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Sentinel Surveys 1995-2018 – 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 for Atlantic Cod from the Sentinel Survey Program in the Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps are updated for 2017, and preliminary results presented for 2018. 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, sharp declines after 1997, and oscillations around or below the series' mean catch rate thereafter. Mean catch rate for small mesh gillnet was consistently higher than that of large mesh gillnet for the entire time-series: peaking at 142 fish per net in 1996, and then averaging 11-36 fish/net; except for its lowest value of 6 fish/net in 2011. Large mesh gillnet yielded the lowest mean catch rate of all gears: declining from 49 fish/net in 1997 to less than 9 fish/net since 2000. Mean catch rate for linetrawl peaked at 223 fish per 1,000 hooks in 1996, and fluctuated around 100 fish/1,000 hooks until 2010 (except in 2006), prior to reaching its lowest value of 62 fish/1,000 hooks in 2014-2015. Sentinel catch rates for large mesh gillnet and linetrawl at control and experimental locations were standardized using Generalized Linear Models. Age-disaggregated standardized catch rates for recent year-classes were generally weaker than those in the past. Age-aggregated catch rates were higher at the beginning of each time-series for both gears, declined over the mid-to-late 1990s, then remained at their lowest levels; decreasing below the series' mean of 6.4 fish/net (large mesh gillnet) in 1999, and 86 fish/1,000 hooks in 2009 (linetrawl). Gillnet and linetrawl catch rates for 2017 were 2.5 fish/net and 47.5 fish/1000 hooks (control sites), and 2.3 fish/net and 53.7 fish/net (experimental sites), respectively.

Length frequencies of Atlantic Cod measured in Sentinel surveys indicated that the small mesh gillnet retained 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: the liver (hepatosomatic index) and gutted body condition (Fulton's K condition factor) declined over winter and early spring (while the gonadosomatic index increased), then improved over summer after spawning. These trends varied annually over the time-series, but generally declined in 2004-17. Total annual removals of Atlantic Cod by Sentinel surveys peaked at 38 t (2001), then declined to a minimum of 9.9 t (2016), prior to increasing to 13.3 t in 2017. At least 15 fish species have being recorded as Sentinel bycatch over 2005-17, with American Plaice and Redfish 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, and currently there are twenty-three complete years of catch and effort data and biological information. The Sentinel survey for 2018 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 (Fig. 1). The main goals of the Sentinel survey program include: to develop 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 assessments (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, along with stomach contents for food and feeding studies.

MATERIAL AND METHODS

Between 16 and 32 inshore fishing enterprises (from Burgeo to St. Bride's) have participated in the Sentinel fisheries survey each year since 1995. Participants in the Sentinel surveys were trained in scientific sampling methods and equipment, computer use, and principles of resource assessment.

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

Sentinel surveys were usually conducted in fall/early winter for 9-12 weeks, except in 1999 (6 weeks), and 2003-04 (8 weeks each). Since 2005, an average of 10 weeks was maintained. In 2017, there were ten sites in Subdivision 3Ps, predominantly fishing large mesh gillnets (5½ inch mesh) in Little Harbour East and North Harbour, linetrawls in Lord's Cove, and one small mesh gillnet (3¼ inch mesh) fished one day per week at three sites in Placentia Bay.

Large mesh gillnet crews deployed a maximum of six 50-fathom monofilament nets (rigged 2-3 to a fleet), and up to three fleets per fishing day. Linetrawl crews fished two tubs of bait hooks (approximately 500 hooks per tub) per fishing day. In addition, one small-mesh gillnet was fished at selected sites a minimum of one day per week.

Data recorded after each fishing set included: set location (latitude, longitude), set start and soak times, marine invertebrates and fish species caught, marine mammals and seabirds at the fishing site, and several environmental parameters (wind direction and speed, percent cloud cover, tidal conditions, in addition to water salinity and temperature at depth in selected sites). All fish (i.e. Atlantic Cod, as well bycatch species) caught by gillnets and linetrawls at control and experimental sites were kept separate and sampled on land. Each catch was sorted by species, and total number of individuals and fork length (cm) by sex were recorded. Atlantic Cod otoliths were sampled using a length-stratified protocol, and up to 100 whole specimens were frozen biweekly and transported to the DFO Northwest Atlantic Fisheries Center laboratory (St. John's, NL) for detailed biological measurements, which included length (cm), gutted weight (g), and liver and gonad weights (g). Total annual removal (t) of Atlantic Cod from Sentinel

surveys (control and experimental sites combined) was calculated by applying a standard weight-length relationship to the length data.

INDICES OF PHYSIOLOGICAL CONDITION

Body weight (gutted), liver and gonad weights were used to calculate three indices that reflect the physiological condition of 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 length (cm), h_i is liver weight (g), and g_i is gonad weight (g) of cod i.

SENTINEL CATCH RATES

Sentinel catch rate for small and large mesh gillnets, and linetrawl were 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 unavailable to the Sentinel survey program.

STANDARDIZED SENTINEL CATCH RATES

As in previous assessments, both 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.

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 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 to the model. Poisson models with a logarithmic link were fitted with the variables Month and Age as "nested effects": Month was nested within Fishing Site, and Age was nested within Year. The generic form of the age-disaggregated model is:

CPUE = Month (Fishing Site) x Age (Year);

and the age-aggregated model:

CPUE = Month (Fishing Site) x Year

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

RESULTS

Sentinel survey data were gathered from twenty locations since 1995; although the number of enterprises participating in this program has decreased by 45-50% since 2003 (Table 1). In 1995-2017, the annual number of fishing sets (all gears combined) ranged from 429 to 1937, and the preliminary results indicate that 253 sets were conducted in 2018; most sets were conducted near Fox Harbour, François, Little Paradise, Lord's Cove, Ramea, Rencronte East, and St. Brides (Fig. 1).

For large mesh gillnet, the number of fishing sets declined from 760 per year in 1995 to 234 in 1999, the lowest value of the time-series, and then fluctuated between 173-499 sets per year thereafter (Fig. 2). The number of sets conducted with small mesh gillnets was initially low, ranging between 2-29 sets annually (1995-99), and then increased to 40-88 sets annually between 2000-17 and then declined to 16 set in 2018. The number of fishing sets with linetrawls was highest in 1995 (1147 sets), and ranged between 315-555 sets per year during the period 1996-2002 (except for 194 sets in 1999), and then declined to 141-259 sets per year after 2002, except in 2018 (64 sets).

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 31,000-45,000 annually in 1995-98 to 1,600-4,000 fish after 2002 (Fig. 2). For small mesh gillnet, the number of fish measured was in general less variable, ranging between 460-2544 annually, except in 1995, 1999 and 2011 (34-288 fish/year). Despite a substantial reduction in fishing effort by linetrawl fishers, the number of fish measured annually remained relatively high as compared to gillnets: 37,000-75,000 in 1995-97; 9,000-21,000 during the 2000s; and 4,400-9,600 since 2011, except in 2018 (2016 fish). The percentage of sets with no catch ranged between 1-31% for large mesh gillnet; 0-19% for small mesh gillnet; and 0-10% for linetrawl (Fig. 2); no trend over time in the percentage of sets with zero cod catch was observed for any of the gear types.

SENTINEL CATCH RATES

Mean annual catch rate for gillnets were similar and showed little variability between most fishing enterprises/communities with a few exceptions, whereas catch rate for linetrawl tended to be more variable among enterprises/communities (Fig. 3). 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, 36 and 73 fish/net respectively. Mean catch rate for large mesh gillnet fluctuated around 13 fish/net for most fishing enterprises/communities, except for enterprises in Little Harbour East, North Harbour, and Hr. Breton (19-103 fish/net). Mean catch rate for linetrawl fluctuated around 120 fish per 1,000 hooks, with the largest ranges from Arnold’s Cove, Placentia, François, and Lord’s Cove (173-363 fish per 1000 hooks).

Trends in annual mean catch rate (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 1996 (linetrawl) and 1997 (gillnets); then values oscillated around or below the overall mean annual catch rate (Fig. 4). Large mesh gillnet yielded the lowest mean annual catch rate of all three gears: declining from 51 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 25 fish/net after 1998 (except for 6 fish/net in 2011). For linetrawl, mean catch rate peaked at 224 fish/1,000 hooks in 1996, fluctuated around 110 fish/1,000 hooks until 2012 (except for 97 fish/1,000 hooks in 2005), then declined to its lowest value of 57 fish/1,000 hooks in 2014. However, a slight increase in mean catch rate has been observed for linetrawl between 2014 and 2017 (57 to 71 fish per 1000 hooks); the catch rate declined somewhat in 2018 but remained above the 2014-2016 (65 fish/1000 hooks). The variability of mean catch rate estimates (standard deviation (SD)) was generally small, with a few exceptions, notably for those associated with high catch rate values.

STANDARDIZED SENTINEL CATCH RATES

No trends were apparent in the distribution of model residuals of standardized catch rates for large mesh gillnet and linetrawl in 1995-2017 at both control and experimental sites; whether by Year, Month, Fishing Sites, or Fishing Effort (Figs. 5-8). Nested effects Month (within Fishing Site) and Age (within Year) in the age-disaggregated model were highly significant ($p < 0.0001$)

for both fishing gears and sites (Tables 2-3). In addition to the explanatory variable Year, and the nested effect of Month (within Fishing Site) in the age-aggregated model was also highly significant in all cases. These results suggested that overall model parameterizations for standardized Sentinel catch rates were appropriate for large mesh gillnet and linetrawl, and no systematic issues regarding model fit were detected.

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. 9). Estimates for 2015-16 were the lowest for most age groups; estimates for 2017 have improved slightly. 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-classes composition for estimates from the experimental sites mirrored those from the control sites to a large extent (Fig. 10). Moreover, the 1997 and 1998 year-classes contributed significantly to the fishery for several years (Rideout et al. 2016). However, these year-classes did not increase the magnitude of Sentinel gillnet catch rate over 2002-06 (i.e., when they would have been in the peak selection range of large mesh gillnet), while being a major contributor to inshore fisheries.

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. 11). Catch rate increased in 2000-02 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 prior to declining once more in 2017. Several year-classes were well-represented over 1995-98: the 1997 year-class, and especially the 1998 year-class, were consistently caught by Sentinel linetrawl. In addition, the 1999 year-class also appeared relatively strong as 4-5 year-old fish, but was generally below average at older ages. Although these year-classes were followed by several weaker ones, catch rates of the 2004 year-class as 3-5 year-old fish in 2007-09 were higher. It should be noted that linetrawl catch rates for 3-10 year-old fish increased in 2006; thereby suggesting a year-effect in the data, rather than a change in the Atlantic Cod stock size. Catch rates and age composition of catches from the experimental sites also followed the same patterns as observed at the control sites (Fig. 12).

Age-aggregated standardized annual catch rate for large mesh gillnet from both control and experimental sites declined rapidly from 29 and 32 fish/net respectively in 1997 to 4 fish/net 1999, then remained stable at low levels (< 5 fish/net) in 1999-2017 (Fig. 13). For linetrawl, catch rate from control and experimental sites decreased over 1995-99, from 181-200 to 75-81 fish per 1000 hooks respectively, remained relatively stable until 2008, then declined to its lowest value (45 fish per 1000 hooks) in this time-series in 2014 (experimental sites) and 2015 (control sites) (Fig.14). In most cases the variability of mean standardized catch rate (confidence interval (CI)) was small, with a few exceptions, notably for those associated with high catch rate values.

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 with few overlapping length-classes, whereas the small mesh gillnet retained small and large fish from multiple length-classes (Fig. 15). Cod from 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). For small mesh gillnet, fish were 20-116 cm, with

smaller bi-modal lengths ranging between 37-43 cm and 53-60 cm for the first and second modal-class, respectively.

Indices of physiological condition

All three indices (K, HSI, GSI) that reflect the physiological condition of Atlantic Cod varied seasonally and annually (Fig. 16). Fulton's K and HSI covaried: showing minimum values in April (HSI) and May (K) for females and May (K and HSI) for males, then peaking 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 2016 (HSI) for males. Female and male GSI fluctuated without any clear pattern over the time-series: their lowest GSI values 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) to present-day. K and HSI have increase from 2016 to 2017 for both males and females. 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 fishery program over different periods of time. Notwithstanding confidence intervals for these three indices were usually small, suggesting that the impact of such unbalanced spatio-temporal design had 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 2001-17 peaked at 38 t (2001), then declined from 33 t in 2006 to 9.9 t in 2016, prior to increasing to 13.3 t in 2017 (Fig. 17). At least 15 fish species have being recorded as Sentinel bycatch over 2005-17 (Fig. 18): American Plaice (*Hippoglossoides platessoides*) was the most common in gillnets, followed by Winter Flounder (*Pseudopleuronectes americanus*) and redfish (*Sebastes* sp.); while redfish, American Plaice (although decreasing to very low levels since 2012), and wolffish (*Anarhichus lupus and Anarhichus* sp.) were the most common on linetrawls. 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

This study shows that the standardized age-disaggregated Sentinel survey catch rate for Atlantic Cod from large mesh gillnet was relatively high during the period 1995-98 and comprised mostly of 6-8 year-old fish; the catch rate declined by near ten-fold thereafter and has remained stable at low levels since; fish 5-6 year-old accounted for most of the large gillnet catch during the period of low relative abundance. Standardized catch rate from linetrawl also followed a similar trajectory as observed for gillnet, however in this case the catch rate declined steadily over time; the age composition of linetrawl catch was also similar to that observed for gillnet during the periods of high and low relative abundance, except that the contribution of 3 year-old fish to catch was higher for linetrawl through the time-series.

Historical trends in Sentinel catch rates (gillnet and linetrawl) for Cod in Subdivision 3Ps have not corresponded well with that observed for the DFO spring bottom trawl survey abundance index for this stock in offshore waters. The inconsistencies between indices have been attributed to (i) the lack of competitive influences while this stock was under moratorium (1994-96); (ii) pressures from commercial fisheries during the post-moratorium period, including competition for fishing sites, local stock depletion, as well concentration of fishing effort in Placentia Bay; and (iii) inter-annual changes in the availability of Atlantic Cod in inshore waters (Rideout et al. 2016). Notwithstanding other independent indices such as the inshore catch rates from Science logbooks and the estimates of exploitation rate in Placentia Bay from tagging studies (Brattey and Healey 2006, Healey et al. 2012) show similar temporal trends as observed in Sentinel catch rate for gillnet during the post-moratorium period.

Furthermore, age-disaggregated catch rate data for linetrawl showed a strong contribution of the 1997-99 year-classes to Sentinel catch in 2000-04 and, to a lesser extent, the 2001-04 year-classes in 2004-08. In the case of large mesh gillnet, the data indicated no strong contributions of any particular year-class to Sentinel catch during the same period. This result differs from the DFO spring bottom trawl survey index, which showed that the 2006 year-class was well above average for 4-5 year-old fish, but near average for 6 year-old (Rideout et al. 2016). The 2011-12 year-classes, which appeared strong in the DFO survey, were not yet of an age to be fully selected by gillnets or linetrawl in the 2015-16 Sentinel surveys. Notwithstanding, one common trend between the DFO spring survey and the Sentinel gillnet and linetrawl time-series is the very low contribution of fish 5 year-old and older to the respective age-disaggregated abundance indices, notably during the last decade. Rideout et al. (2016) indicated that the average total mortality of 5 to 10 year-old Atlantic Cod in offshore waters increased from approximately 30% in 1997 to 76% in 2015. Although no estimates of Cod mortality are available from the Sentinel survey program, these findings suggest that the processes (e.g. biological, environmental, harvest strategies) driving the population dynamics of both inshore and offshore components of the Subdivision 3Ps Cod stock were similar in recent periods.

While the number of enterprises participating in the Sentinel surveys has greatly decreased since 2012, this program constitutes an independent source of information that can be readily incorporated in resource assessments of commercial fish stocks (e.g., Subdivision 3Ps Cod). It also engages stakeholders (e.g. inshore fish harvesters) to participate in the shared responsibilities of resource conservation and sustainable exploitation.

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APPENDIX I – TABLES

Table 1. Number of Sentinel survey sets (all gears) per fishing enterprise/community in Subdivision 3Ps, 1995-2018 (including sets with no catches).Data for 2018 are preliminary.

Community	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Arnold's Cove	151	63	69	27	7	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Burgeo	0	46	60	62	28	36	64	45	36	24	28	44	40	36	41	40	40	24	34	32	32	36	40	42
Fair Haven	0	0	0	0	0	0	0	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fox Harbour	146	87	71	71	36	48	60	60	48	54	54	54	60	60	60	60	60	57	60	58	50	59	60	53
François	181	66	74	68	30	52	35	30	25	10	42	38	28	32	22	27	0	0	0	0	0	0	0	0
Garden Cove	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61	63	69	62	70	14
Grand Bank	0	0	0	0	0	0	60	59	38	44	43	42	42	46	46	46	27	47	41	38	41	31	36	0
Harbour Breton	154	39	27	28	32	45	31	53	34	30	33	40	30	38	34	37	36	36	32	40	36	32	44	8
Lawn	0	57	69	71	36	64	78	80	36	72	68	72	59	54	40	36	6	0	0	0	0	0	0	0
Little Harbour East	157	36	53	48	10	56	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Paradise	60	50	51	51	36	49	69	64	42	58	52	56	66	58	63	48	68	40	56	68	75	61	68	70
Lord's Cove	54	48	61	50	36	48	61	82	47	70	69	68	80	80	79	80	77	80	79	80	60	60	60	6
Monkstown	145	69	72	72	36	57	60	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North Harbour	114	73	67	50	19	73	55	42	45	30	55	50	54	43	46	61	52	49	10	0	0	0	0	0
Placentia	0	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ramea	201	46	96	60	38	88	92	82	46	36	44	44	49	50	48	48	48	48	46	48	48	0	0	0
Red Harbour	41	36	40	37	20	32	33	57	22	33	36	34	41	34	32	40	37	30	32	25	40	12	48	32
Rencontre East	174	96	69	74	36	90	71	60	20	32	40	36	36	36	36	36	36	40	40	40	40	40	40	0
Seal Cove	199	71	44	42	33	58	46	48	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
St. Bride's	160	84	70	80	2	49	63	79	59	49	61	64	70	63	49	30	32	36	35	36	25	36	40	28
Total	**1937**	**1088**	**993**	**891**	**435**	**887**	**945**	**972**	**507**	**542**	**625**	**642**	**655**	**630**	**596**	**589**	**519**	**487**	**526**	**528**	**516**	**429**	**506**	**253**

Table 2. Model information and results of fitting age-disaggregated and age-aggregated standardized Sentinel catch rate for large mesh gillnet (5½ inch), using data from control and experimental sites in Subdivision 3Ps, 1995-2017.

Class	Level	Values
Fishing Site	16	61 61.5 63 63.5 64 65 66 66.5 67 68 69 70 71 71.5 73 75
Month	6	6 7 8 9 10 11
Year	23	1995-2017
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)	57	3551	87.10	<.0001	4964.77	<.0001
Age (Year)	183	3551	106.18	<.0001	19431.8	<.0001

Age-disaggregated - Experimental Sites

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	61	3595	67.14	<.0001	4095.42	<.0001
Age (Year)	183	3595	114.11	<.0001	20883.0	<.0001

Age-aggregated - Control Sites

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	57	394	12.82	<.0001	730.85	<.0001
Year	22	394	51.93	<.0001	1142.38	<.0001

Age-aggregated - Experimental Sites

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	61	396	9.88	<.0001	602.81	<.0001
Year	22	396	53.90	<.0001	1185.76	<.0001

Table 3. Model information and results of fitting age-disaggregated and age-aggregated standardized Sentinel catch rate for linetrawl, using data from control and experimental sites in Subdivision. 3Ps, 1995-2017.

Class	Level	Values
Fishing Site	16	62 65 68 69 70 71 71.5 73 74 75 76 76.5 76.75 77 77.5 78
Month	6	6 7 8 9 10 11
Year	23	1995-2017
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)	69	2883	29.02	<.0001	2002.54	<.0001
Age (Year)	183	2883	40.25	<.0001	7366.17	<.0001

Age-disaggregated - Experimental Sites

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	68	2884	24.60	<.0001	1672.54	<.0001
Age (Year)	183	2884	42.45	<.0001	7768.81	<.0001

Age-aggregated - Control Sites

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	69	300	5.99	<.0001	413.24	<.0001
Year	22	300	8.07	<.0001	177.47	<.0001

Age-aggregated - Experimental Sites

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	68	301	5.08	<.0001	345.61	<.0001
Year	22	301	8.32	<.0001	183.02	<.0001

APPENDIX II – FIGURES

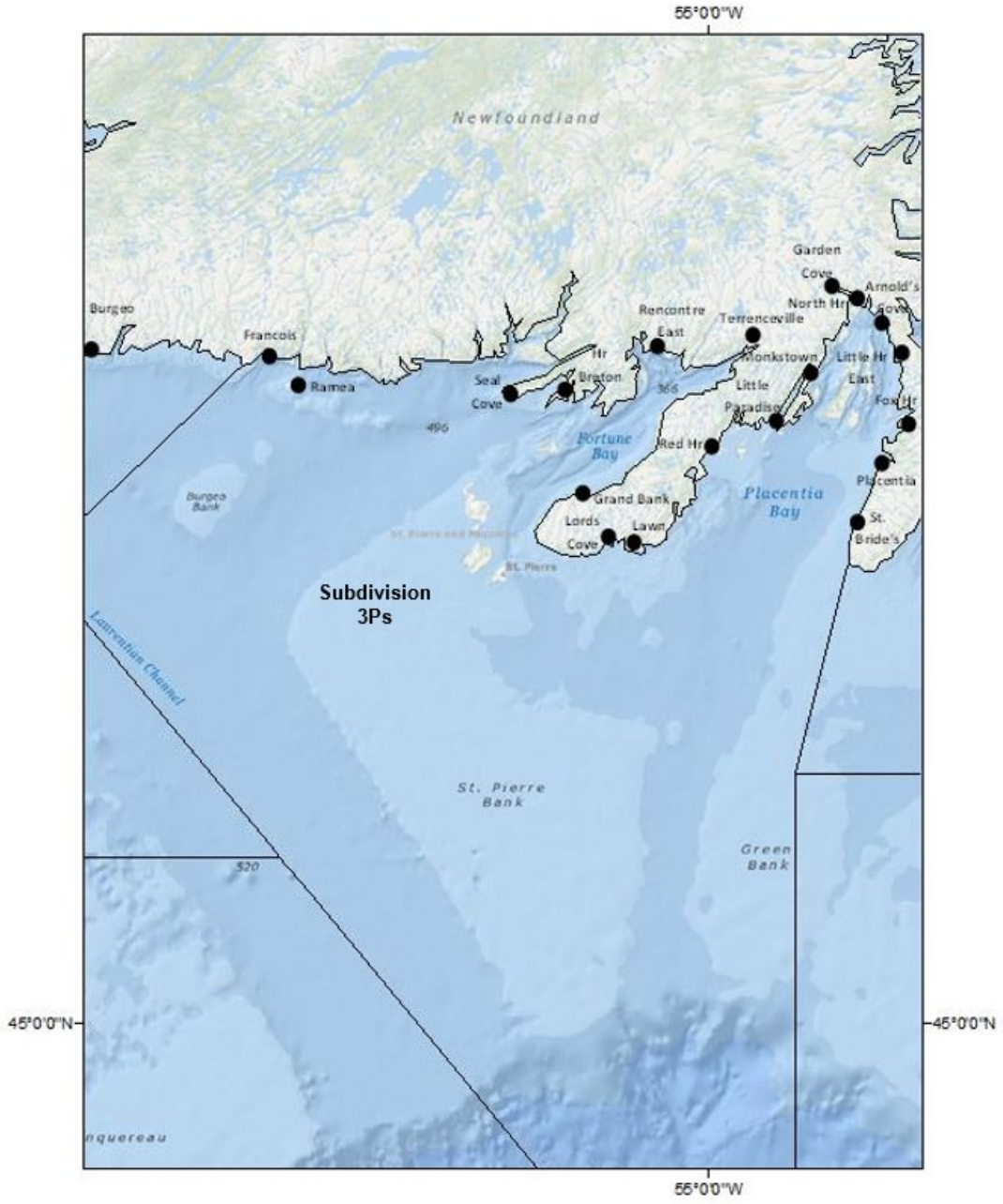

Figure 1. Map of NAFO Subdivision 3Ps indicating the Sentinel survey communities, 1995-2018.

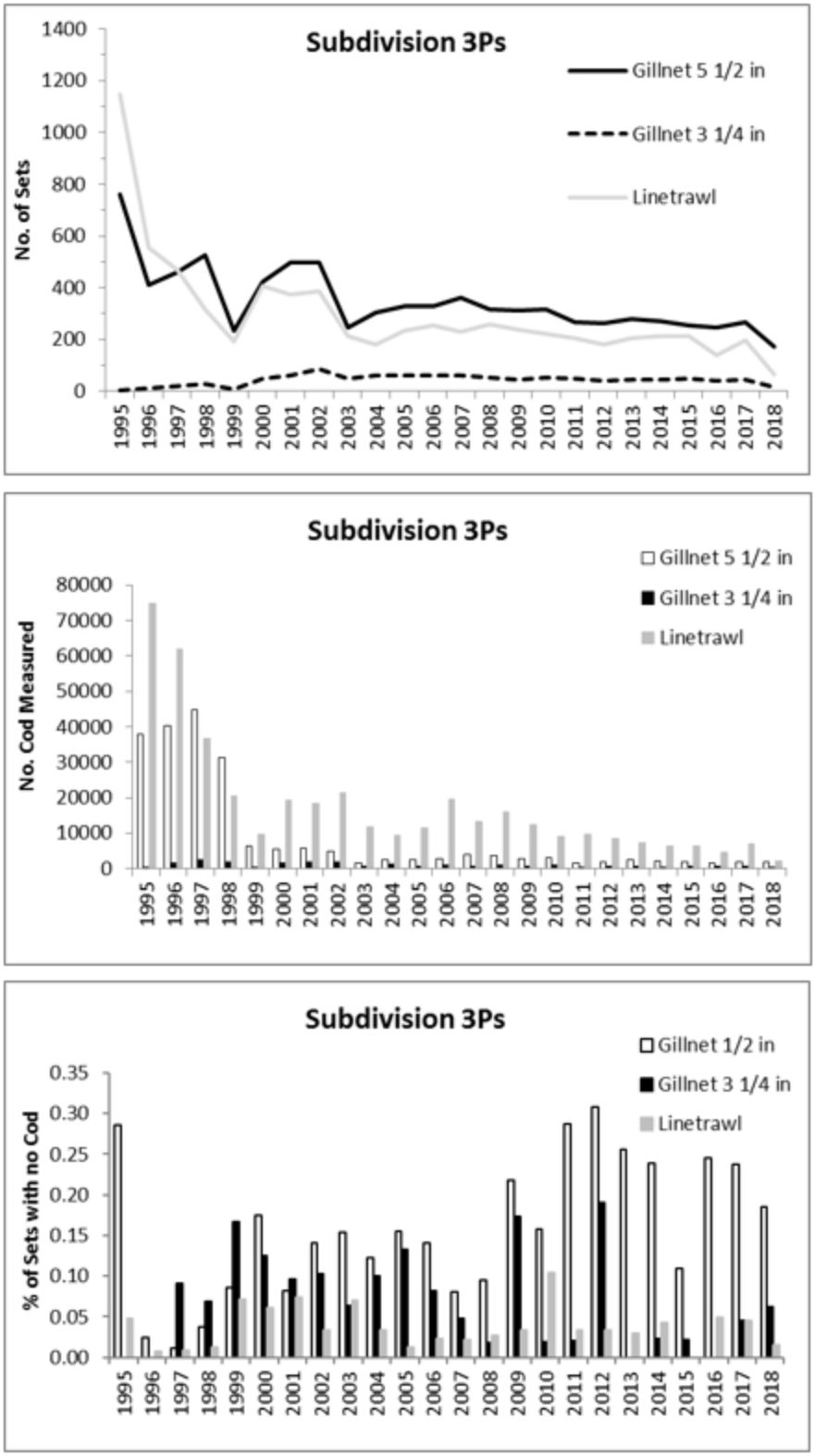

Figure 2. Annual Sentinel survey number of sets by gear type (top panel), the number of Atlantic Cod caught by gear type (mid panel), and the percentage of sets with no cod catch (lower panel) in Subdivision 3Ps, 1995-2018.Data for 2018 are preliminary.

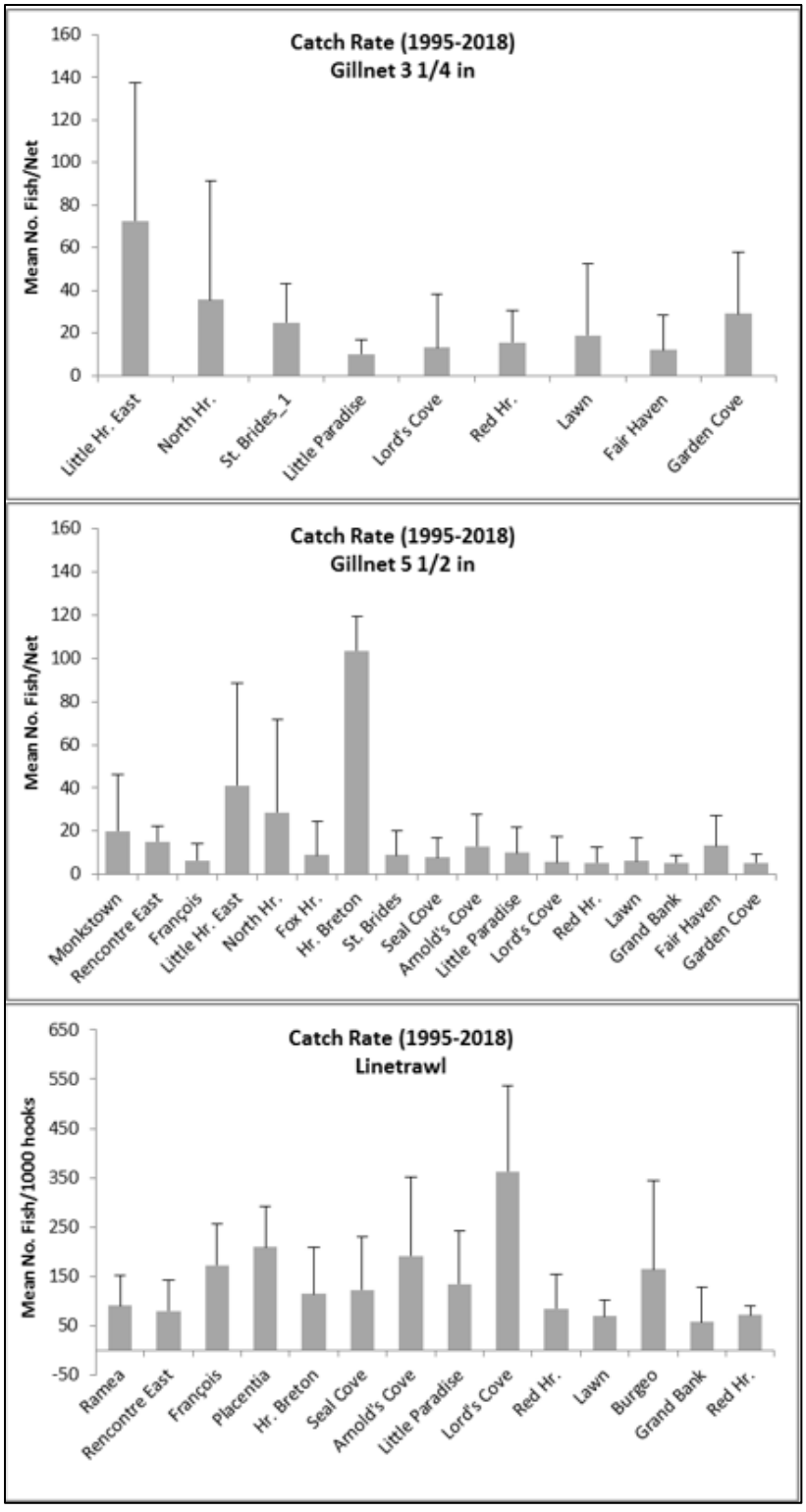

Figure 3. Distribution of mean annual catch rate of Atlantic Cod from small and large mesh gillnets and linetrawl (1995-2018), aggregated by fishing communities of Sentinel surveys in Subdivision 3Ps (control and experimental sites combined).T-bars = 1 SD. Data for 2018 are preliminary.

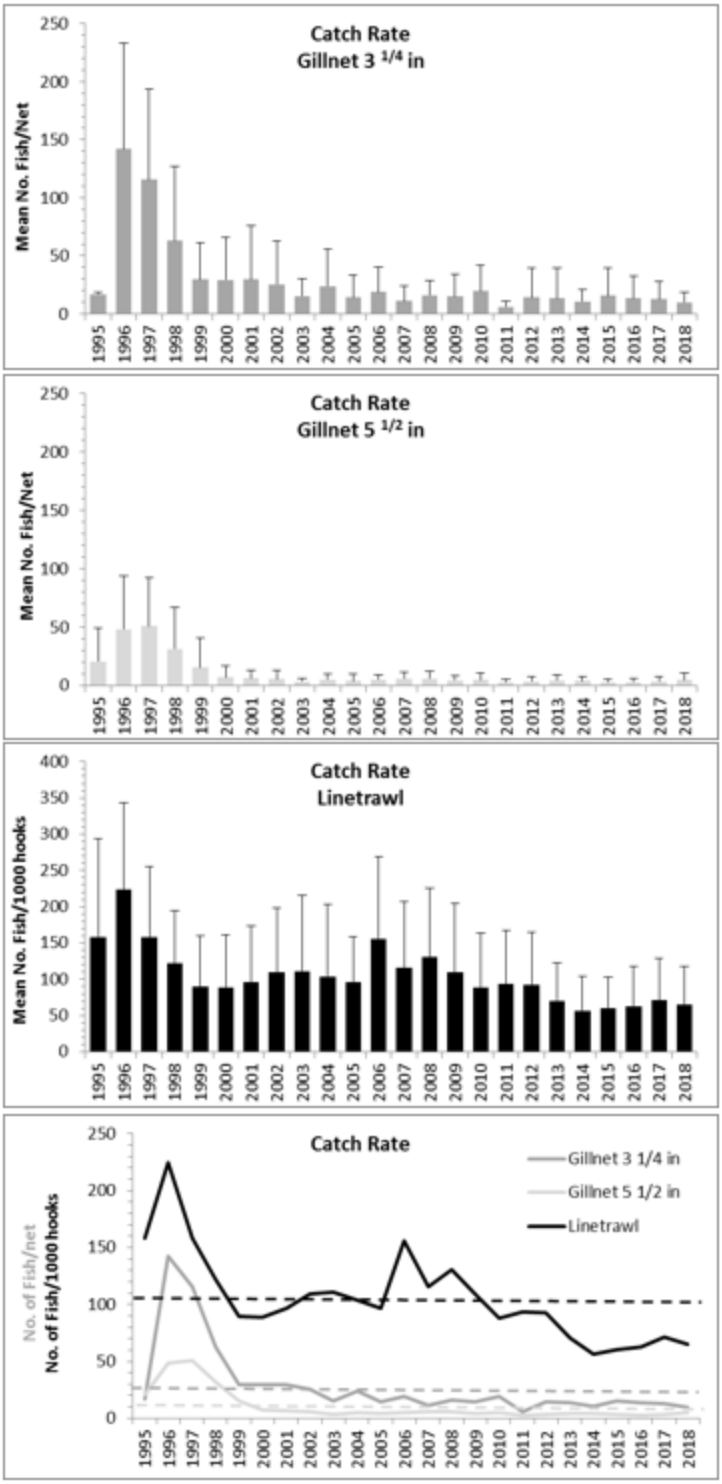

Figure 4. Mean annual catch rate of Atlantic Cod from small and large mesh gillnets and linetrawl (top 3 panels), and for all gears combined in a single plot to facilitate comparison (bottom panel) from Sentinel surveys in Subdivision 3Ps (control and experimental sites combined).T-bars = 1 SD. Horizontal dashed lines (bottom panel) represent the time-series' overall mean for each gear type. Data for 2018 are preliminary.

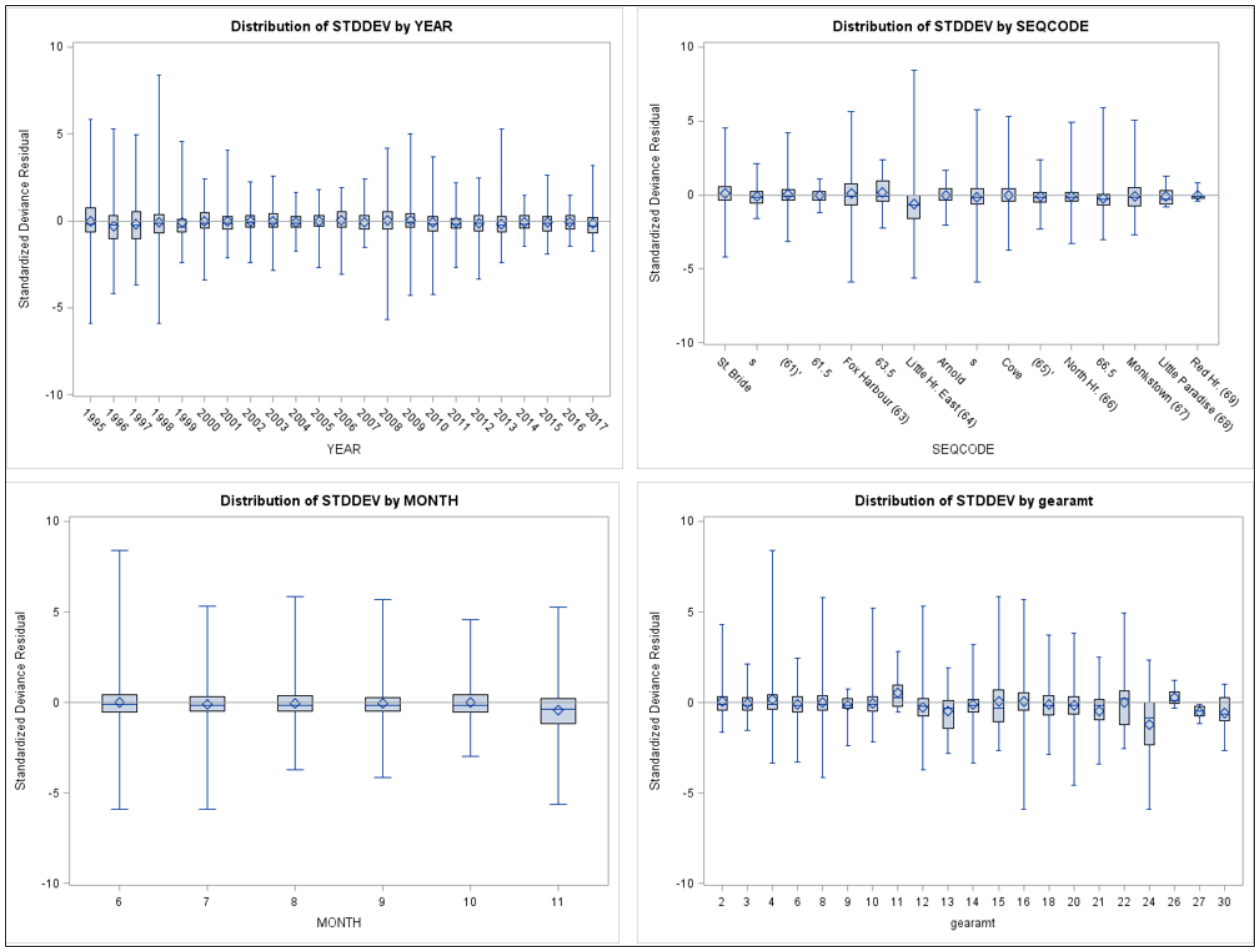

Figure 5. Deviance residuals (+/-95%CI) from the standardized catch rate model (control sites) for large mesh gillnet (5½ inch) in Subdivision 3Ps, 1995-2017. Panels show residuals plotted by Year, Month, Fishing Site (SEQCODE), and Fishing Effort (gearamt).

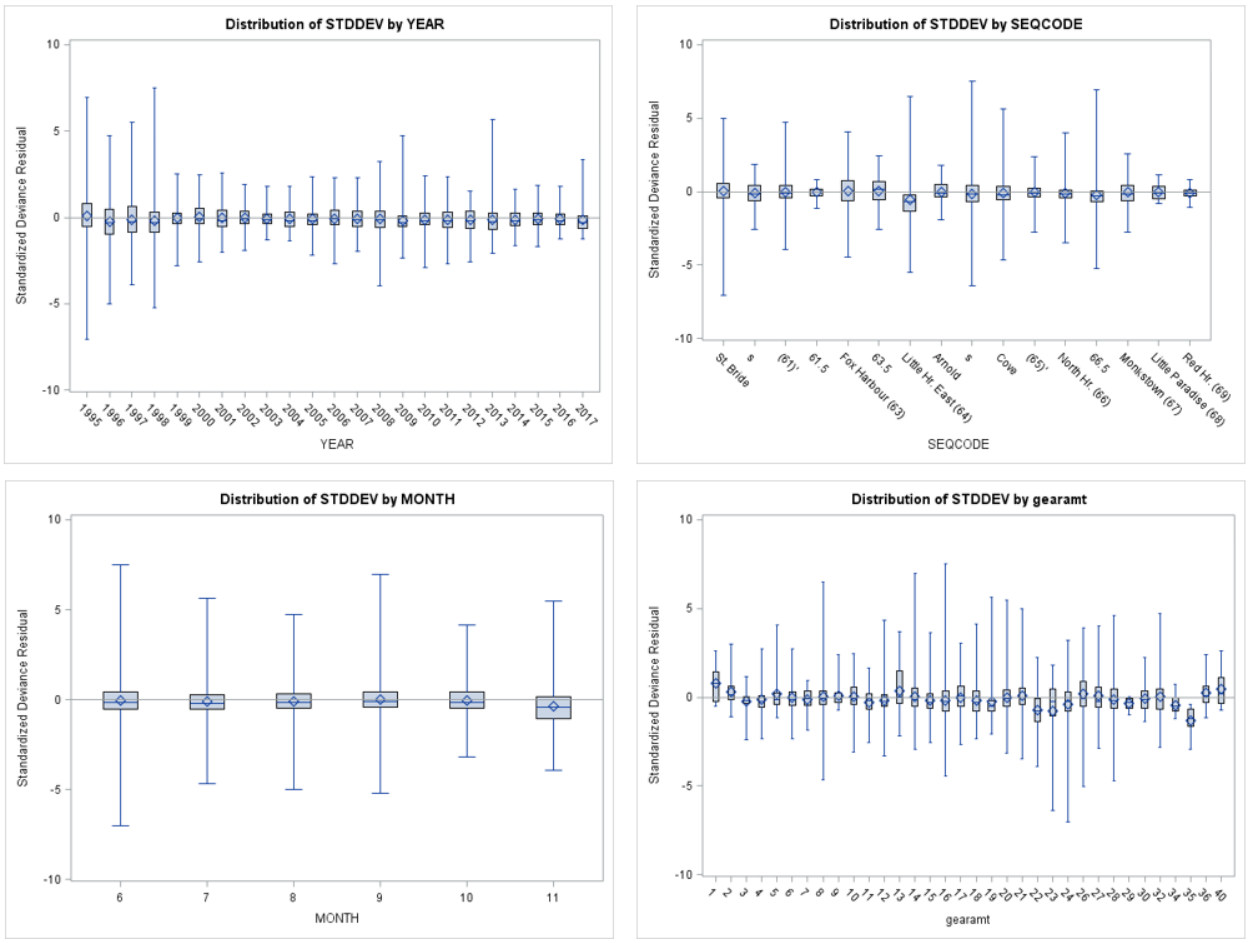

Figure 6. Deviance residuals (+/-95%CI) from the standardized catch rate model (experimental sites) for large mesh gillnet (5½ inch) in Subdivision 3Ps, 1995-2017. Panels show residuals plotted by Year, Month, Fishing Site (SEQCODE), and Fishing Effort (gearamt).

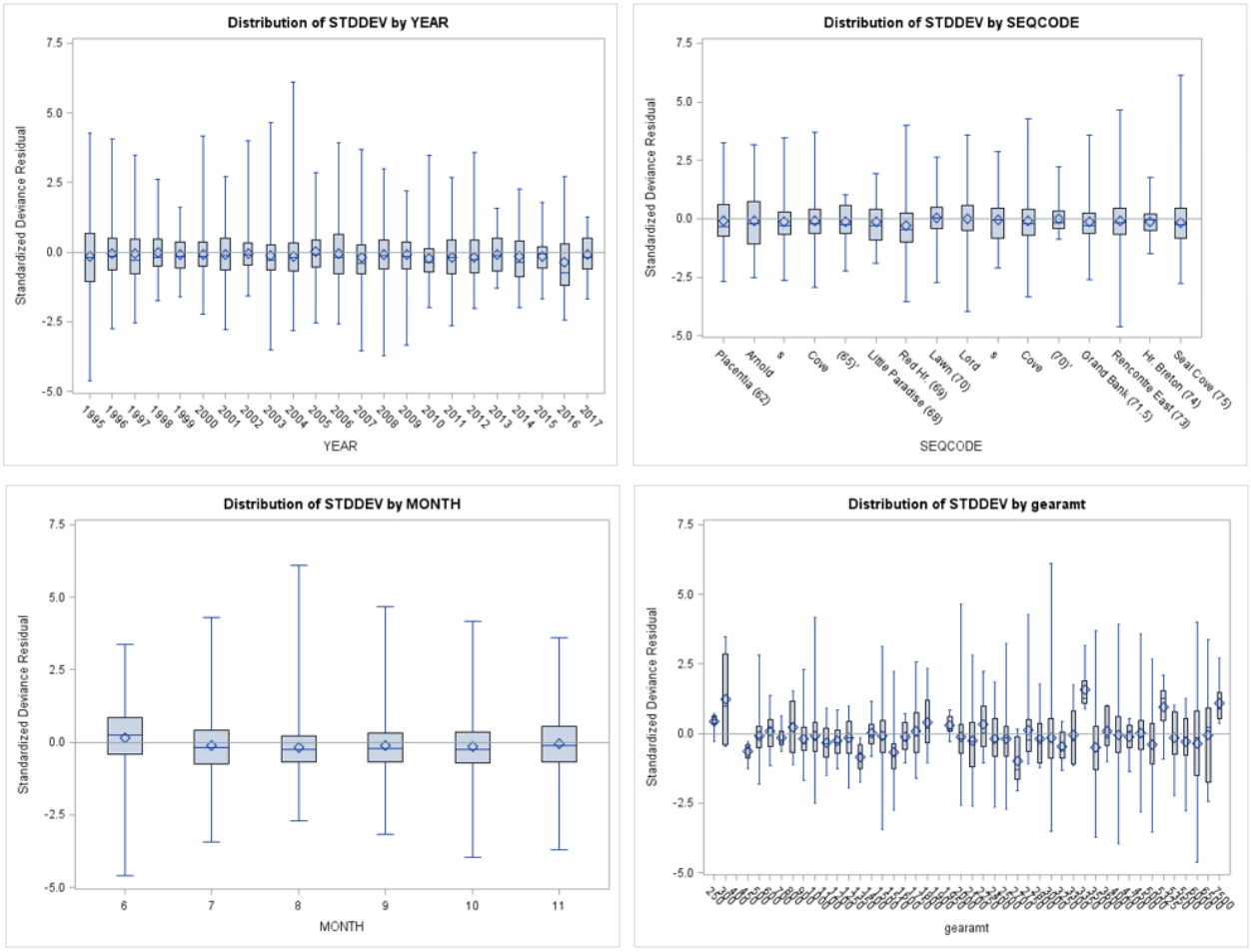

Figure 7. Deviance residuals (+/-95%CI) from the standardized catch rate model (control sites) for linetrawl in Subdivision 3Ps, 1995-2017. Panels show residuals plotted by Year, Month, Fishing Site (SEQCODE), and Fishing Effort (gearamt).

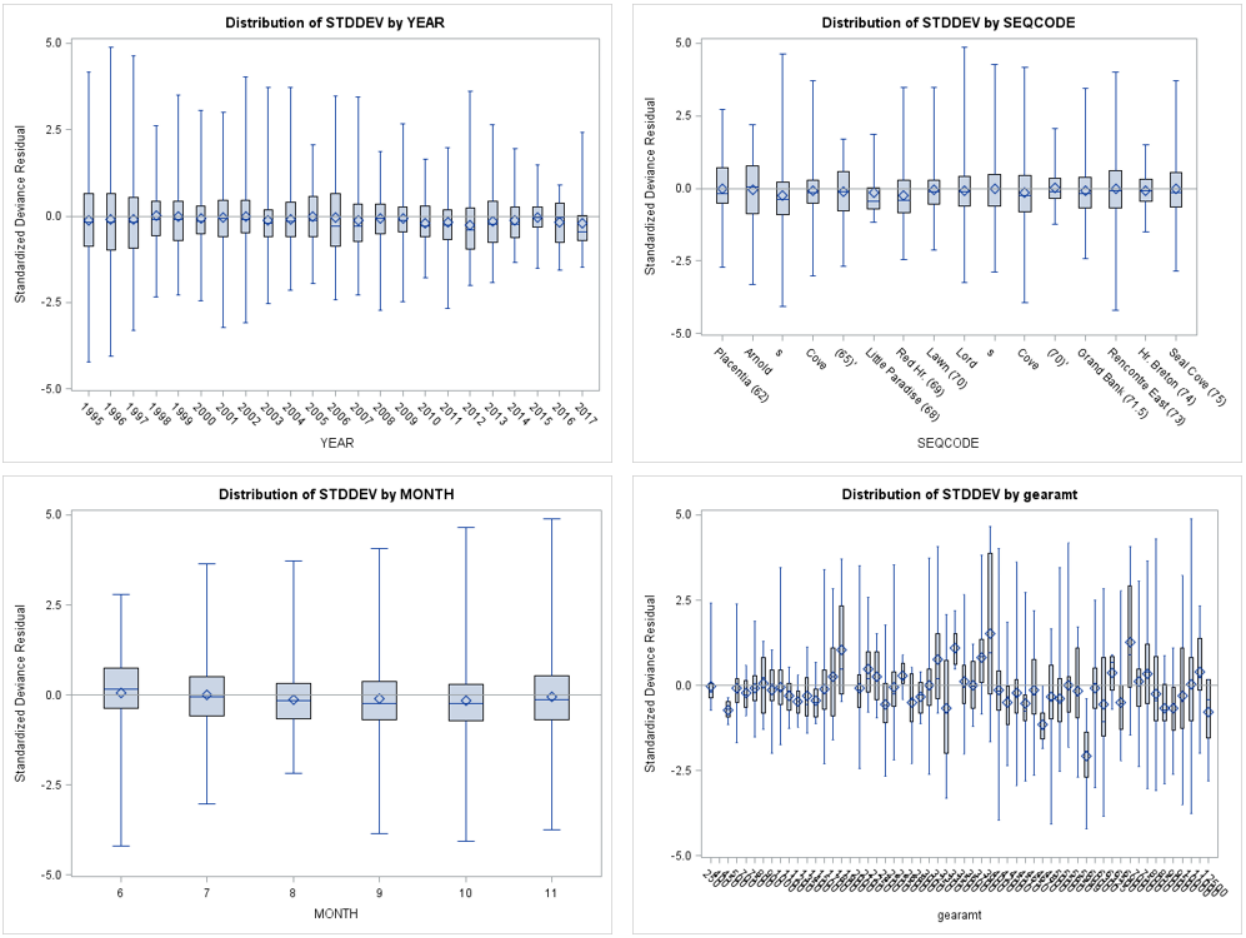

Figure 8. Deviance residuals (+/-95%CI) from the standardized catch rate model (experimental sites) for linetrawl in Subdivision 3Ps, 1995-2017. Panels show residuals plotted by Year, Month, Fishing Site (SEQCODE), and Fishing Effort (gearamt).

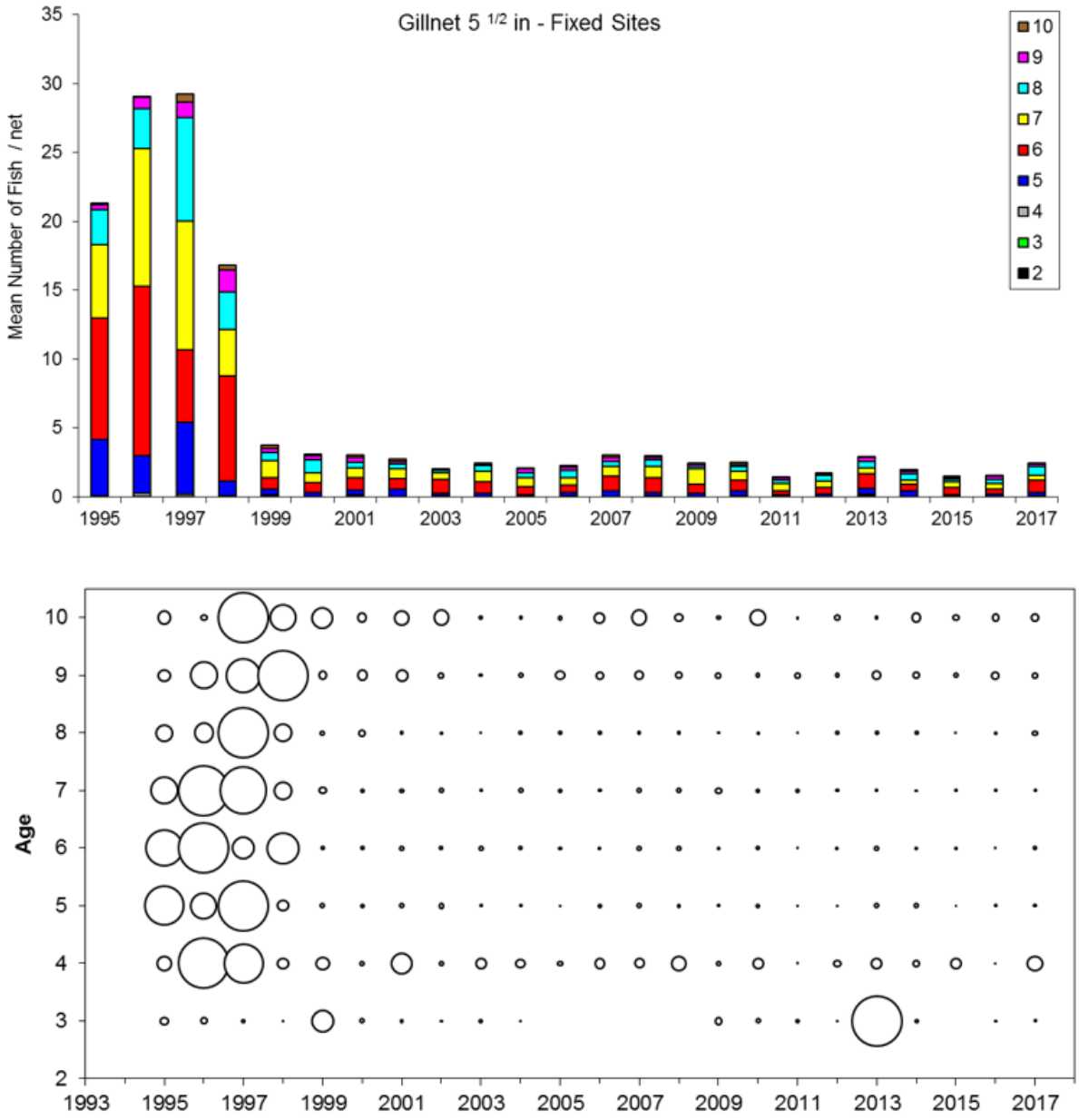

Figure 9. Standardized age-disaggregated catch rate for large mesh gillnet (top panel), and the proportions of Sentinel catch rate-at-age (lower panel) using data from Sentinel survey control sites in Subdivision 3Ps, 1995-2017.

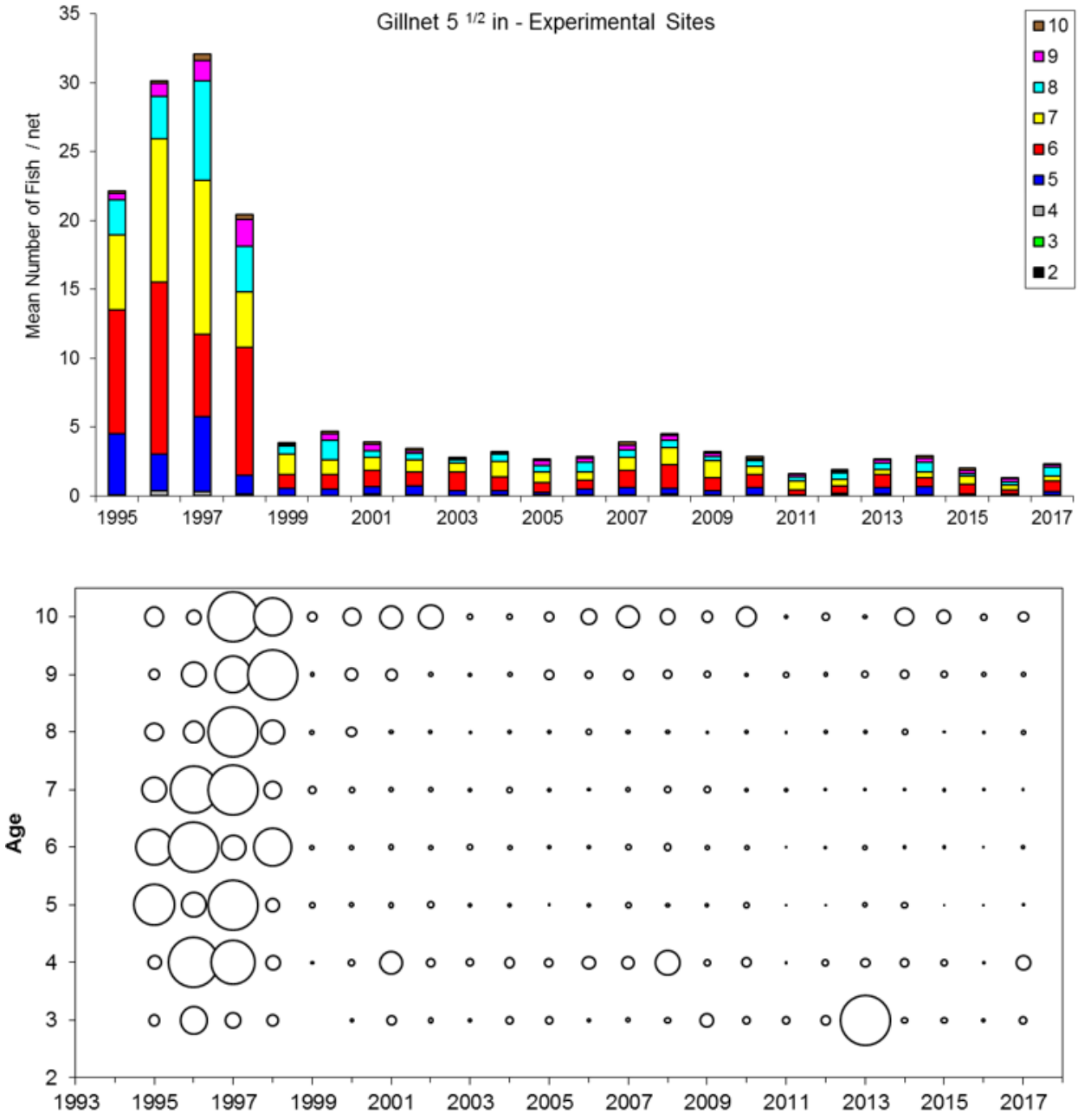

Figure 10. Standardized age-disaggregated catch rate for large mesh gillnet (top panel), and the proportions of Sentinel catch rate-at-age (lower panel) using data from Sentinel survey experimental sites in Subdivision 3Ps, 1995-2017.

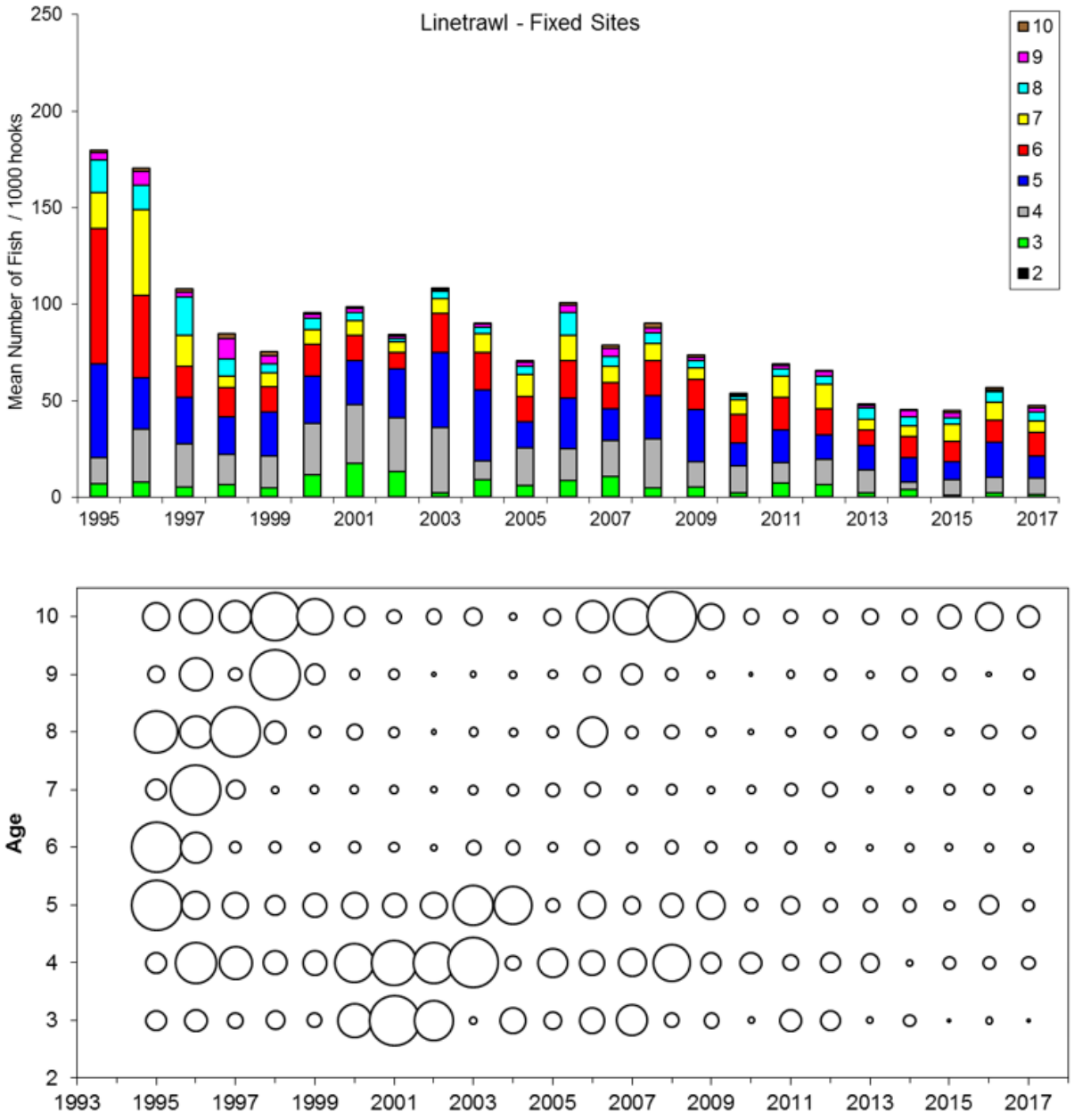

Figure 11. Standardized age-disaggregated catch rate for linetrawl (top panel), and the proportions of Sentinel catch rate-at-age (lower panel) using data from Sentinel survey control sites in Subdivision 3Ps, 1995-2017.

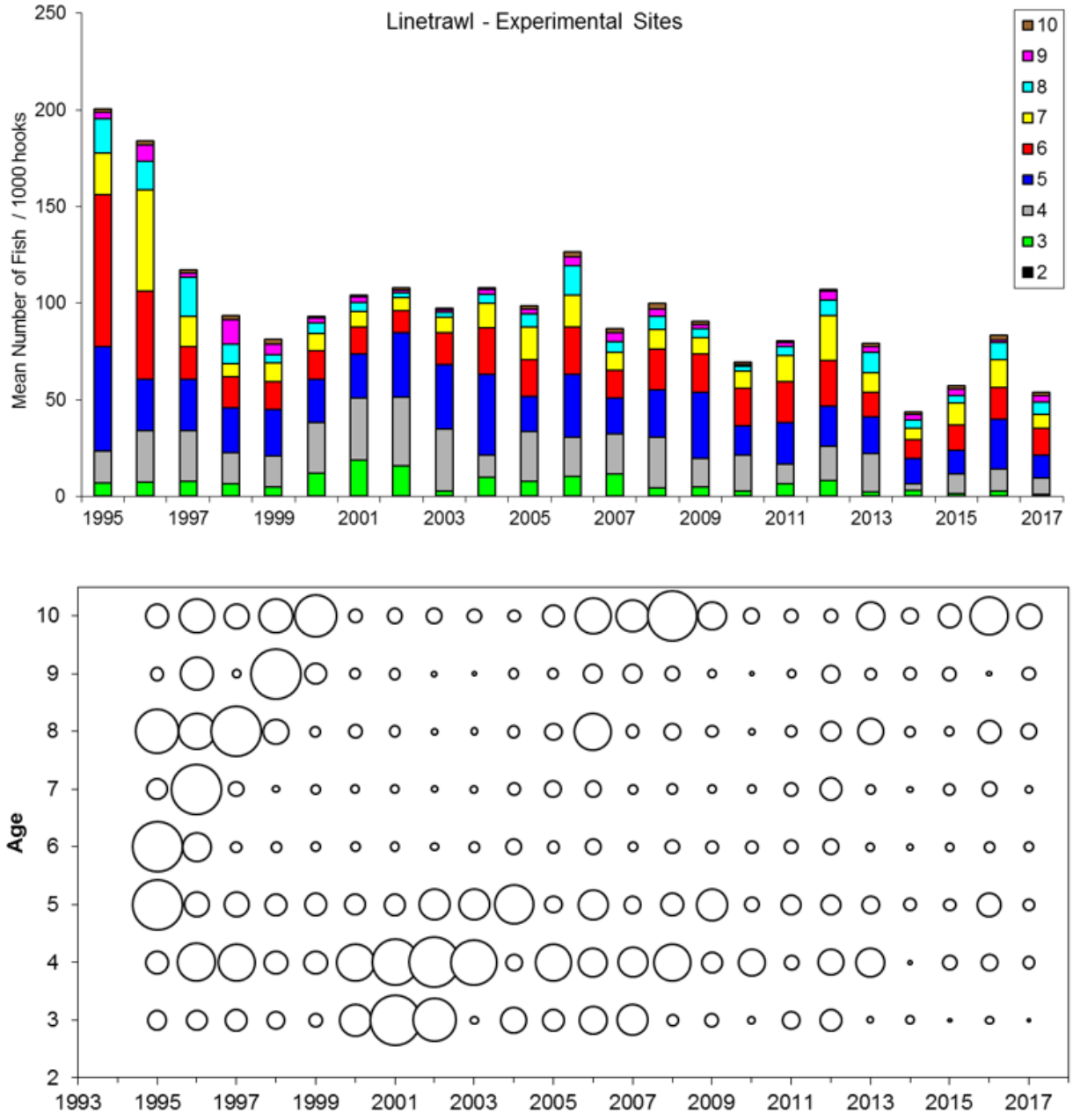

Figure 12. Standardized age-disaggregated catch rate for linetrawl (top panel), and the proportions of Sentinel catch rate-at-age (lower panel) using data from Sentinel survey experimental sites in Subdivision 3Ps, 1995-2017.

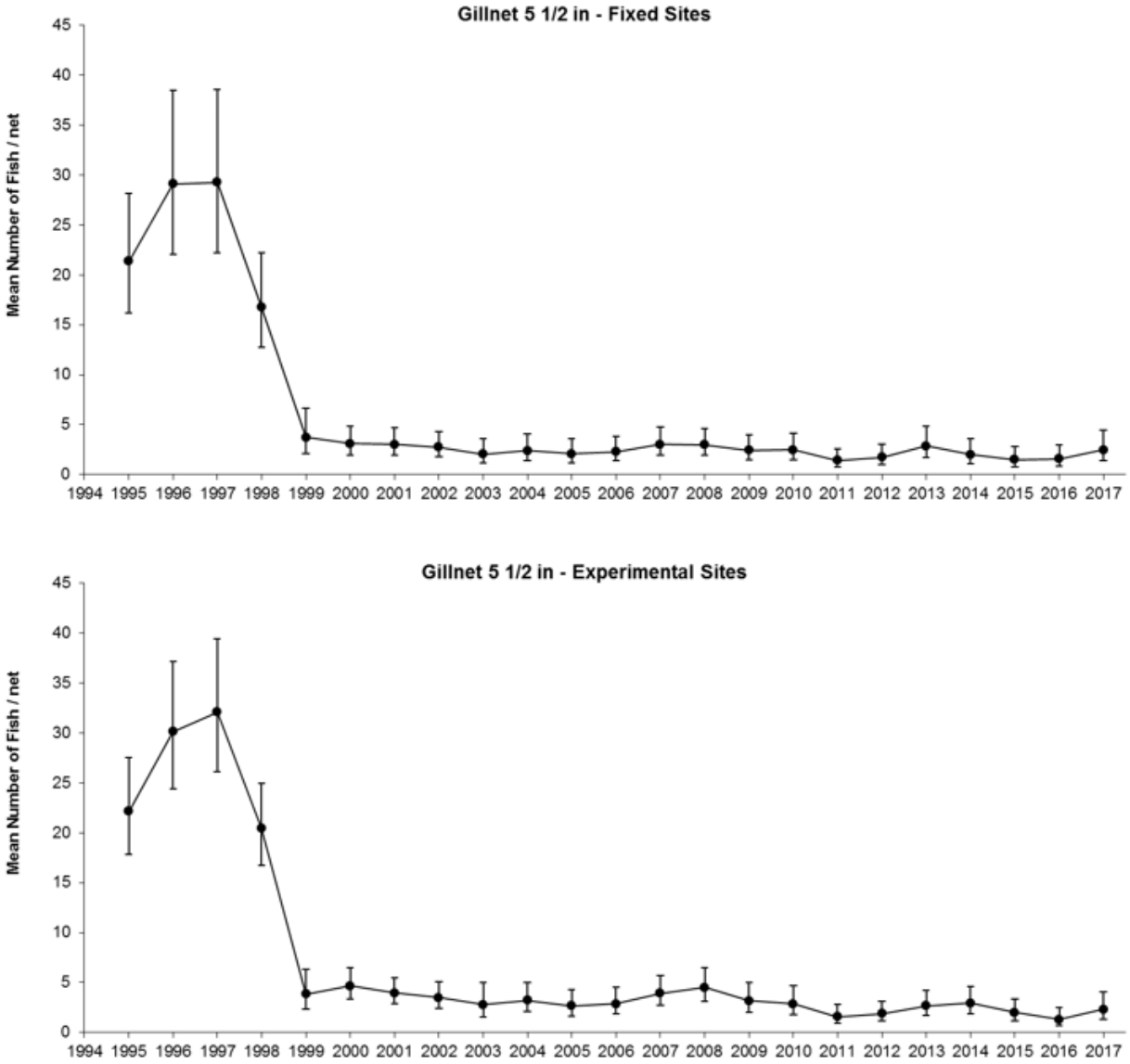

Figure 13. Standardized age-aggregated catch rate for large mesh gillnet (+/-95% CI), using data from Sentinel survey control (top panel) and experimental (lower panel) sites in Subdivision 3Ps, 1995-2017.

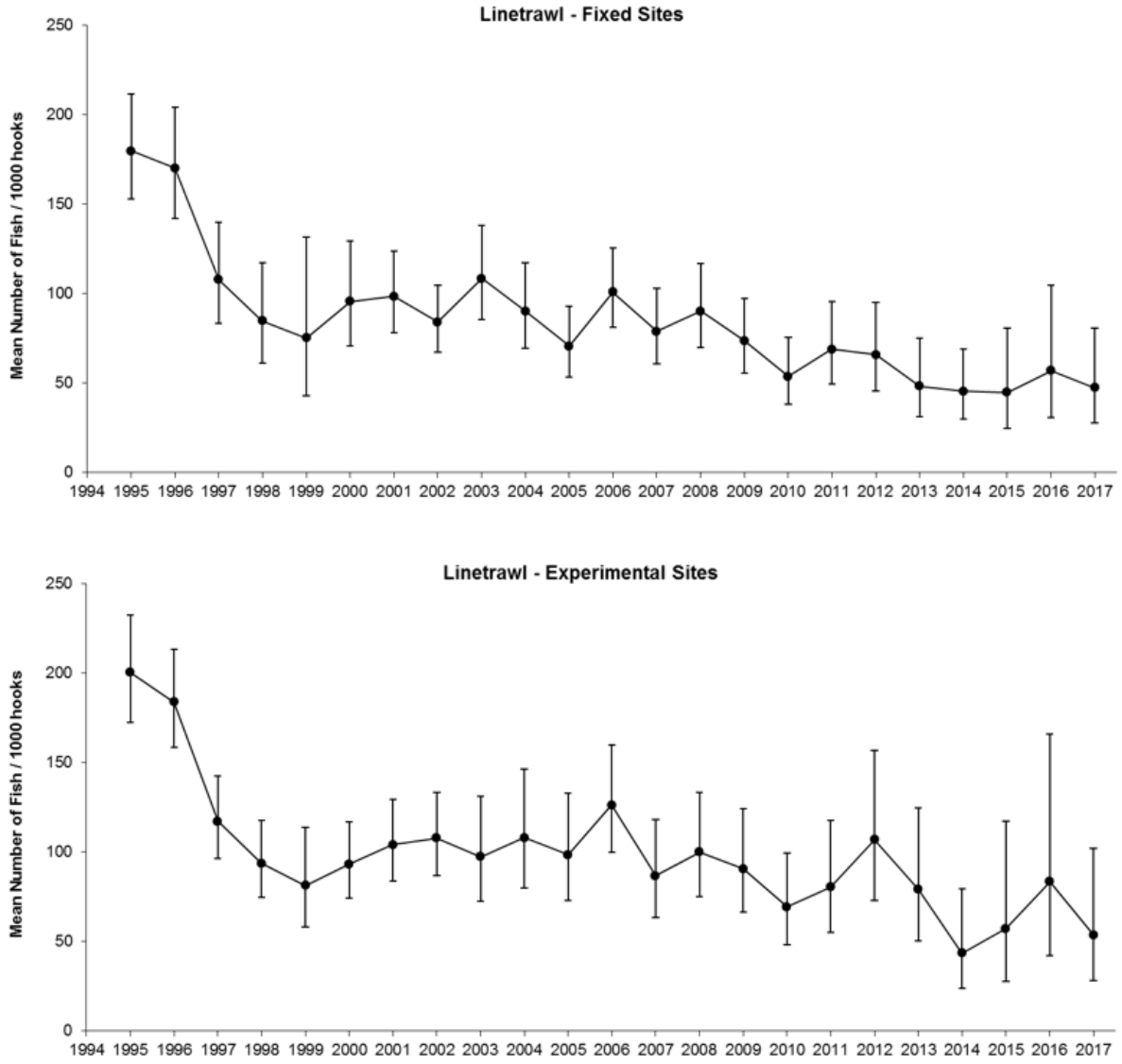

Figure 14. Standardized age-aggregated catch rate for linetrawl (+/-95% CI), using data from Sentinel survey control (top panel) and experimental (lower panel) sites in Subdivision 3Ps, 1995-2017.

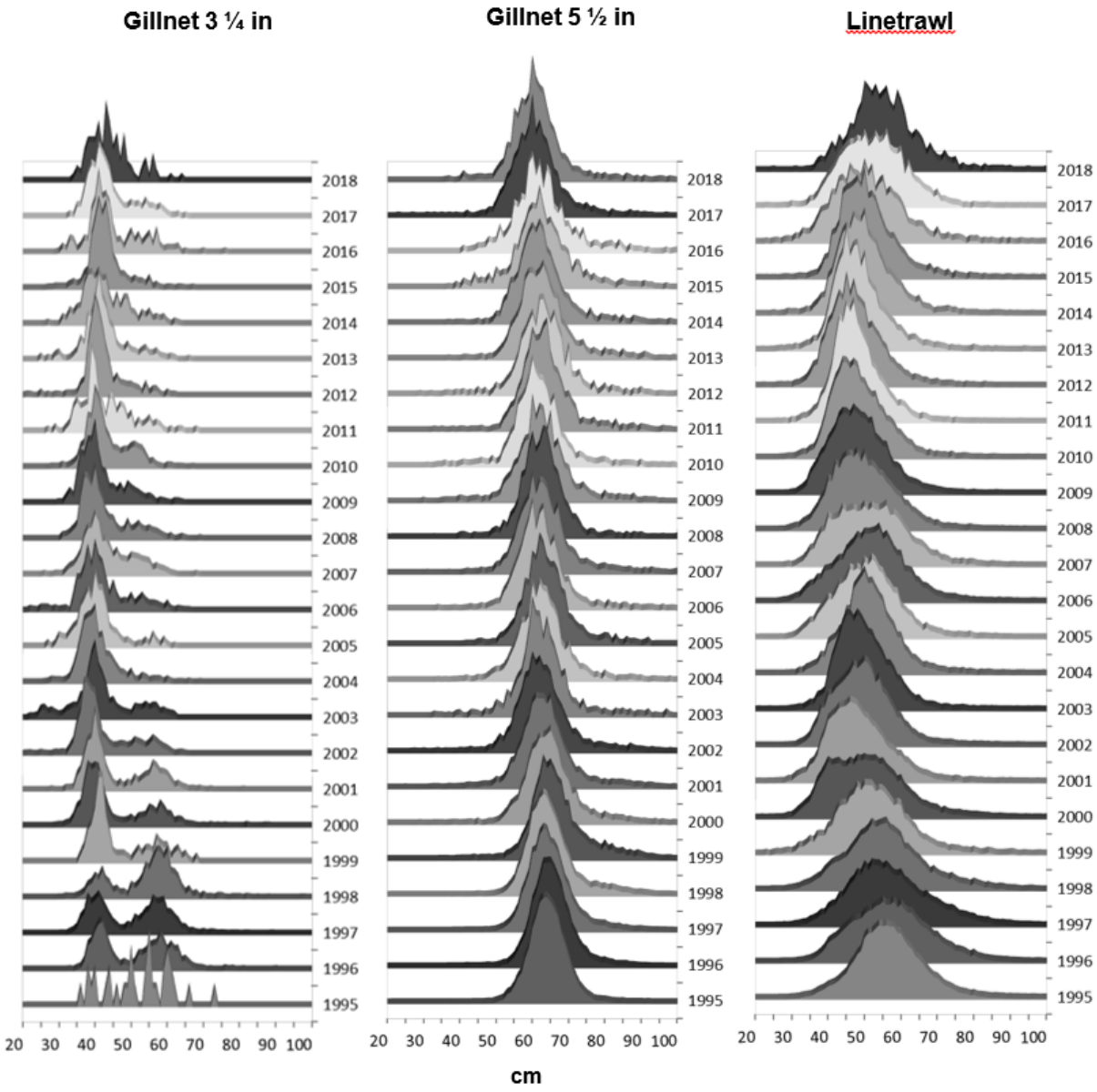

Figure 15. Length distributions (N=92424 fish, number at length scaled to 1) of Cod from Sentinel surveys in Subdivision 3Ps (control and experimental sites combined), 1995-2018.Data for 2018 are preliminary.

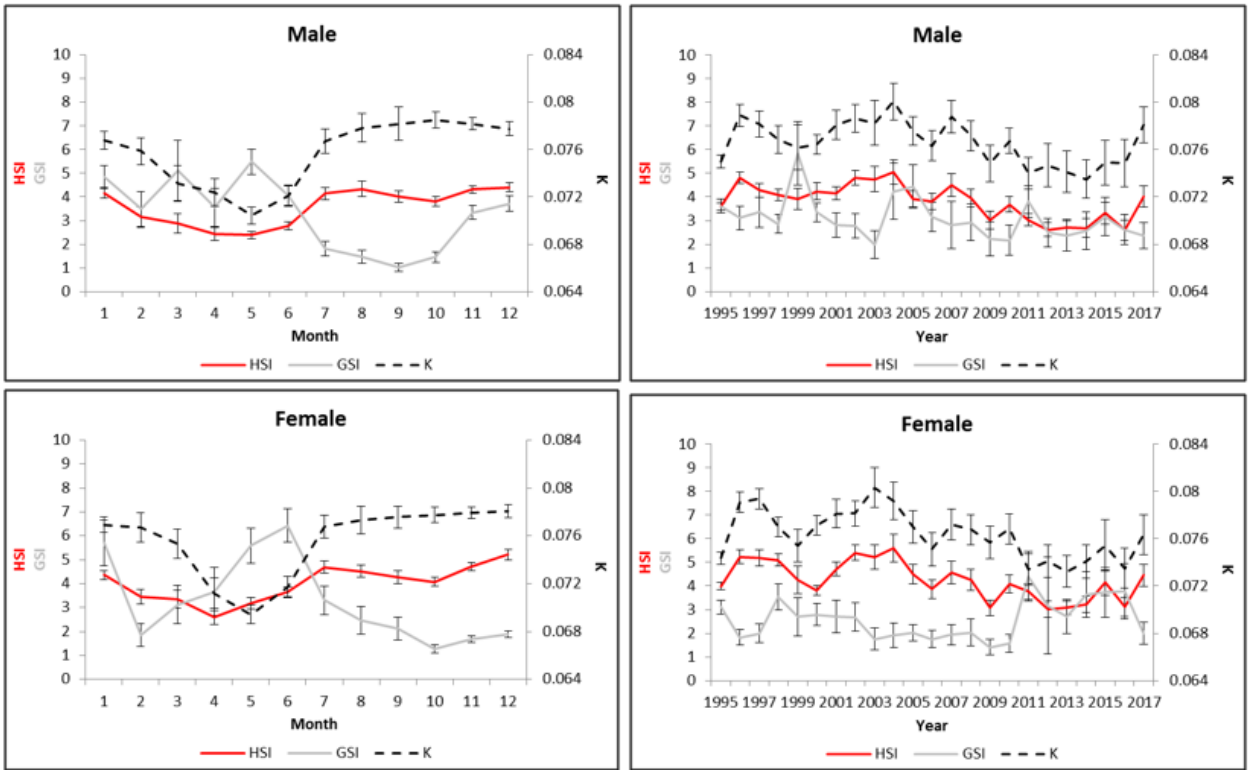

Figure 16. Temporal changes in mean Fulton's K condition factor (N=6,358 fish), mean Hepatosomatic Index (HSI; N=6,066 fish), and mean Gonadosomatic Index (GSI; N=6,211 fish) by sex for Atlantic Cod (sizes combined) from Sentinel surveys in Subdivision 3Ps, 1995-2017. T-bars represent +/-95% CI.

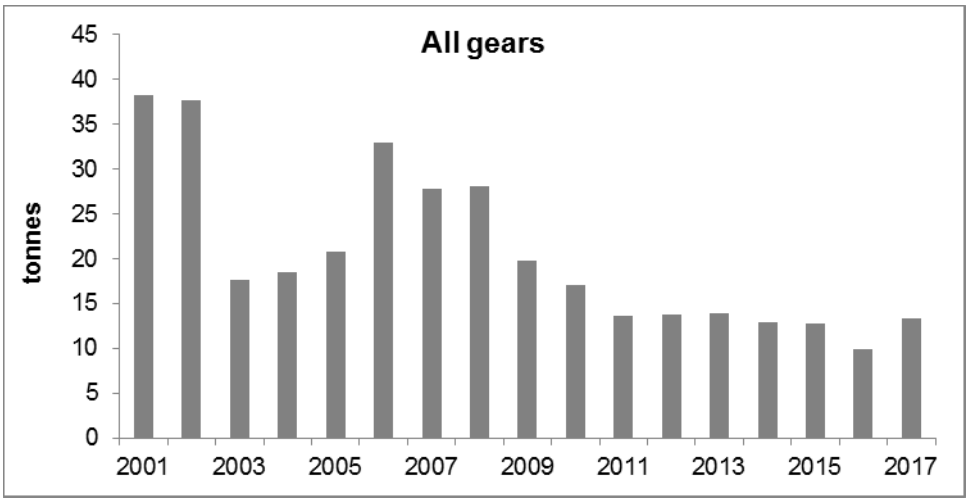

Figure 17. Total annual removals of Atlantic Cod (t) from Sentinel surveys (control and experimental sites; all gears combined) in Subdivision 3Ps, 2001-17.

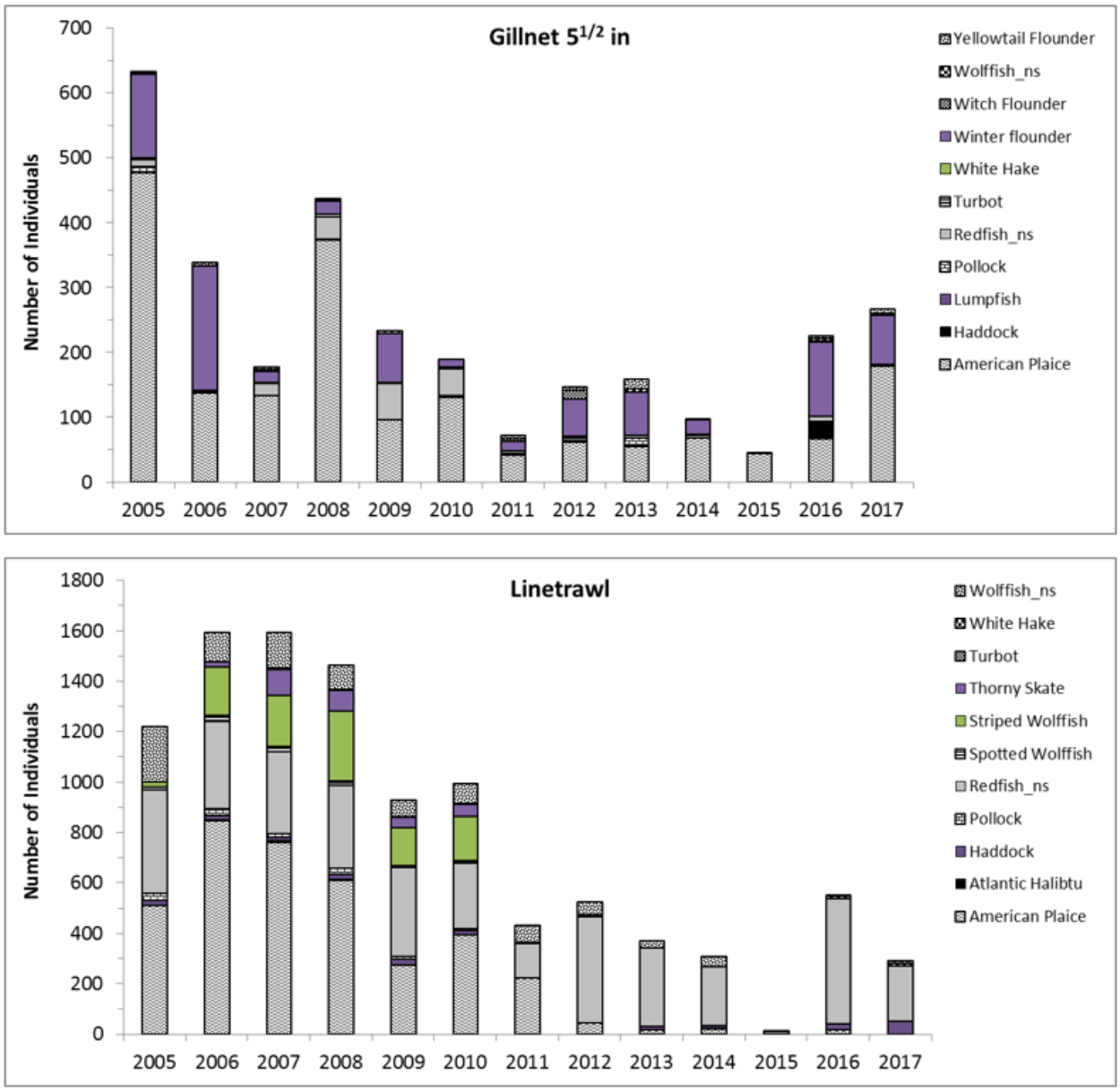

Figure 18. Total annual number of fish per bycatch species from Sentinel surveys (control and experimental sites; all gears combined) in Subdivision 3Ps, 2005-17.