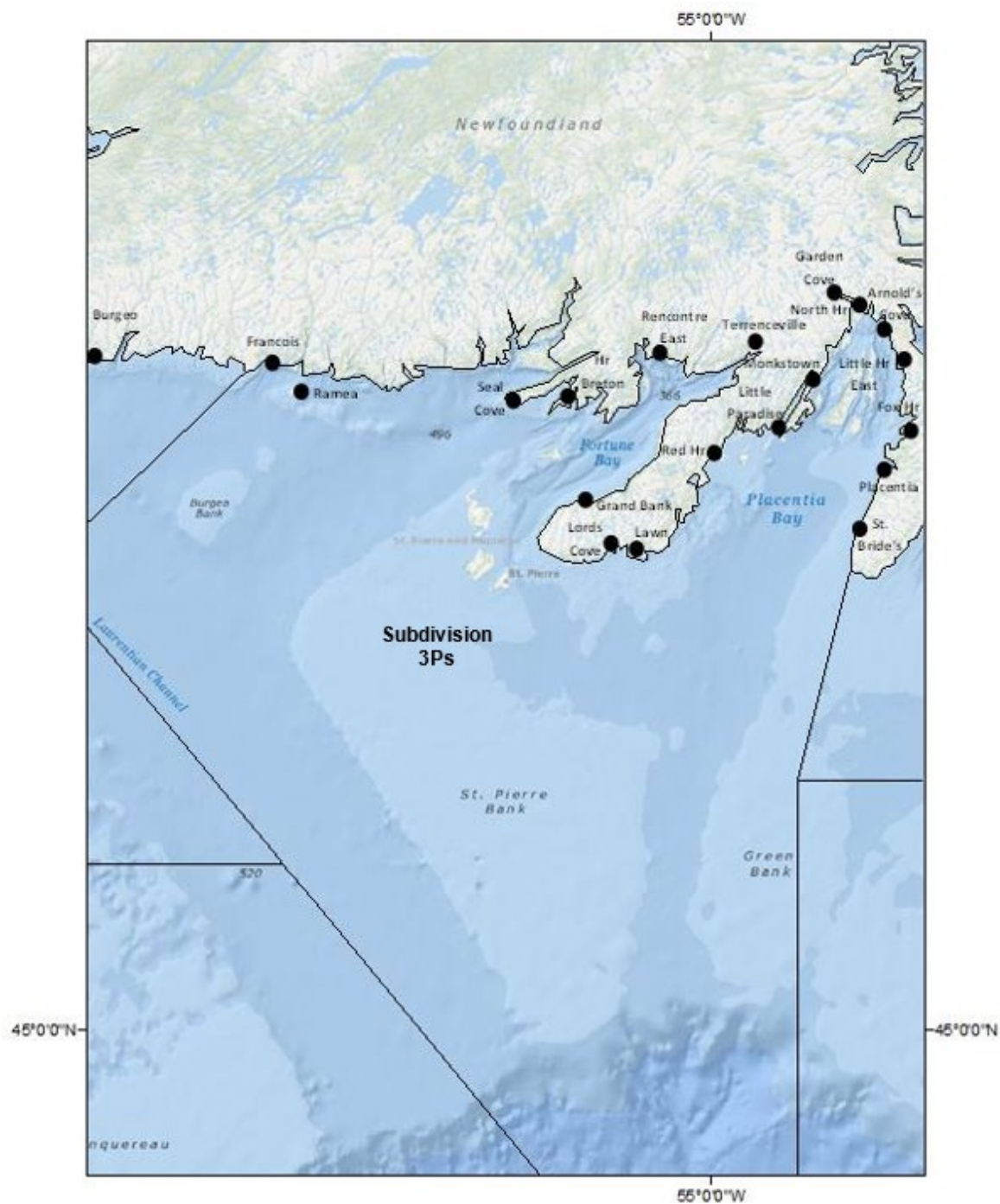
Figure 1. Map of NAFO Subdivision 3Ps indicating the communities that have participated in Sentinel survey, 1995–2021.
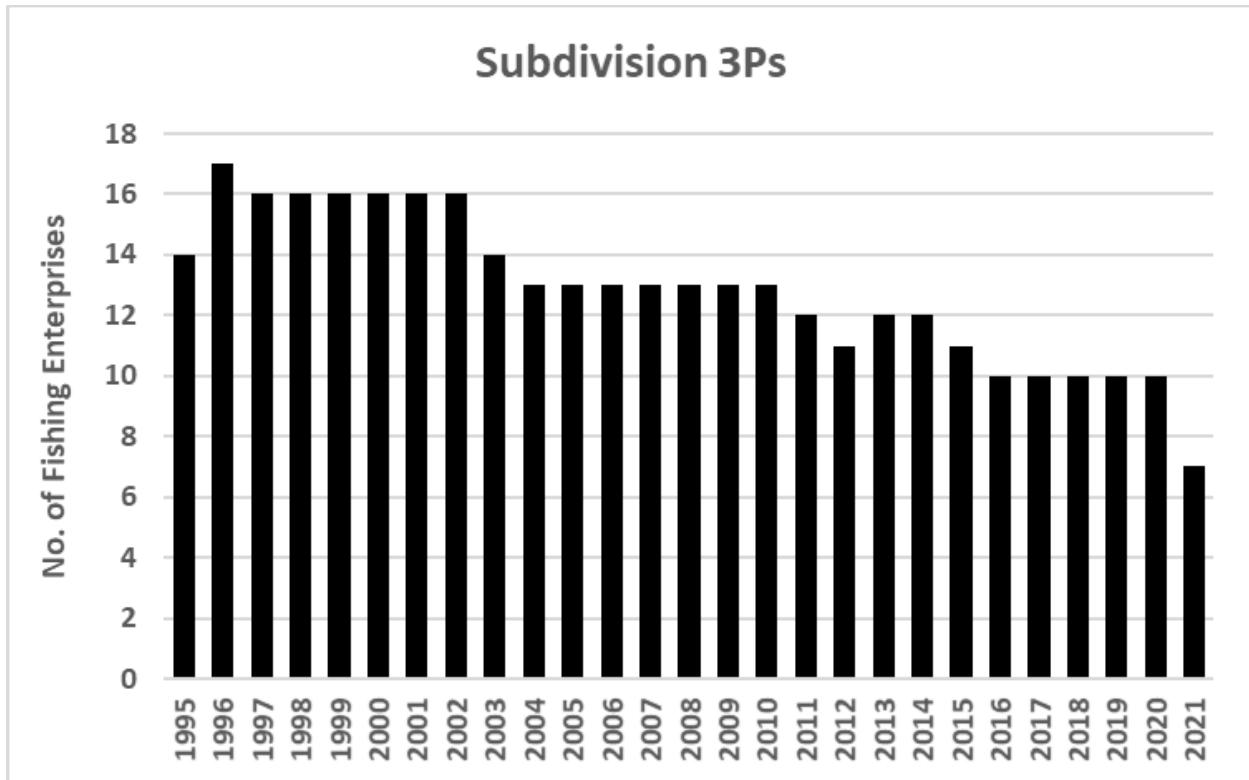
Figure 2. Number of fishing enterprises that have participated in the Sentinel survey annually between 1995 and 2021. Data for 2021 are preliminary.
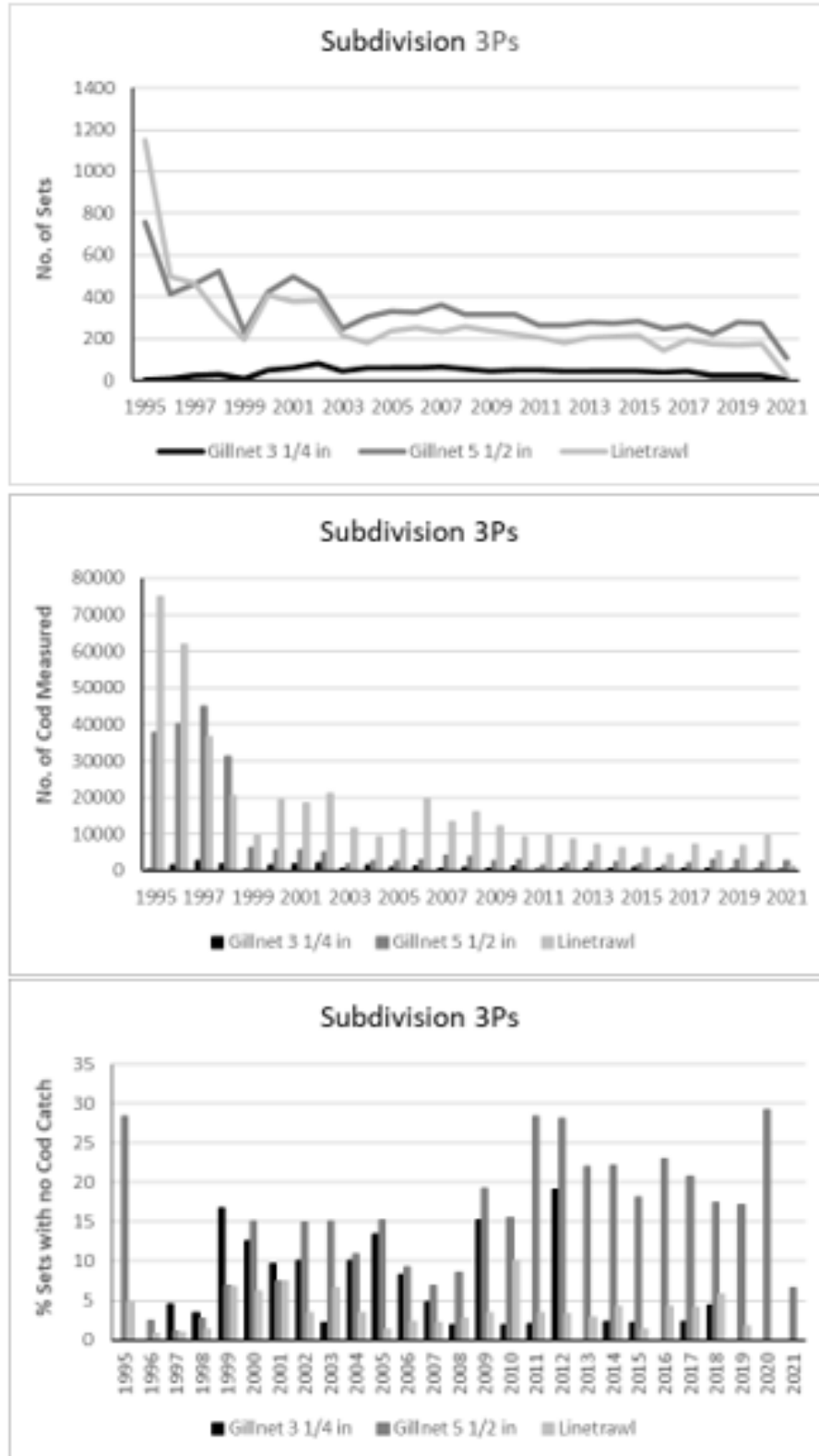
Figure 3. Annual Sentinel survey number of sets by gear type (top panel), the number of Atlantic Cod caught by gear type (middle panel), and the percentage of sets with no cod catch (bottom panel) in Subdivision 3Ps, 1995–2021. Data for 2021 are preliminary.
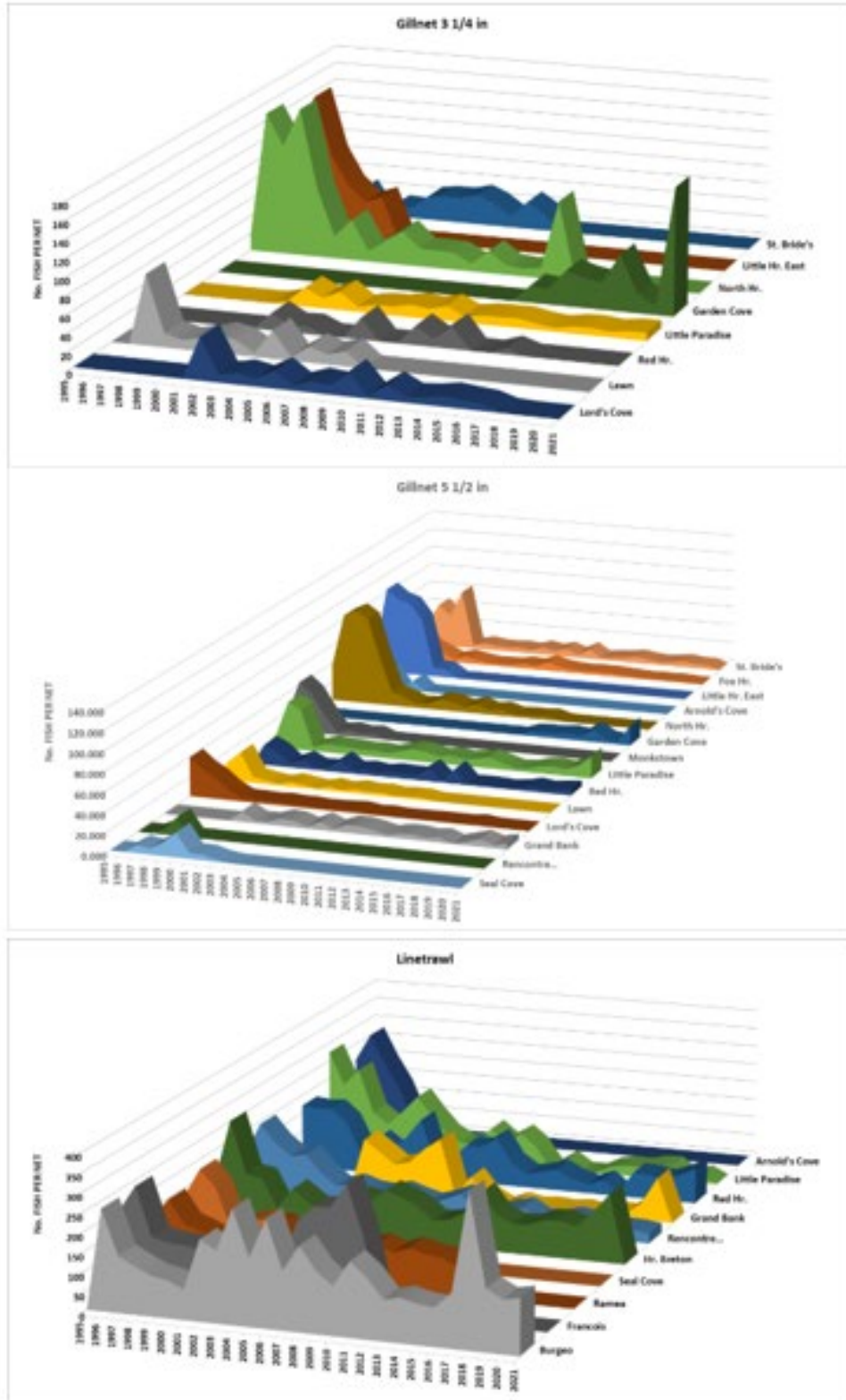
Figure 4. Distribution of mean annual catch rates of Atlantic Cod from small and large mesh gillnet and linetrawl (1995–2021), aggregated by fishing communities of Sentinel surveys in Subdivision 3Ps (control and experimental sites combined). Data for 2021 are preliminary.
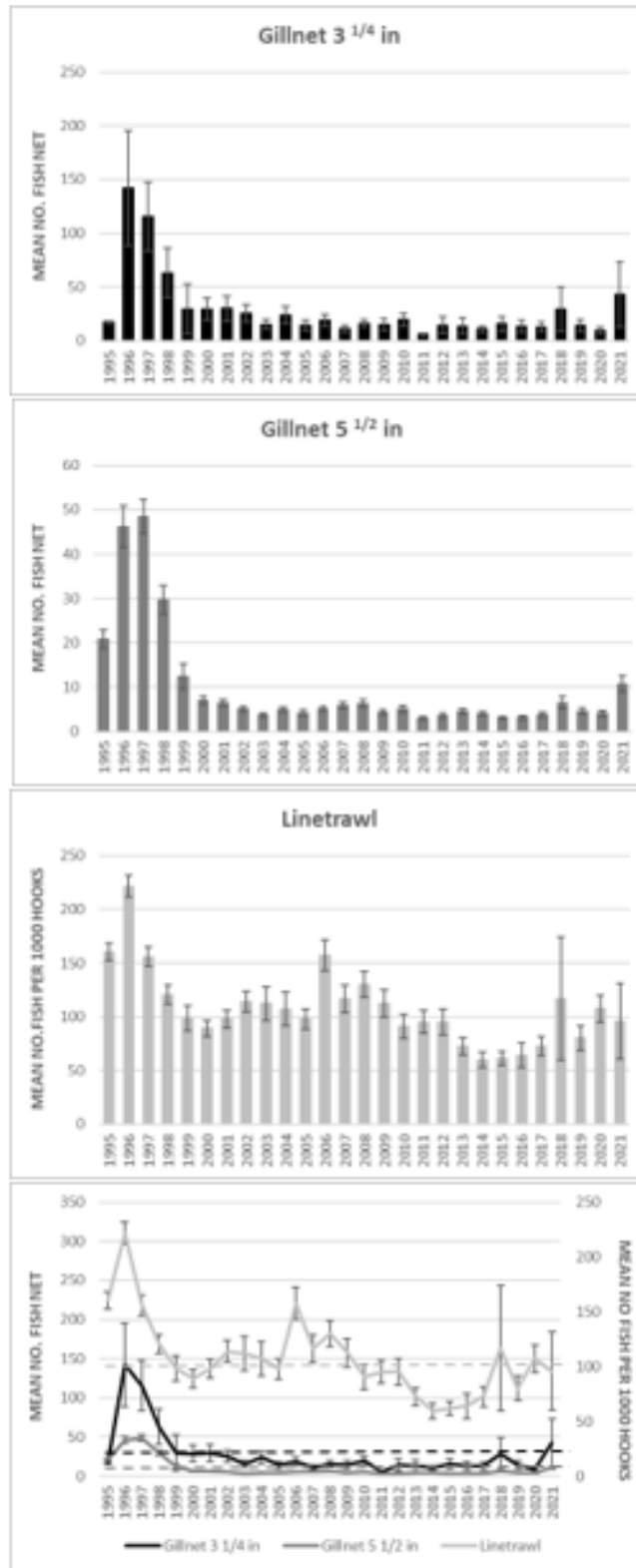
Figure 5. Mean annual catch rate of Atlantic Cod from small and large mesh gillnets and linetrawl, as well all gears combined in a single plot from Sentinel surveys in Subdivision 3Ps (control and experimental sites combined). Dotted line = time-series mean, T-bars = +/- 95% CI. Data for 2021 are preliminary.
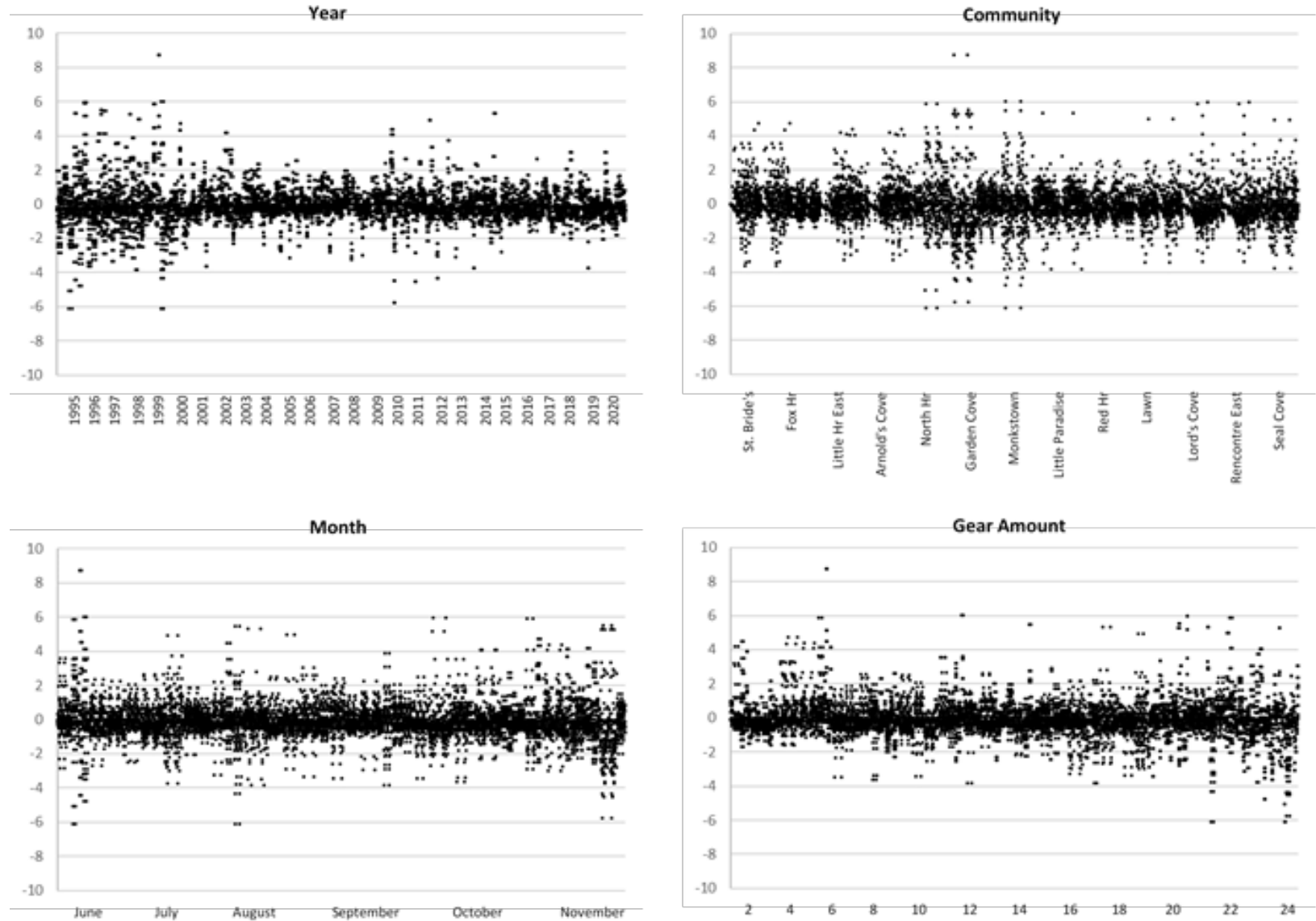
Figure 6. Deviance residuals from the standardized catch rate model (control sites) for large mesh gillnet in Subdivision 3Ps, 1995–2020. Panels show residuals plotted by Year, Month, Fishing Site (Community), and Fishing Effort (Gear Amount).
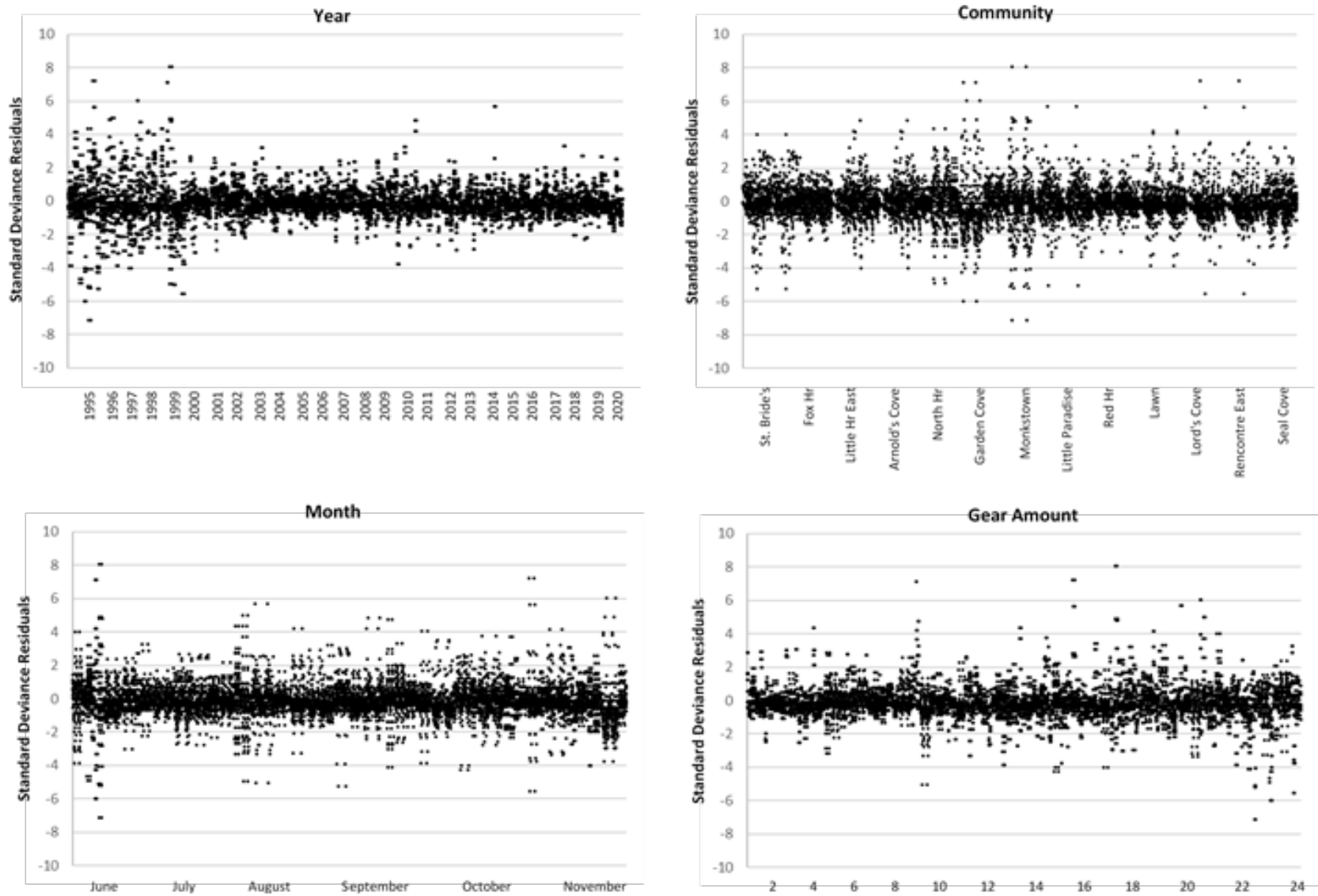
Figure 7. Deviance residuals from the standardized catch rate model (experimental sites) for large mesh gillnet in Subdivision 3Ps, 1995–2020. Panels show residuals plotted by Year, Month, Fishing Site (Community), and Fishing Effort (Gear Amount).
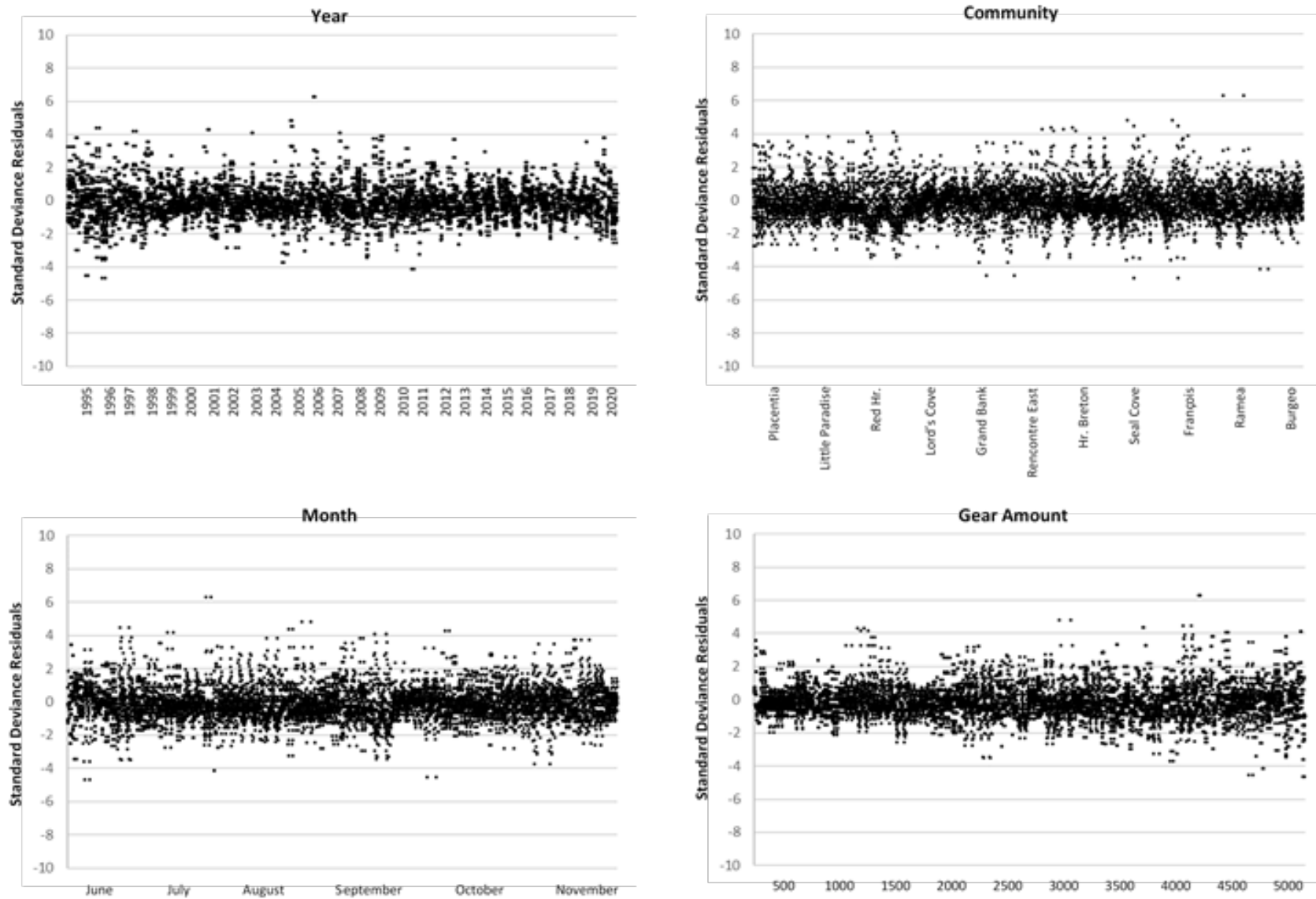
Figure 8. Deviance residuals from the standardized catch rate model (control sites) for linetrawl in Subdivision 3Ps, 1995–2020 Panels show residuals plotted by Year, Month, Fishing Site (Community), and Fishing Effort (Gear Amount).
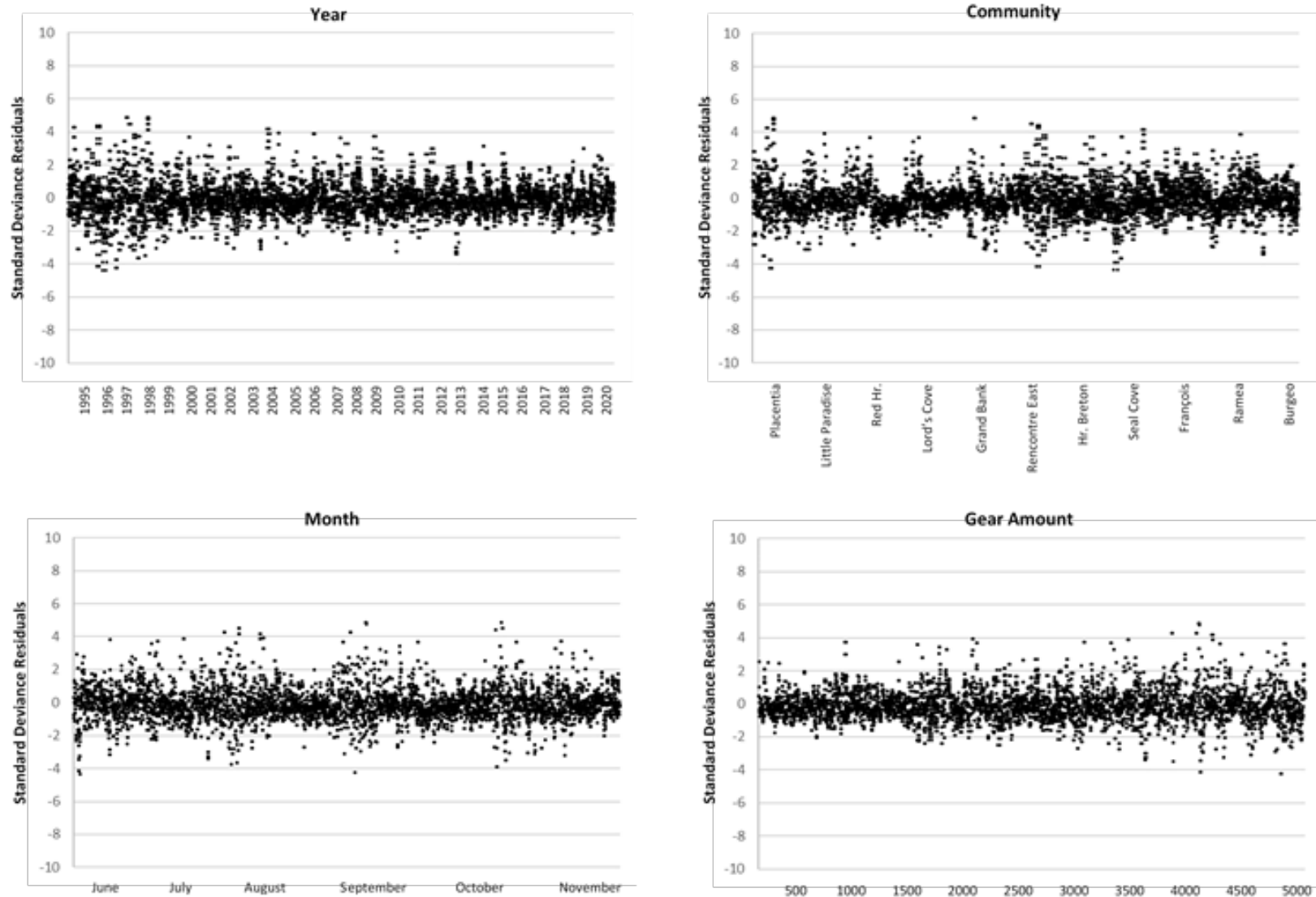
Figure 9. Deviance residuals from the standardized catch rate model (experimental sites) for linetrawl in Subdivision 3Ps, 1995–2020. Panels show residuals plotted by Year, Month, Fishing Site (Community), and Fishing Effort (Gear Amount).
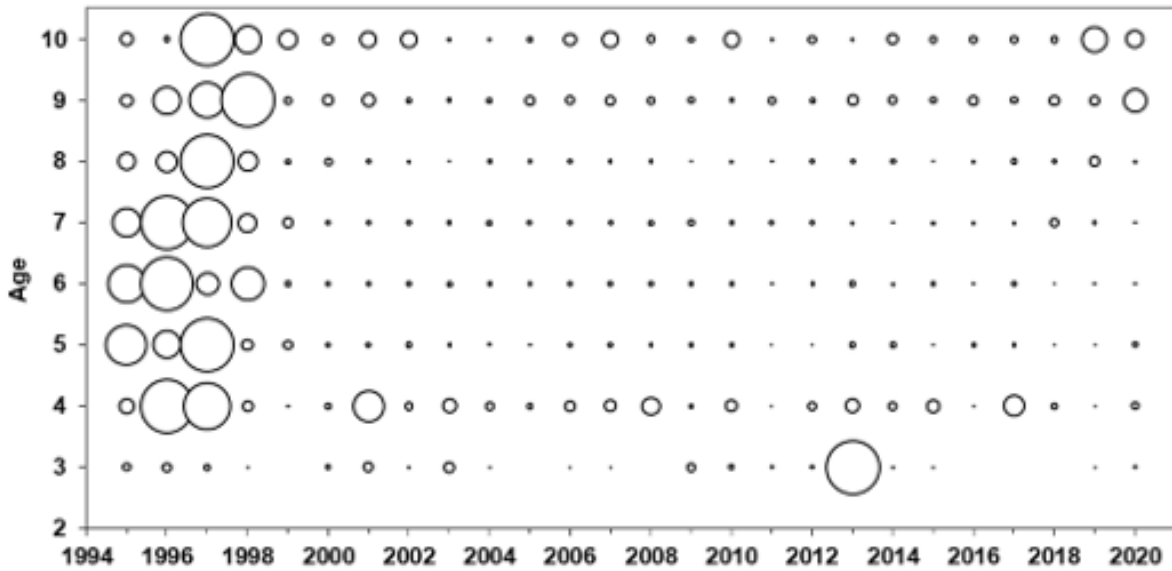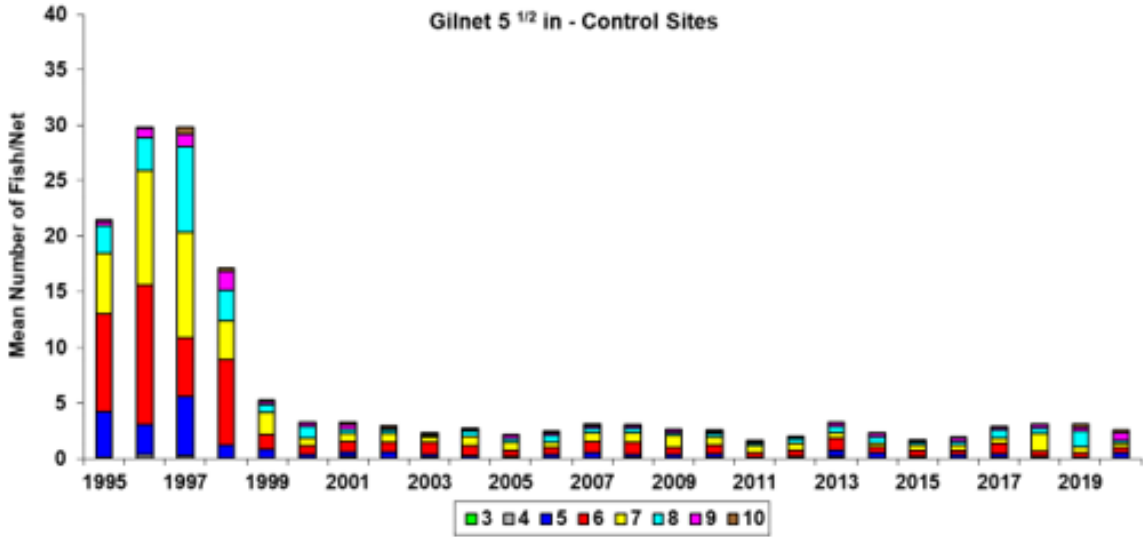
Figure 10. Standardized age-disaggregated catch rate for large mesh gillnet (top panel), and the proportions of Sentinel catch rate at age (bottom panel) using data from Sentinel survey control sites in Subdivision 3Ps, 1995–2020.
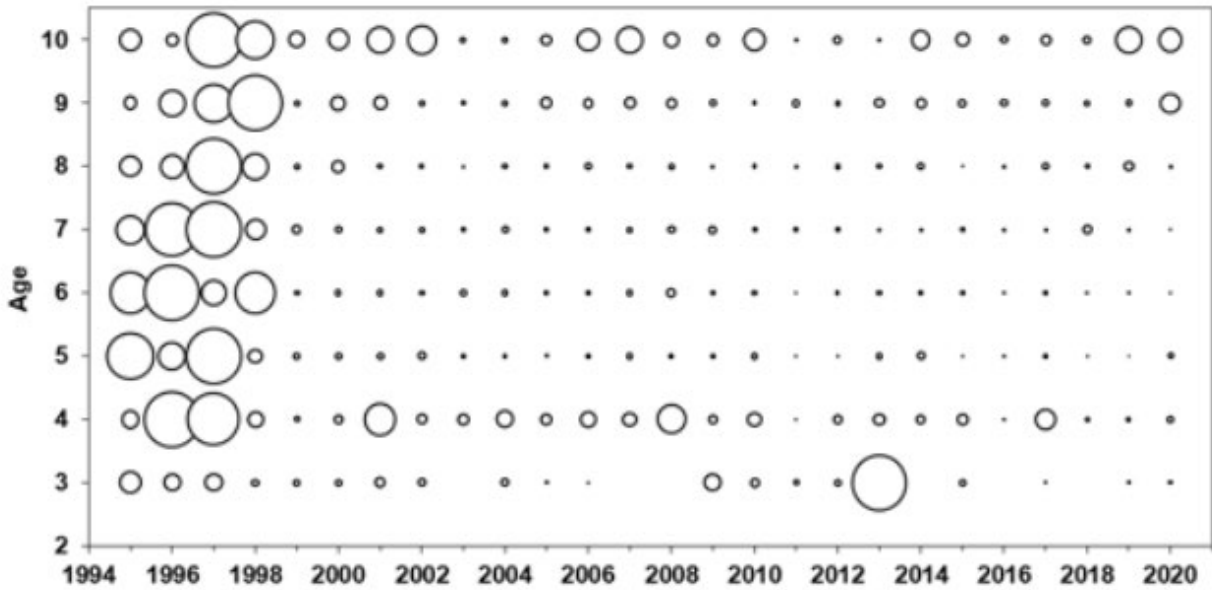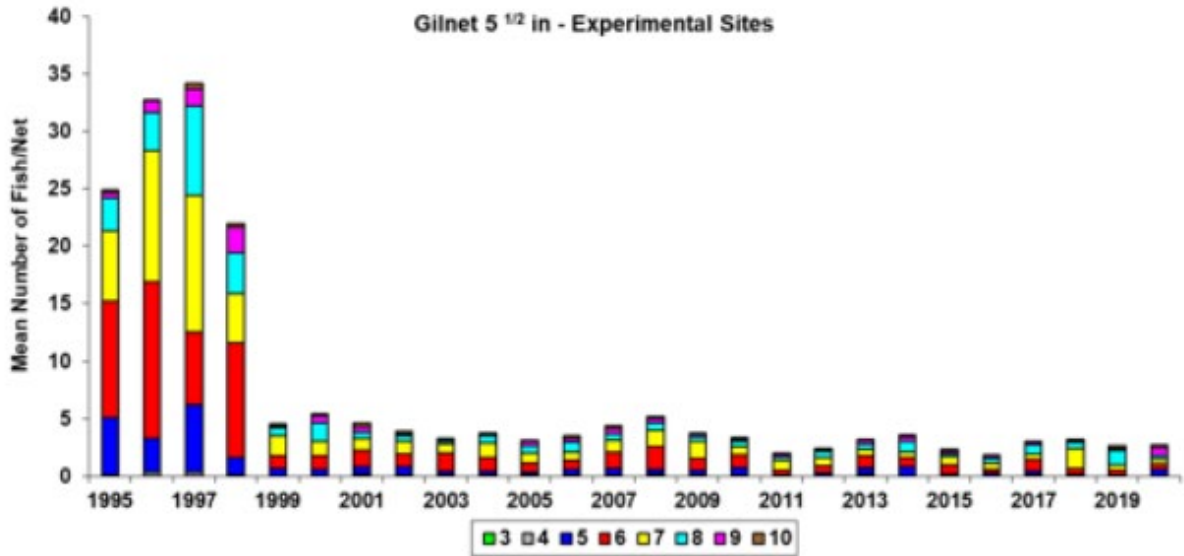
Figure 11. Standardized age-disaggregated catch rate for large mesh gillnet (top panel), and the proportions of Sentinel catch rate at age (bottom panel) using data from Sentinel survey experimental sites in Subdivision 3Ps, 1995–2020.
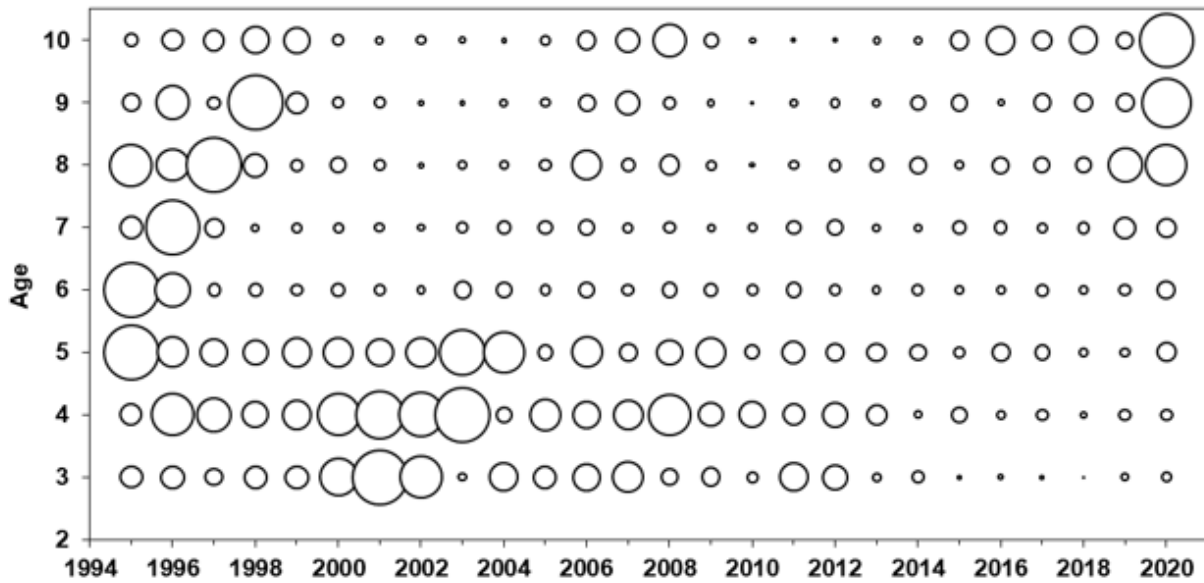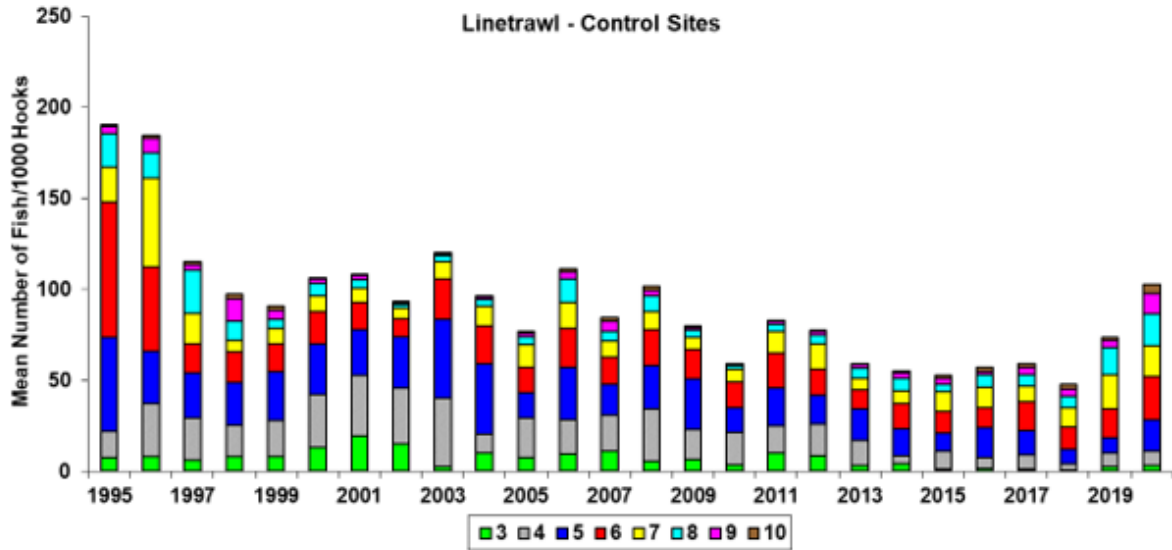
Figure 12. Standardized age-disaggregated catch rate for linetrawl (top panel), and the proportions of Sentinel catch rate at age (bottom panel) using data from Sentinel survey control sites in Subdivision 3Ps, 1995–2020.
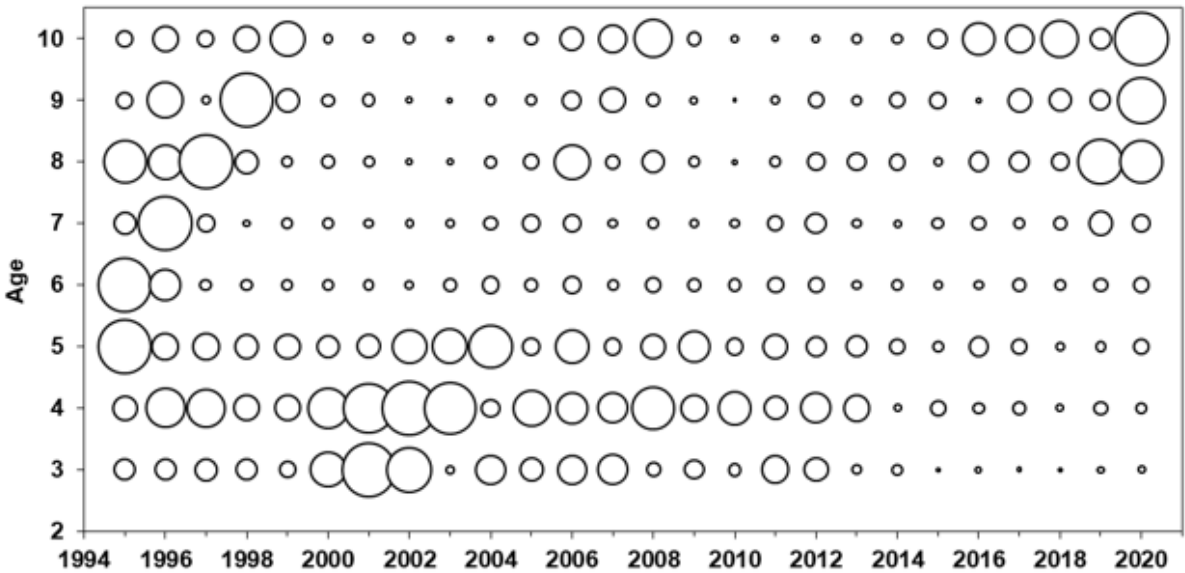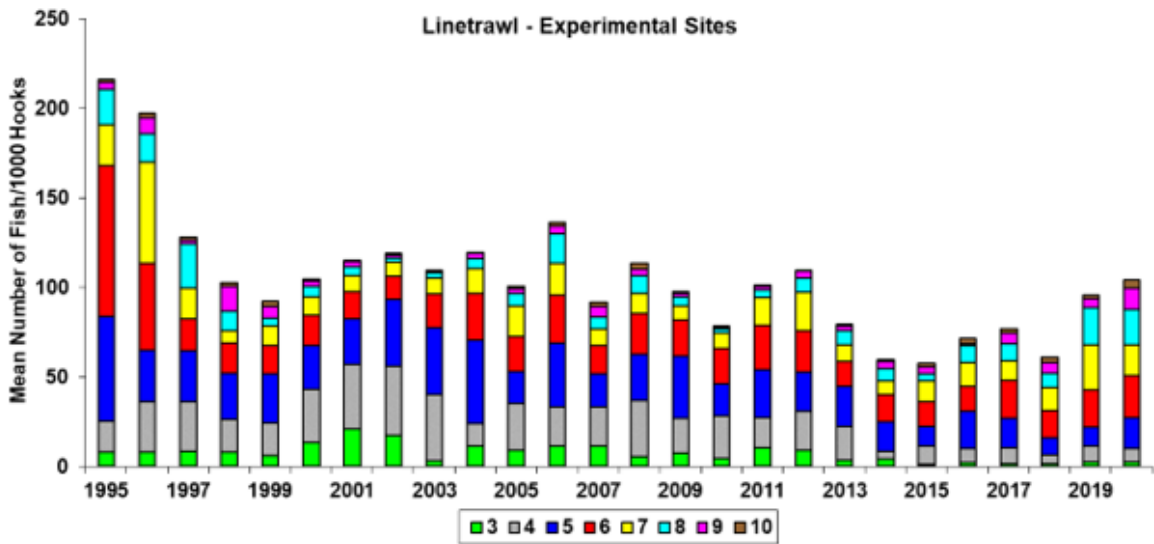
Figure 13. Standardized age-disaggregated catch rate for linetrawl (top panel), and the proportions of Sentinel catch rate at age (bottom panel) using data from Sentinel survey experimental sites in Subdivision 3Ps, 1995–2020.
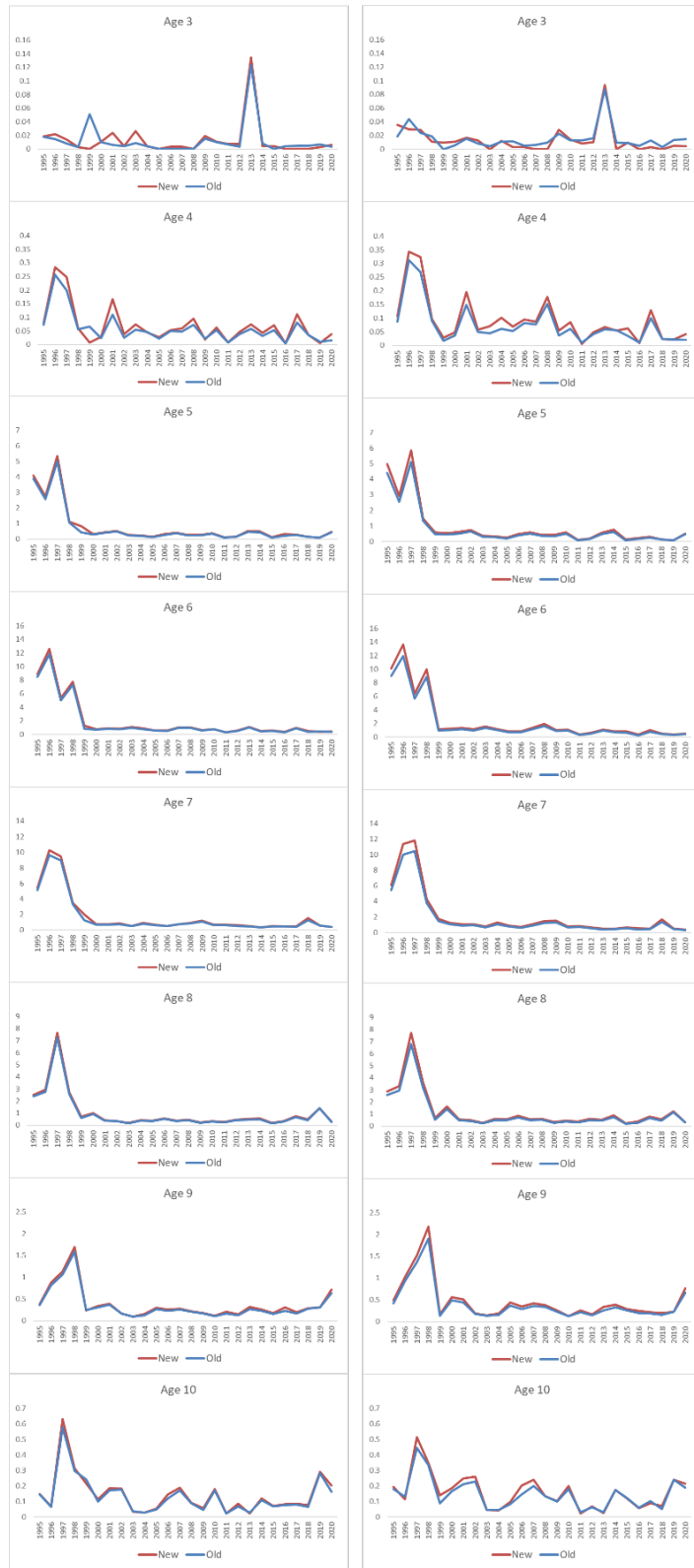
Figure 14. Standardized age-disaggregated catch rate for large mesh gillnet using data from Sentinel survey control sites (left column) and experimental sites (right column) in Subdivision 3Ps, 1995–2020. Red and blue lines refer to the assessments conducted using the current (new) and former (old) computer code.
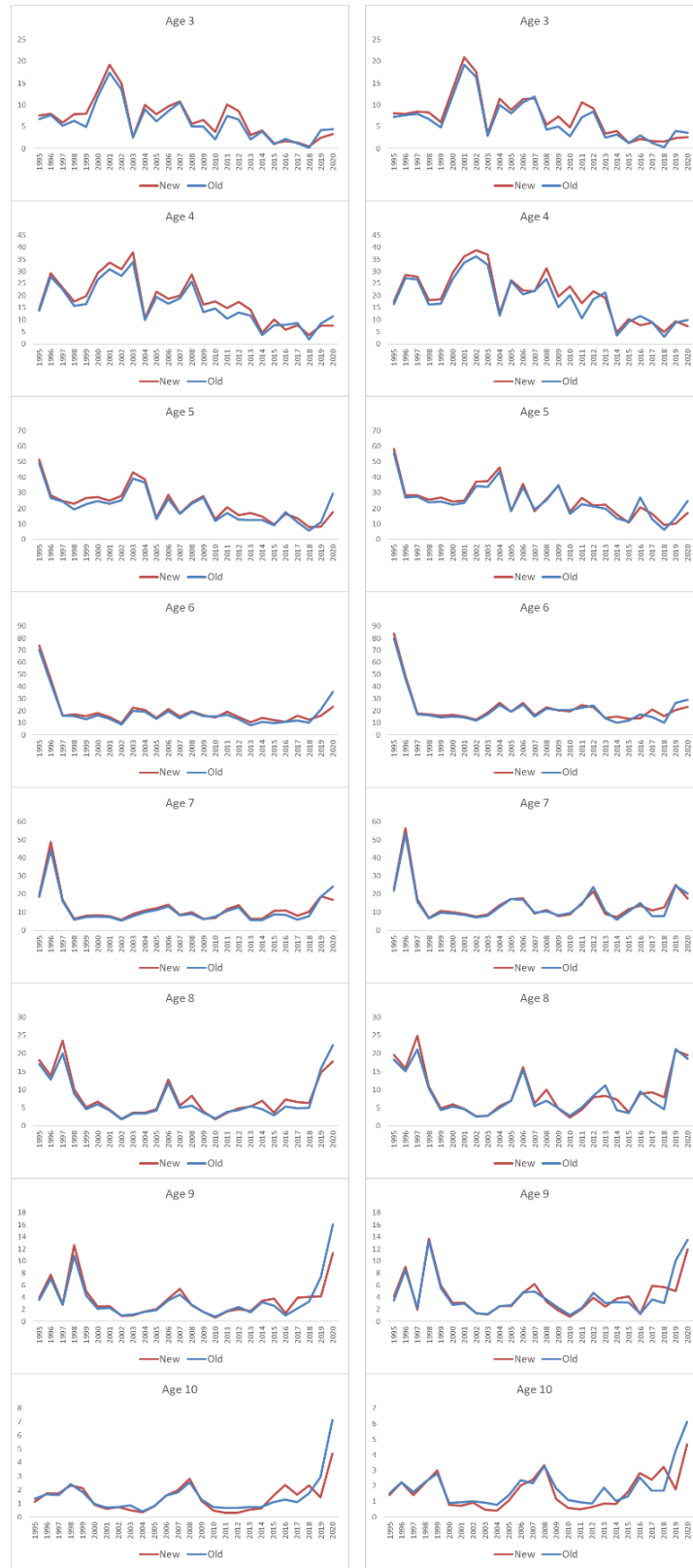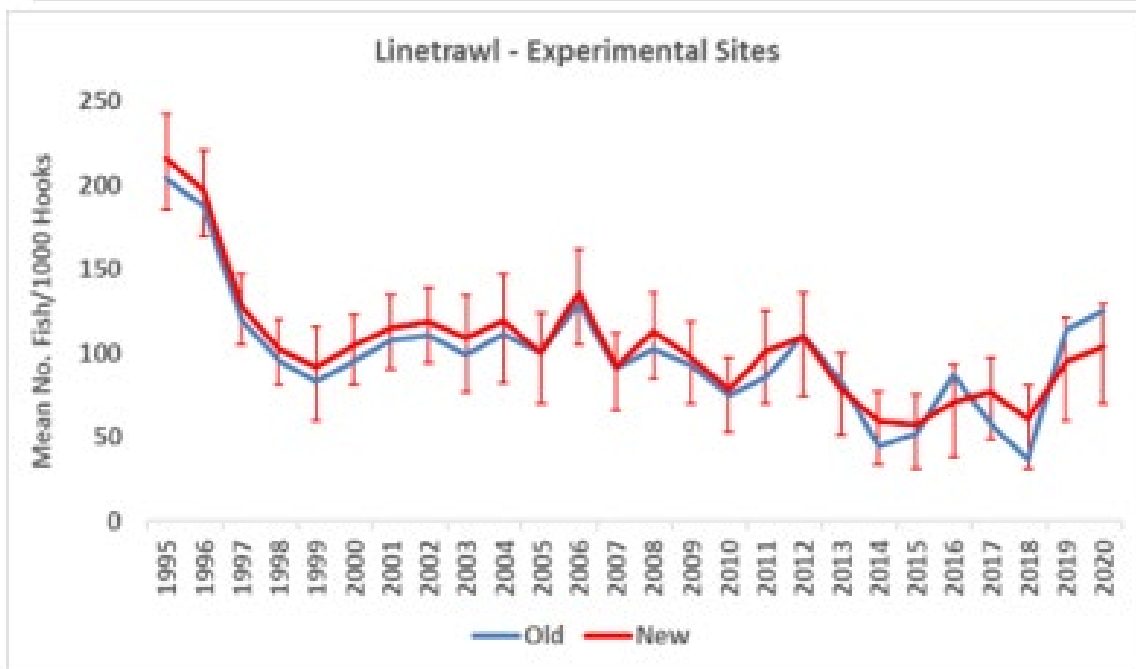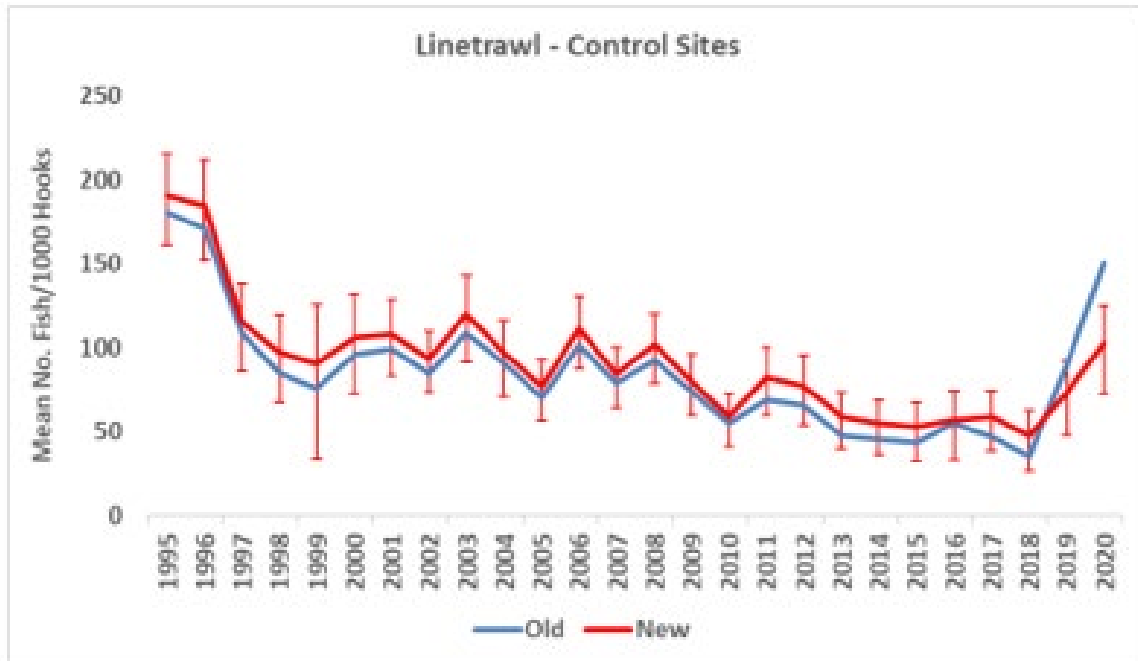
Figure 15. Standardized age-disaggregated catch rate for linetrawl using data from Sentinel survey control sites (left column) and experimental sites (right column) in Subdivision 3Ps, 1995–2020. Red and blue lines refer to the assessments conducted using the current (new) and former (old) computer code.
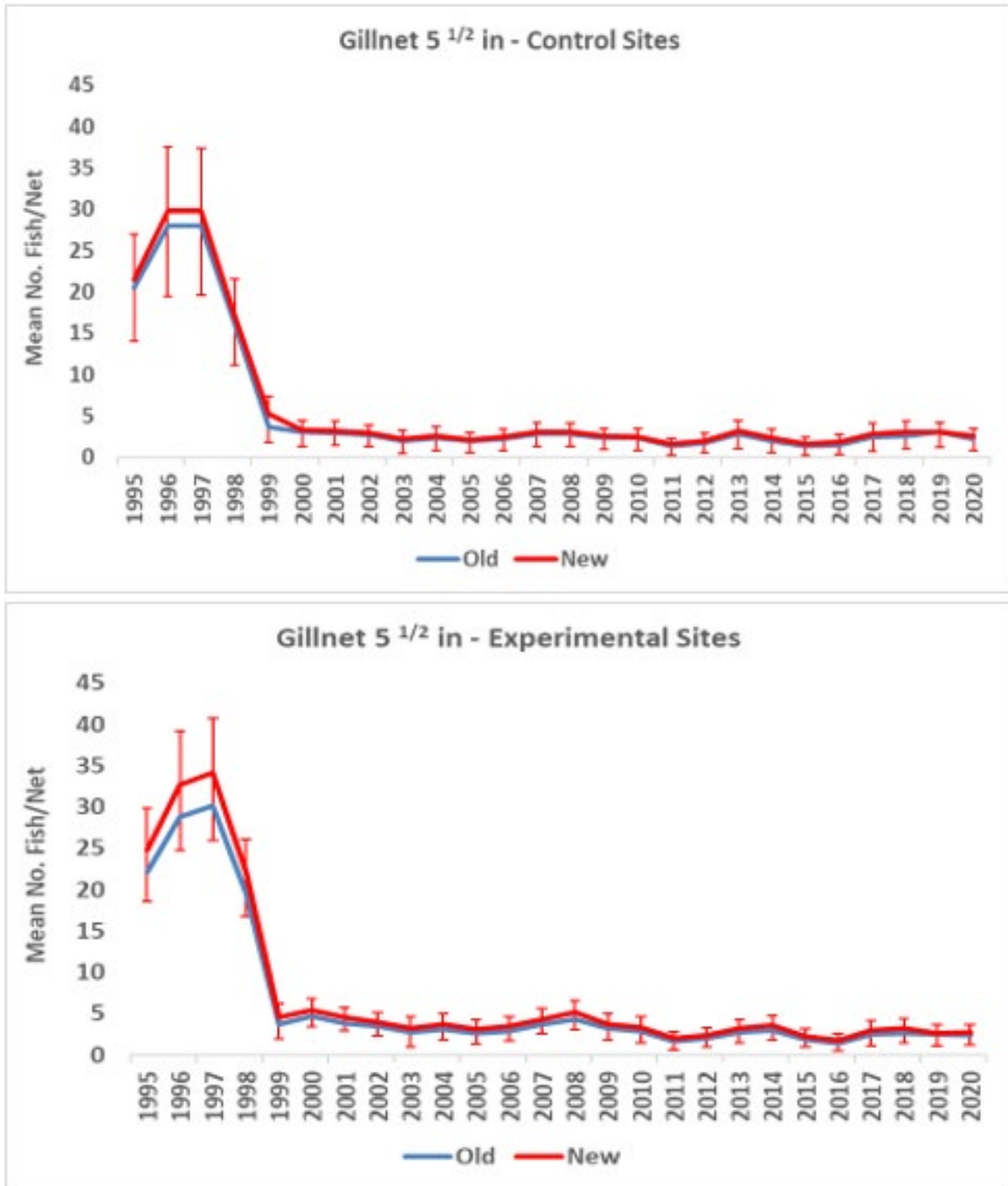
Figure 16. Standardized age-aggregated catch rate for large mesh gillnet (+/-95% CI), using data from Sentinel survey control (top panel) and experimental (bottom panel) sites in Subdivision 3Ps, 1995–2020. Red and blue lines refer to the assessments conducted using the current (new) and former (old) computer code.
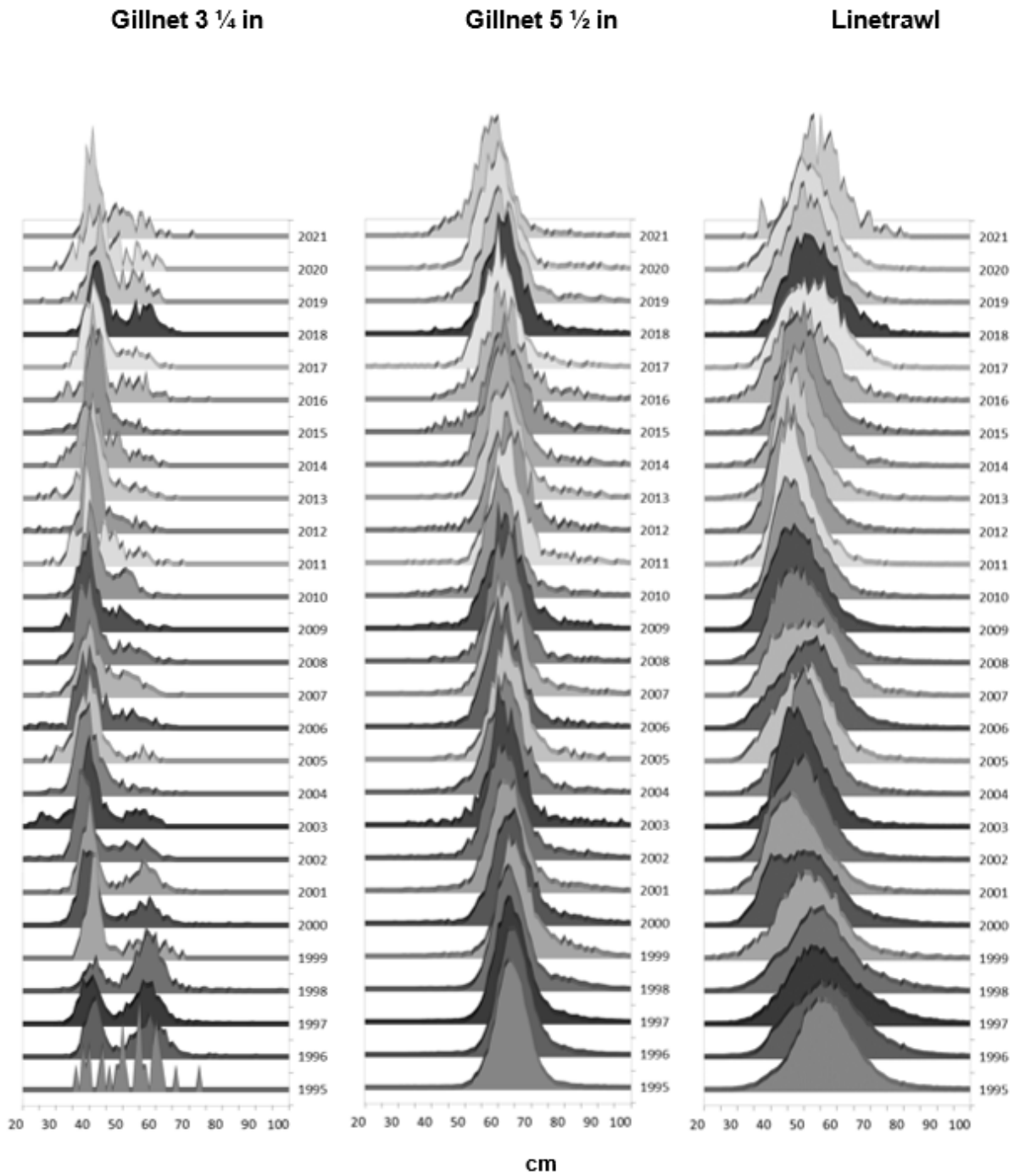
Figure 17. Standardized age-aggregated catch rate for linetrawl (+/-95% CI), using data from Sentinel survey control (top panel) and experimental (bottom panel) sites in Subdivision 3Ps, 1995–2020. Red and blue lines refer to the assessments conducted using the current (new) and former (old) computer code.

Figure 18. Length distributions (N=704,348 fish, number at length scaled to 1) of Atlantic Cod from Sentinel surveys in Subdivision 3Ps (control and experimental sites combined), 1995–2021. Data for 2021 are preliminary.
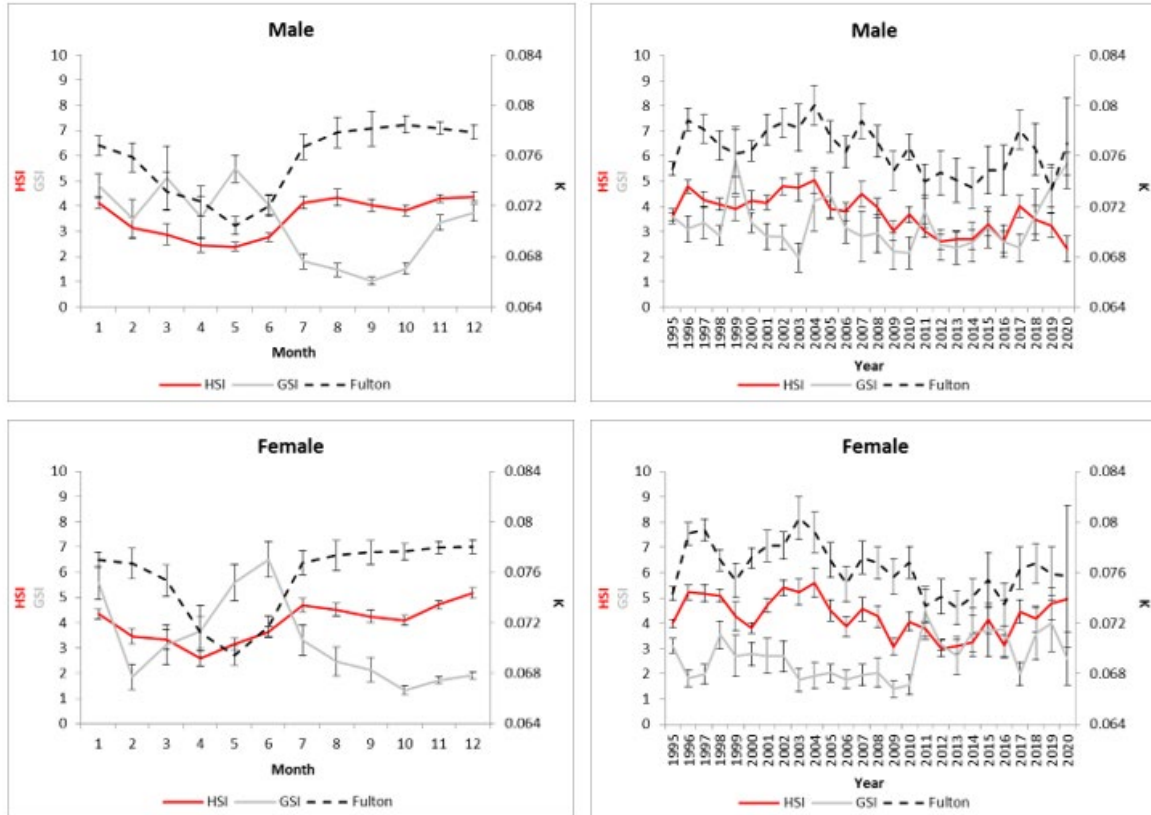
Figure 19. Temporal changes in mean Fulton's K condition factor (N=6,609 fish), mean Hepatosomatic Index (HSI; N=6,461 fish), and mean Gonadosomatic Index (GSI; N=6,319 fish) by sex for Atlantic Cod (sizes combined) from Sentinel surveys in Subdivision 3Ps, 1995–2020. T-bars represent +/-95% CI. Data for 2021 are not available.
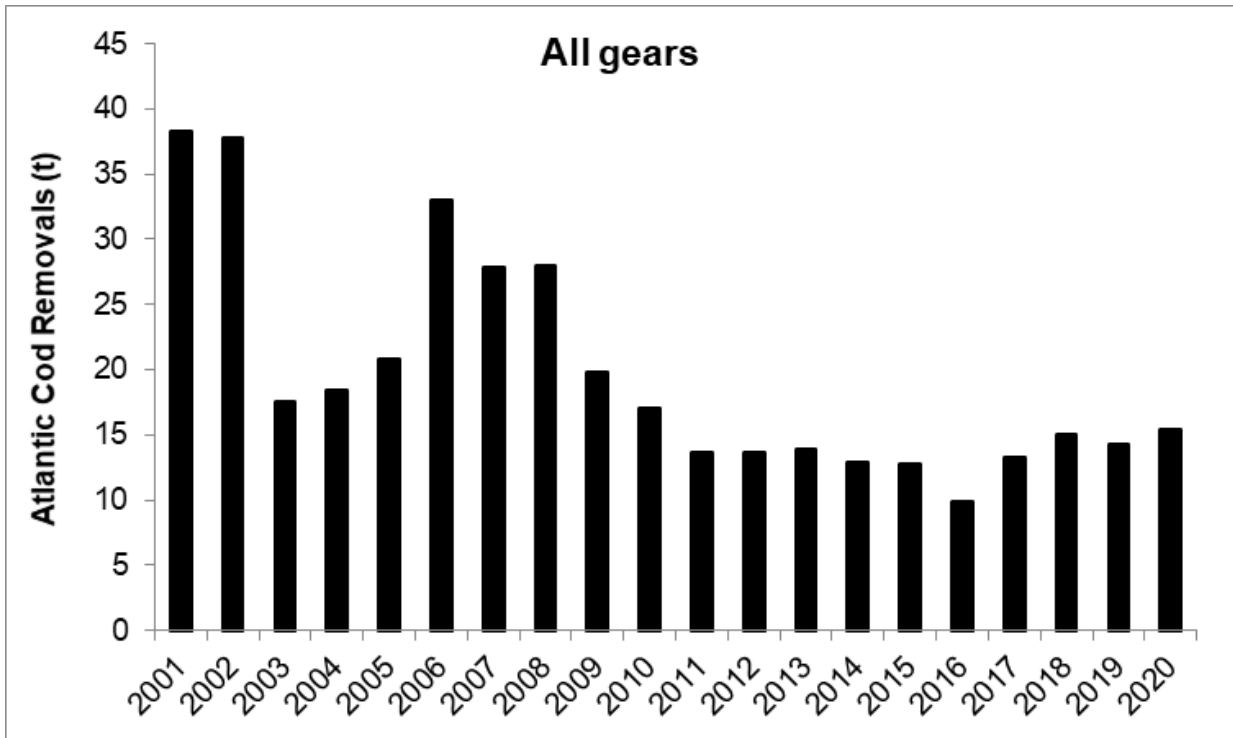
Figure 20. Total annual removals (t) of Atlantic Cod from Sentinel surveys (control and experimental sites; all gears combined) in Subdivision 3Ps, 2001–20. Data for 2021 are not available.
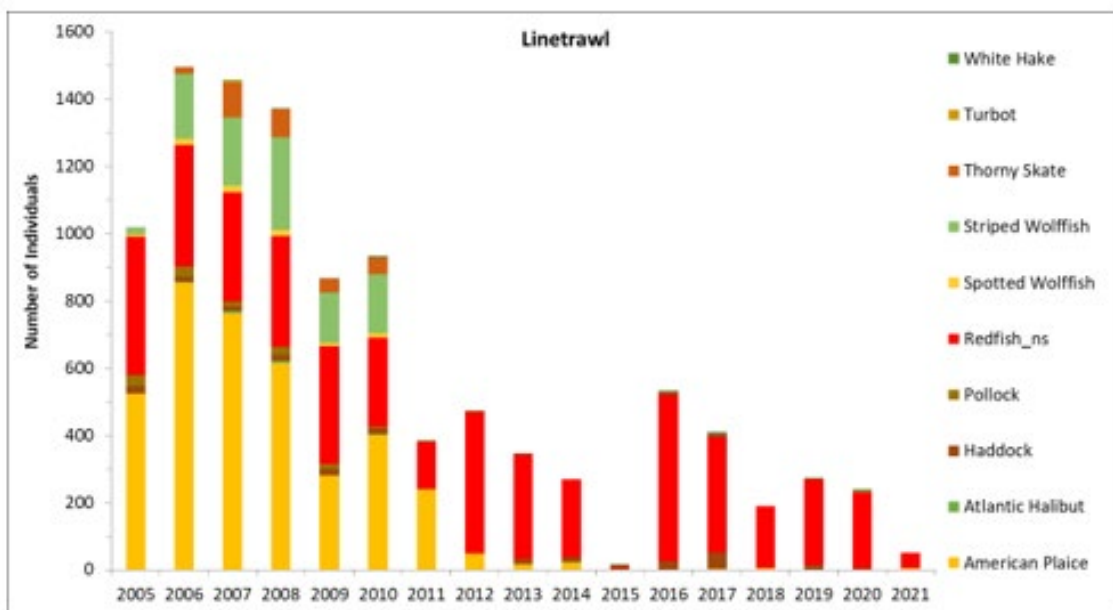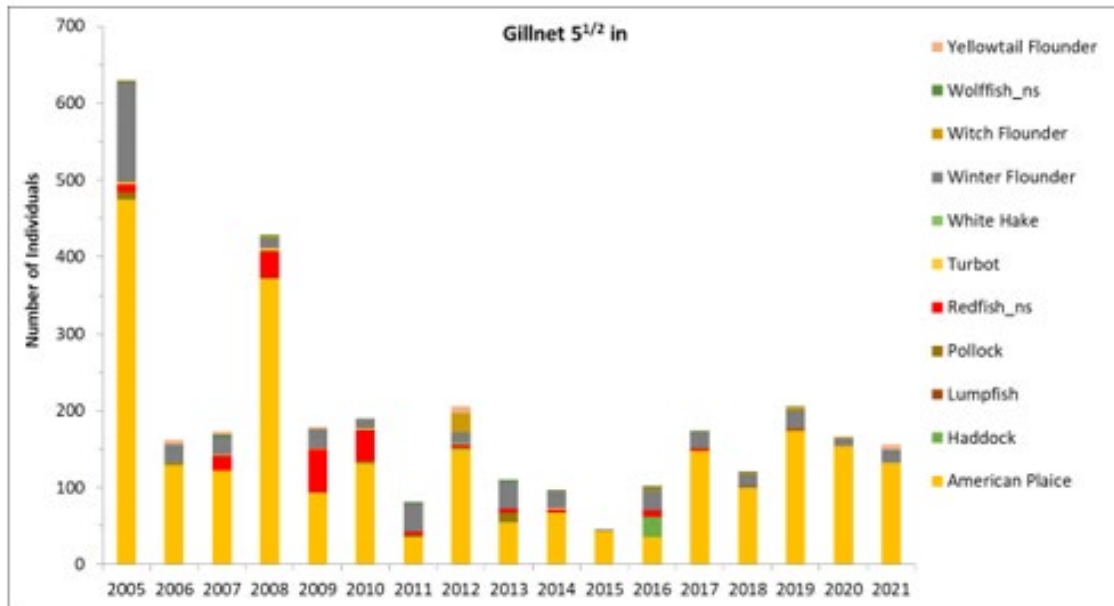
Figure 21. Total number of bycatch fish per species from Sentinel surveys (control and experimental sites) in Subdivision 3Ps, 2005–20. Data for 2021 are preliminary, no data are available for small mesh gillnet.