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Georges Bank Yellowtail Flounder Estimates from VIMS Industry-Based Scallop Dredge Surveys of Closed Area II and Surrounds

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ABSTRACT

The Virginia Institute of Marine Science (VIMS) conducted fine scale spatial dredge surveys of Closed Area II (CAII) in 2005, 2007, 2008, 2011, 2012, 2013, 2016, 2017, 2018, and 2019 for the purposes of examining scallop abundance and distribution. The spatial extent of surveys varied between years. From 2005–2011, the traditional CAII scallop access area was surveyed. In 2012, a portion of the CAII groundfish closure and surrounds on the northern edge of Georges Bank (GB) were surveyed. In 2013, area in the Essential Fish Habitat (EFH) and surrounds on the northern edge of GB were surveyed again. For 2016–2019, the traditional CAII scallop access area and surrounds along the southern flank of GB were surveyed. In 2018 and 2019, the survey domain was expanded to cover additional area along the southern flank of GB. Scallop and finfish catch were enumerated, and length measurements were taken. Survey catches were examined to determine whether there were trends in Yellowtail Flounder abundance in the surveyed area. Results indicated a decline in Yellowtail Flounder abundance over the time period, as well as a truncation of the size distribution observed.

INTRODUCTION

The stock assessment model for Georges Bank (GB) Yellowtail Flounder uses an empirical assessment approach, developed at the 2014 GB Yellowtail Flounder Diagnostic and Empirical Approach Benchmark and subsequent Transboundary Resource Assessment Committee (TRAC) meeting, and further refined following an intersessional TRAC conference call in June 2017 (i.e., adjusted survey catchability). The three bottom trawl surveys used are Fisheries and Oceans Canada (DFO), National Marine Fisheries Service (NMFS) Spring, and NMFS Fall, which create a model-free estimate of population biomass (Legault and McCurdy, 2018). An exploitation rate is applied to the average of these three surveys to derive catch advice.

Catches of GB Yellowtail Flounder by the groundfish fishery have been at historic-low levels because of low quotas, resulting in a decline in fishery-dependent information on the stock. There have also been uncertainties associated with the Research Vessel (R/V) surveys from both the NMFS and DFO. In the case of the R/V *Bigelow* (NMFS survey vessel), there have been several investigations on the catchability assumptions used to convert relative survey indices into biomass estimates, and, in the past few years, there have been concerns raised about the accuracy of the area-swept by the survey vessel at different depths. In the fall of 2017, a different research vessel was used because of mechanical difficulties with the R/V *Bigelow*. The Spring DFO survey also used a different vessel than normal in 2017. The NMFS also completed fewer tows in 2017 and 2018, due to weather and mechanical issues (Legault and McCurdy, 2018). As a result of the uncertainty caused by factors such as these, additional information on recent abundance trends could be helpful when interpreting the results of the empirical approach.

The U.S. Atlantic sea scallop fishery has an extensive research program, referred to as a Research Set-Aside (RSA) program, funded by a set-aside of the annual fishery quota. A key part of this program is the funding of surveys using several different gears: commercial dredges, a standardized sea scallop survey dredge, and cameras. The Virginia Institute of Marine Science (VIMS) dredge survey focuses primarily on areas of sea scallop abundance, but also collects biological information related to finfish and other biota as a secondary objective. Surveys on GB often overlap areas of historic Yellowtail Flounder distribution, such as the VIMS dredge surveys of the Closed Area (CA) II access area, CAII groundfish closed area, and surrounds in 2005, 2007, 2008, 2011, 2012, 2013, 2016, 2017, 2018, and 2019. Here, the VIMS survey data in CAII and surrounds were examined for trends in Yellowtail Flounder abundance.

DATA AND METHODS

VIMS received scallop RSA funding to conduct high resolution surveys to sample several areas of GB CAII and surrounds. Survey domains varied across the time period examined. Areas surveyed included the CAII scallop access area, CAII groundfish closed area, EFH area, additional area on the northern edge of GB, a rotational closure area south of the scallop access area, and additional area on the southern flank of GB (Figures 1–10). While the focus of these surveys was to conduct a high-resolution survey of the scallop resource in these areas, a secondary objective was to collect information on finfish catch. One finfish species of interest was Yellowtail Flounder because the scallop fishery catch of this species is limited to a small allocation. While the survey does not cover all of GB, the majority of survey coverage focuses on the area of historical Yellowtail abundance that corresponds to an area with limited coverage by the NMFS bottom trawl Spring and Fall surveys in more recent years (2016–2018), shown in Figure 11 (Legault and McCurdy, 2017; Legault and McCurdy, 2018).

In addition to changing survey domains, other aspects of the surveys were also variable, including survey design, commercial gear used, and number of stations sampled. Summary information for each survey is provided in Table 1. The number of stations sampled during each survey is provided in Table 2.

SURVEY DESIGN AND STATION ALLOCATION

Each survey consisted of one annual cruise that sampled pre-determined stations within a given survey domain. The survey design was changed from a systematic sampling grid design to a stratified random design in 2016. A systematic grid design was used from 2003–2013. The methodology to generate the systematic random grid entailed the decomposition of the defined domain of interest into smaller sampling cells. The dimensions of the sampling cells were primarily determined by a sample size analysis conducted using the catch data from survey trips conducted in the same areas during prior years. Since sampling domains were of different dimensions and the total number of stations sampled per survey remained fairly constant, the distance between stations varied. Generally, the distance between stations was roughly 5.5–7.4 km. Once the cell dimensions were set, a point within the most northwestern cell was randomly selected. This point served as the starting point, and all the other stations in the grid were based on its coordinates. Since 2016, a stratified random survey design has been employed (Cochran, 1977). In 2016, stations were allocated using proportional allocation based on stratum size. For 2017–2019, a hybrid approach consisting of both proportional and optimal allocation techniques (Neyman allocation) determined station allocation (Cochran, 1977). A percentage of stations were allocated based on stratum area, the number of scallops observed in the previous year, and the biomass (grams) of scallops observed in the previous year. To ensure all strata in a survey domain were sampled, each stratum was allocated a minimum of two stations. Stratification was based on the NMFS shellfish strata.

SURVEY PROTOCOLS

All surveys were conducted onboard commercial sea scallop dredge vessels in the spring/summer (Table 1). At each station, the vessel simultaneously towed two dredges. The NMFS sea scallop survey dredge, 2.4 m in width equipped with 5.08 cm rings, 10.16 cm diamond twine top and a 3.8 cm diamond mesh liner was towed on one side of the vessel. On the other side of the vessel, a 3.96 m, 4.27 m, or 4.57 m commercial scallop dredge equipped with 10.16 cm rings, a 25 cm diamond mesh twine top and no liner was fished (Table 1). In this paired design, it is assumed that the dredges cover a similar area of substrate and sample from the same population of scallops. For each paired tow, the dredges were fished for 15 minutes with a towing speed of approximately 3.8–4.0 kts, and a scope to depth ratio of 3:1. Since 2016, a Star Oddi tilt sensor (records angle of inclination, temperature, and depth) has been used to determine dredge bottom contact time, and high-resolution navigational logging equipment has been used to accurately determine vessel position and speed over ground. Time stamps for both the inclinometer and the navigational log determined the location and duration fished by the dredges. Bottom contact time and vessel location were integrated to estimate the swept area of each gear.

CATCH SAMPLING

Sampling of the catch was conducted in the same manner described by DuPaul and Kirkley (1995) and DuPaul et al. (1989) for all VIMS scallop surveys since 2005. For each paired tow, the entire scallop catch, from both the survey and commercial dredges, was kept separate and placed in traditional scallop baskets to quantify total catch. Total scallop catch, or a subsample depending upon catch volume, was measured. Prior to 2016, scallops were measured with NMFS sea scallop measuring boards in 5 centimeter (cm) intervals. Since 2016, scallops have been measured to the nearest millimeter (mm) to determine size frequency.

Other species sampled included typical sea scallop fishery bycatch: groundfish, skates, crabs and starfish. All groundfish (flatfish, Monkfish, Cod, Haddock, and Dogfish) were counted and measured (by species) for Total Length (TL) to the nearest centimeter (cm), prior to 2016, and to the nearest millimeter, 2016 onward, for each dredge. Since 2016, all station-level data has been entered into the Fisheries Environment for Electronic Data (FEED) data-acquisition program. Data collected included number of animals, length measurements, bridge information, and shell height – meat product quality data. Length measurements were recorded using an electronic Ichthystick measuring board integrated with the FEED program that allows for automatic recording of length measurements. The bridge data included station level information, including location, time, tow time (break-set/haul-back), tow speed, water depth, weather, and comments relative to the quality of the tow. Data collection has been consistent across years. Before 2016, all data was recorded on paper logs and entered into a database after a cruise was completed.

SCALLOP DREDGE EFFICIENCY

Dredge efficiency estimates for Yellowtail Flounder for either the survey or commercial dredges are limited, with literature on this topic coming from past TRAC working papers (Barkley et al., 2013; Hennen, 2014; Shank et al., 2013; DeCelles et al., 2014). Shank et al. (2013) and Hennen (2014) each provided several Yellowtail Flounder efficiency estimates for the survey dredge from data collected by the NMFS' sea scallop Habcam optical survey. Shank et al. (2013) estimated efficiency values of 0.43 for 2010 data, 0.82 for 2012 data, and a mean of 0.62. The authors suggested the 2012 estimate of 0.82 may be more accurate for several reasons related to the timing between the dredge and Habcam surveys, Yellowtail Flounder seasonal migration patterns, and gear avoidance observed by Yellowtail Flounder in relation to the Habcam gear (Shank et al., 2013; Shank and Duquette, 2013). Yellowtail Flounder migration into CAII has shown to vary seasonally, with Yellowtail Flounder moving into the area in the late summer/early fall (Barkley et al., 2013; Winton et al., 2017). Hennen (2014) also provided the following efficiency estimates: 0.46, 0.49, 0.77, and 0.83. These values were also estimated with the NMFS Habcam dredge data. The author noted the efficiency estimates "provide some limited information on the efficiency of the scallop survey dredge for YTF [Yellowtail Flounder]. It is, however, important to incorporate the coefficient of variation [CV] of these estimates as they are highly imprecise."

Barkley et al. (2013) and DeCelles et al. (2014) estimated efficiency values for the commercial New Bedford style scallop dredge. These estimates were derived from data collected in 2012 as part of a seasonal bycatch survey conducted by the Coonamesset Farm Foundation in CAI and CAII. A ratio of the efficiency of the survey dredge to the value from a regression through the origin for catch data from the study was used to estimate commercial dredge efficiency. This resulted in efficiency estimates of 0.201 and 0.25 for the commercial dredge from Barkley at al. (2013) and DeCelles et al., (2014), respectively. The ratio presented in both papers could be used to estimate commercial dredge efficiency for a range of survey efficiency estimates.

BIOMASS ESTIMATION

Yellowtail Flounder length data were converted to centimeters. Length-weight parameters from Wigley et al. (2003) were used to calculate individual Yellowtail Flounder weights in kilograms (kg). For trips taken in 2007, 2013, 2016, 2017, 2018, and 2019, spring parameter estimates of ln a = -12.3581 and b = 3.2099 were used. For trips taken in 2005, 2008, 2011, and 2012, the average of spring and autumn estimates were used (ln a = -12.0981 and b = 3.1329), since no estimates for summer months were available (Barkley et al., 2013; DeCelles et al., 2014). The total number-per-tow and weight-per-tow was the sum of all individual fish at a given station.

Area-swept for each station by gear type was calculated by multiplying the dredge-width (m) by the tow-distance (km). For trips taken prior to 2016, tow-distance was calculated with the geodist function in R, using the start and end coordinates for a station (R Core Team, 2016). For trips after 2016, the Star Oddi sensor informed actual time on bottom. Data from the sensor was integrated with the vessel's tow track to calculate tow-distance with the same R function. The appropriate dredge-width for the commercial dredge by year was used for commercial gear calculations (Table 1). The calculated area-swept for each gear prior to 2016 may be slightly overestimated as a result of using the start and end coordinates. This would lead to a minor underestimate of Yellowtail Flounder density at the station-level, depending on the difference between the realized tow-distance and the estimated tow-distance.

Area-swept total biomass (kg/tow) and abundance (number/tow) estimates for each year and gear were calculated from station-level density estimates. Density was scaled to estimate absolute biomass or abundance with a range of catchability coefficients (*q*) by gear type. The following *q* values were used for the survey dredge: 0.43, 0.62, 0.83, and 1 (Shank et al., 2013). Hennen's estimates were not considered, based on the author's conclusions regarding the values. For the commercial dredge, *q* values applied were 0.25, 0.43, and 1 (DeCelles et al., 2014). The DeCelles' et al. (2014) *q* value was selected over the Barkley et al. (2013) estimate because data issues were found in the Barkley et al. paper (DeCelles, *per. comm.*). A *q* of 1 for either gear represents the minimum area-swept biomass estimate and should be considered the lower bound of biomass estimates.

The absolute density of Yellowtail Flounder (kg/km^2 and number/km^2) for station i, gear g and year y was calculated as:

$$Yellowtail\ Flounder\ density_{i,g,y} = \frac{Yellowtail\ Flounder\ _{i,g,y}(kg/number)}{area\ swept_{i,g,y}\ \ (km^2)} * \frac{1}{q_g}$$

Total biomass (mt) or total number for each year and gear was calculated as the mean Yellowtail Flounder density ($\overline{Yellowtail\ Flounder\ density_{g,y}}$) in the survey domain multiplied by the survey area:

$$Total\ Biomass_{y,g} = \overline{Yellowtail\ Flounder\ density_{g,y}} * Survey\ Area_y\ (km^2)$$

The variance and 95 percent confidence intervals were calculated for all estimates.

Stratification of the survey domain for 2016–2019 was not considered in biomass estimation, since strata were based on NMFS shellfish strata and the survey design was not consistent across years.

RESULTS

The number and total weight (kg) of Yellowtail Flounder by year and gear are provided in Table 3. The number and weight of Yellowtail Flounder caught in either dredge has declined over the time period, although there was an increase in the number of fish observed in both gears in

2019 compared to 2018. This overall decline is evident in the most recent years (2016–2019), even though there was an increase in the number of stations, and area covered, compared to earlier years. The greatest number of fish were observed from 2005–2008. The number of fish caught in the survey dredge in 2019 was the greatest recorded since 2013. The increase was more modest in the commercial gear. The commercial gear in 2019 was smaller than previous commercial gears, with a width of 3.96 m compared to larger dredges used in 2017 and 2018.

Length frequency distributions by year and gear are included in Figures 12–13. The survey dredge retained smaller Yellowtail Flounder than the commercial dredge, which is expected since the survey dredge uses a 3.8 cm liner that is not used in the commercial dredge. The selectivity of the commercial dredge also limits the catch of smaller Yellowtail Flounder (Legault et al., 2010). The size range of Yellowtail Flounder caught in either dredge has narrowed since 2012, as the number of fish caught as decreased. In 2019, the number of smaller fish caught in the survey dredge increased. The majority of fish sampled were in the 10 to 20 cm length range.

The spatial distribution of Yellowtail Flounder catches for each year and gear are provided in Figures 14–23. Between 2005 and 2011, Yellowtail Flounder were observed throughout the CAII access area. In 2012 and 2013, surveys focused on the northern portion of CAII, and Yellowtail Flounder were observed throughout the survey domains in both years. In 2016 and 2017, fish were sampled primarily in the central portion and northeast area of the CAII access area. In 2018 and 2019, Yellowtail Flounder were mainly observed along the southern and eastern boundaries of the CAII access area.

Absolute biomass and abundance estimates with varying q values are provided in Tables 4–7. Biomass and abundance have declined since 2005 for both gears. Biomass estimates for 2018 and 2019 were comparable for the survey dredge, with estimates ranging from 63.90 mt ($q = 1$) to 150.33 mt ($q = 0.43$). Estimates for the commercial dredge in 2019 were approximately double the 2018 estimates. Abundance in 2019 was greater than 2018 for the survey dredge due to the increase in the number of small fish observed this year. For the commercial dredge, the 2018 biomass estimates are the lowest for the time period. The lower bound estimate in 2018 was 30.17 mt. Biomass increased slightly in 2019 to 64.64 mt, when assuming the commercial dredge catchability was 1.

DISCUSSION

The VIMS scallop surveys provide detailed spatial coverage of a portion of the GB Yellowtail Flounder stock area. With its consistent and well-documented methods, it can provide additional information on the status of the GB Yellowtail Flounder stock—albeit for a limited area at one time of the year. However, the area covered by the surveys is an area long recognized as important for this stock. The information from this survey can be used as ancillary information to assist with the interpretation of assessment results and trends from surveys traditionally used for management.

Over the time period the surveys were conducted, biomass estimates reflect a decline in Yellowtail Flounder abundance in the areas monitored. The decline in biomass in 2007, followed by an increase in 2008, is probably related to the timing of the surveys and Yellowtail Flounder migration into the survey area. In 2007, the survey was conducted in the spring, while the 2005 and 2008 surveys were conducted in the summer. The spring period may be too early to monitor Yellowtail Flounder that have not begun to migrate into the CAII access area. The 2018 and 2019 estimates are the lowest in the time period for both gears. The 2018 results are similar to the biomass indices from the 2018 DFO and Spring NMFS trawl surveys in terms of being the lowest estimates during the time period (Legault and McCurdy, 2018).

The overall reduction in biomass may be related to a lack of recruitment, as illustrated by the contraction of the length distribution of fish observed over the time period and a decline in the number of fish caught. Given the limited number of fish caught in the latter years, this conclusion, however, is uncertain. The increase in the number of small fish observed in 2019 also contributes to the uncertainty regarding recruitment.

Biomass values are comparable to previous estimates provided by VIMS to the TRAC in 2014 for the 2005, 2007, 2008, and 2011 surveys (Rudders and Legault, 2014). Rudders and Legault (2014) estimated absolute biomass with catchability coefficients of 0.46 and 1. While the catchability coefficient of 0.43 is slightly lower than the value used in 2014, the difference between estimates in small. The minimum area-swept estimates, assuming a catchability coefficient of 1, were also equivalent for all years. There is a similar signal of declining biomass over time from both sets of estimates. When comparing the 2019 estimate to previous estimates, the 2019 lower bound estimates of 64.64 mt for the survey gear and 61.24 mt for the commercial dredge are considerably lower than any estimate provided by Rudders and Legault (2014) for either gear. The lowest minimum estimate provided by Rudders and Legault (2014) for the survey dredge was 901.21 mt and 782.60 mt for the commercial dredge.

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TABLES

Table 1. Summary information for the VIMS surveys including vessel, commercial dredge-width (m), survey area (km2), and survey design.

Year	Vessel	Dates	Commercial Dredge-Width (m)	Survey Area (km^2)	Survey Design
2005	Celtic	8/18–8/23/2005	4.27	3,865	Systematic Grid
2007	Celtic	5/24–5/31/2007	4.27	3,865	Systematic Grid
2008	Celtic	7/19–7/24/2008	4.27	3,865	Systematic Grid
2011	Celtic	5/6–5/15/2011	4.27	3,865	Systematic Grid
2012	Regulus	7/17–7/25/2012	4.57	7,592	Systematic Grid
2013	Celtic	5/27–5/31/2013	4.27	2,040	Systematic Grid
2016	KATE	6/21–6/29/2016	4.57	6,407	Stratified Random
2017	Flavian S	6/16–6/24/2017	4.27	6,407	Stratified Random
2018	Arcturus	6/8–6/16/2018	4.57	7,553	Stratified Random
2019	Polaris	6/7–6/14/2019	3.96	7,553	Stratified Random

Table 2. Number of stations competed for the VIMS surveys by year and gear. Total area-swept (km^2) and the average area-swept (m^2) calculated from the survey dredge are also provided.

Year	Gear	Number of Stations	Total Area-swept (km^2)	Average Area-swept (m^2)
2005	Commercial	103	7,115.27	
	Survey	103	4,065.87	1,618.87
2007	Commercial	112	7,754.20	
	Survey	116	4,589.22	1,622.47
2008	Commercial	101	6,771.68	
	Survey	101	3,869.53	1,619.30
2011	Commercial	100	6,910.46	
	Survey	103	4,067.00	1,619.32
2012	Commercial	136	10,119.85	
	Survey	136	5,397.26	1,627.53
2013	Commercial	101	7,022.84	
	Survey	101	4,013.05	1,629.48
2016	Commercial	100	9,061.27	
	Survey	100	4,885.69	1,854.86
2017	Commercial	100	7,758.81	
	Survey	100	4,170.55	1,695.52
2018	Commercial	122	9,642.12	
	Survey	122	5,101.06	1,700.79
2019	Commercial	130	8,335.22	
	Survey	130	5,132.47	1,619.12

Table 3. Number and weight (kg) of Yellowtail Flounder caught in the VIMS survey by year and gear along with totals.

Year	Commercial Gear		Survey Gear		Total Number	Total Weight (kg)
	Number	Weight (kg)	Number	Weight (kg)		
2005	684	304.04	919	312.00	1,603	616.05
2007	571	145.99	501	141.90	1,072	287.89
2008	609	257.64	506	220.75	1,115	478.39
2011	122	49.65	168	72.28	290	121.92
2012	52	24.75	102	34.22	154	58.97
2013	67	34.69	126	43.96	193	78.65
2016	22	10.87	21	9.60	43	20.47
2017	25	11.90	15	7.84	40	19.74
2018	7	3.77	9	4.11	16	7.88
2019	12	6.75	57	4.38	69	11.13
Total	2,171	850	2,424	851	4,595	1,701.09

Table 4. Absolute biomass (mt) estimates for the VIMS survey dredge by year with varying catchability coefficients, as well as 95 percent Lower Confidence Intervals (LCI) and 95 percent Upper Confidence Intervals (UCI).

	q = 0.43			**q = 0.62**			**q = 0.83**			**q = 1**		
Year	Biomass (mt)	LCI	UCI	Biomass (mt)	LCI	UCI	Biomass (mt)	LCI	UCI	Biomass (mt)	LCI	UCI
2005	6,890.16	5,317.28	8,463.04	4,778.66	3,687.79	5,869.53	3,613.13	2,788.33	4,437.93	2,962.77	2,286.43	3,639.11
2007	2,785.14	2,220.94	3,349.34	1,931.63	1,540.33	2,322.93	1,460.50	1,164.64	1,756.36	1,197.61	955.00	1,440.22
2008	4,975.53	3,811.82	6,139.24	3,450.77	2,643.68	4,257.86	2,609.12	1,998.88	3,219.36	2,139.48	1,639.08	2,639.87
2011	1,595.89	1,106.02	2,085.77	1,106.83	767.08	1,446.58	836.87	579.99	1,093.76	686.23	475.59	896.88
2012	1,036.56	641.13	1,431.98	718.90	444.65	993.15	543.56	336.20	750.92	445.72	275.69	615.75
2013	520.07	315.23	724.92	360.70	218.63	502.77	272.72	165.30	380.14	223.63	135.55	311.72
2016	322.00	119.25	524.75	223.32	82.71	363.94	168.85	62.53	275.17	138.46	51.28	225l64
2017	294.69	116.10	473.28	204.38	80.52	328.24	1542.53	60.88	248.19	126.72	49.92	203.51
2018	148.60	40.05	257.16	103.06	27.78	178.35	77.98	21.00	132.85	63.90	17.22	110.58
2019	150.33	61.59	239.06	104.26	42.71	165.80	78.83	32.30	125.36	64.64	24.48	102.80

Table 5. Absolute biomass (mt) estimates for the VIMS survey dredge by year with varying catchability coefficients, as well as 95 percent Lower Confidence Intervals (LCI) and 95 percent Upper Confidence Intervals (UCI).

Year	**q = 0.43**			**q = 0.62**			**q = 0.83**			**q = 1**		
	Number	LCI	UCI	Number	LCI	UCI	Number	LCI	UCI	Number	LCI	UCI
2005	20,297,239.63	15,921,948.33	24,672,530.94	14,077,117.81	11,042,641.59	17,111,594.04	10,643,674.44	8,349,314.37	12,938,034.52	8,727,813.04	6,846,437.78	10,609,188.30
2007	9,820,336.07	7,862,704.83	11,777,967.31	6,810,878.24	5,453,166.25	8,168,590.23	5,149,688.43	4,123,125.70	6,176,251.15	4,222,744.51	3,380,963.08	5,064,525.94
2008	11,404,480.45	8,879,720.13	13,929,240.78	7,909,559.02	6,158,515.57	9,660,602.47	5,980,398.29	4,656,438.60	7,304,357.97	4,903,926.59	3,818,279.65	5,989,573.53
2011	3,710,210.39	2,685,536.07	4,734,884.72	2,573,210.44	1,862,549.21	3,283,871.66	1,945,598.13	1,408,268.91	2,482,927.36	1,595,390.47	1,154,780.51	2,036,000.43
2012	3,145,702.20	2,049,336.86	4,242,067.54	2,181,696.69	1,421,314.28	2,942,079.10	1,649,575.54	1,074,652.26	2,224,498.83	1,352,651.95	881,214.85	1,824,089.04
2013	1,490,430.74	941,277.85	2,039,583.63	1,033,685.83	652,821.73	1,414,549.94	781,567.34	493,596.92	1,069,537.76	640,885.22	404,749.47	877,020.96
2016	701,727.34	259,307.65	1,144,147.04	486,681.87	179,842.40	793,521.33	367,978.97	135,978.40	599,979.54	301,742.76	111,502.29	491,983.23
2017	553,833.88	270,462.24	837,205.52	384,110.60	187,578.65	580,642.54	290,452.08	141,827.76	439,022.41	238.148.57	116,298.76	359,998.38
2018	319,083.96	96,008.58	542,159.34	221,300.17	66,586.59	376,013.74	167,324.52	50,345.96	284,303.07	137,206.10	41,283.69	233,128.52
2019	1,950,887.63	1,210,014.94	2,691,760.32	1,353,034.97	839,203.91	1,866,866.03	1,023,026.44	634,520.03	1,411,532.85	838,881.68	520,306.42	1,157,456.94

Table 6. Absolute biomass (mt) estimates for the VIMS survey dredge by year with varying catchability coefficients, as well as 95 percent Lower Confidence Intervals (LCI) and 95 percent Upper Confidence Intervals (UCI).

Year	**q = 0.25**			**q = 0.43**			**q = 1**		
	Biomass(mt)	LCI	UCI	Biomass(mt)	LCI	UCI	Biomass(mt)	LCI	UCI
2005	6,650.63	5,019.47	8,281.79	3,835.71	2,894.95	4,776.47	1,649.36	1,244.83	2,053.88
2007	2,936.77	2,336.56	3,536.97	1,693.76	1,347.60	2,039.93	728.32	579.47	877.17
2008	5,753.20	4,601.67	6,904.73	3,318.13	2,653.99	3,982.26	1,426.79	1,141.21	1,712.37
2011	1,119.17	735.72	1,502.62	645.47	424.32	866.62	277.55	182.46	372.65
2012	732.36	384.19	1,080.53	422.39	221.58	623.19	181.63	92.28	267.97
2013	406.86	216.94	596.78	234.65	125.12	344.19	100.90	53.80	148.00
2016	335.20	154.73	515.67	193.32	89.24	297.41	83.13	38.37	127.89
2017	430.43	188.11	672.74	248.25	108.49	388.00	106.75	46.65	166.84
2018	121.67	30.56	212.78	70.17	17.62	122.72	30.17	7.58	52.77
2019	246.95	74.00	419.90	142.43	42.68	242.18	61.24	18.35	104.14

Table 7. Absolute biomass (mt) estimates for the VIMS survey dredge by year with varying catchability coefficients, as well as 95 percent Lower Confidence Intervals (LCI) and 95 percent Upper Confidence Intervals (UCI).

Year	**q = 0.25**			**q = 0.43**			**q = 1**		
	Number	LCI	UCI	Number	LCI	UCI	Number	LCI	UCI
2005	14,964,118.80	11,448,423.51	18,479,814.10	8,630,468.52	6,602,811.70	10,658,125.34	3,711,101.46	2,839,209.03	4,582,993.90
2007	11,485,950.82	8,985,566.57	13,986,335.07	6,624,455.36	5,182,373.28	8,066,537.44	2,848,515.80	2,228,420.51	3,468,611.10
2008	13,599,572.40	10,932,847.36	16,266,297.44	7,843,474.31	6,305,456.15	9,381,492.48	3,372,693.95	2,711,346.15	4,034,041.76
2011	2,750,251.74	1,877,169.55	3,623,333.92	1,586,191.70	1,082,646.62	2,089,736.77	682,062.43	465,538.05	898,586.81
2012	1,542,833.01	927,550.79	2,158,215.23	889,848.81	534,959.52	1,244,738.09	382,634.99	230,032.60	535,237.38
2013	785,945.49	404,763.30	1,167,127.67	453,389.49	233,444.88	673,134.10	194,914.48	100,381.30	289,447.66
2016	680,216.64	300,349.01	1,060,084.28	392,310.99	173,224.55	611,397.44	168,693.73	74,486.55	262,900.90
2017	906,202.51	435,636.03	1,376,769.00	522,647.03	251,250.54	794,043.52	224,738.22	108,037.73	341,438.71
2018	226,255.27	63,509.17	389,001.37	130,491.41	36,628.54	224,354.28	56,111.31	15,750,27	96,472.34
2019	438,920.21	144,152.20	733,688.22	253,144.68	83,138.95	423,150.42	108,852.21	35,749.75	181,954.68

FIGURES

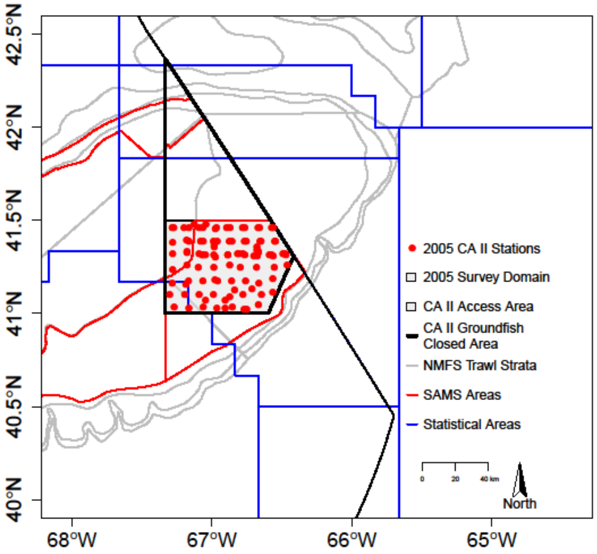

Figure 1. VIMS 2005 survey domain (light gray) and stations sampled (red circles). The map also includes the CAII scallop access area, CAII groundfish closed area, NMFS trawl survey strata, Scallop Area Management Simulator areas (SAMS) for 2019, and NMFS statistical areas.

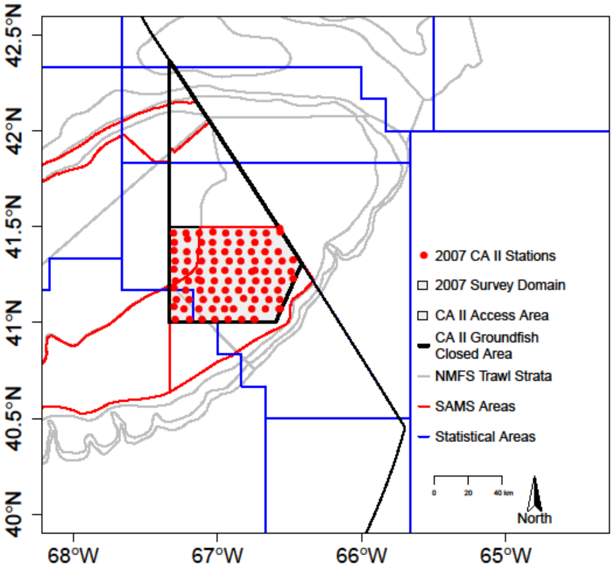

Figure 2. VIMS 2007 survey domain (light gray) and stations sampled (red circles). The map also includes the CAII scallop access area, CAII groundfish closed area, NMFS trawl survey strata, Scallop Area Management Simulator areas (SAMS) for 2019, and NMFS statistical areas.

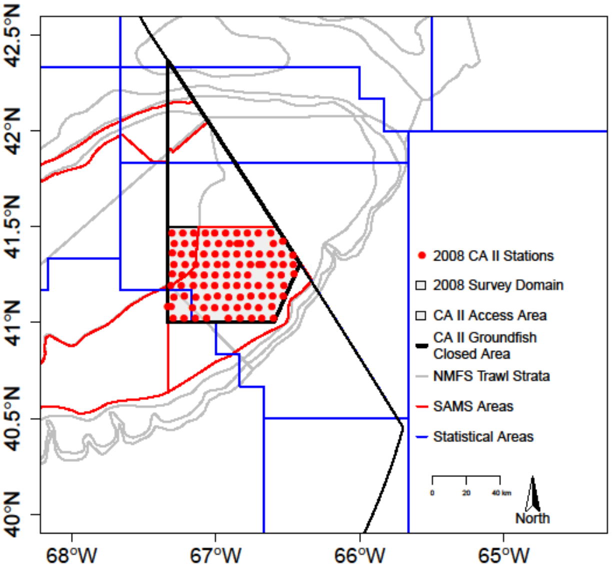

Figure 3. VIMS 2008 survey domain (light gray) and stations sampled (red circles). The map also includes the CAII scallop access area, CAII groundfish closed area, NMFS trawl survey strata, Scallop Area Management Simulator areas (SAMS) for 2019, and NMFS statistical areas.

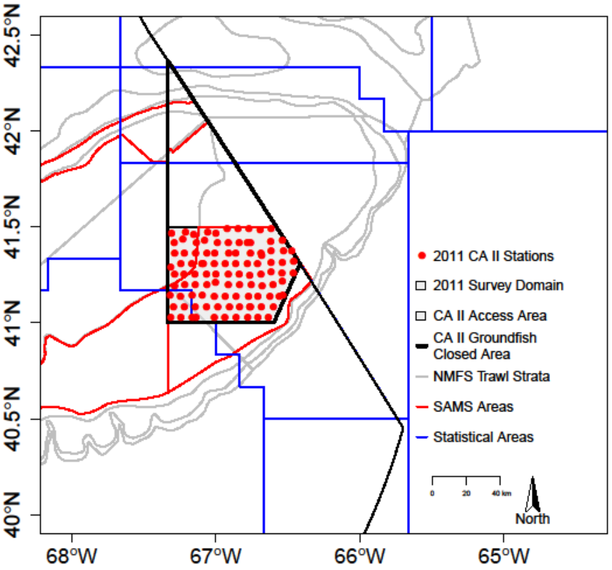

Figure 4. VIMS 2011 survey domain (light gray) and stations sampled (red circles). The map also includes the CAII scallop access area, CAII groundfish closed area, NMFS trawl survey strata, Scallop Area Management Simulator areas (SAMS) for 2019, and NMFS statistical areas.

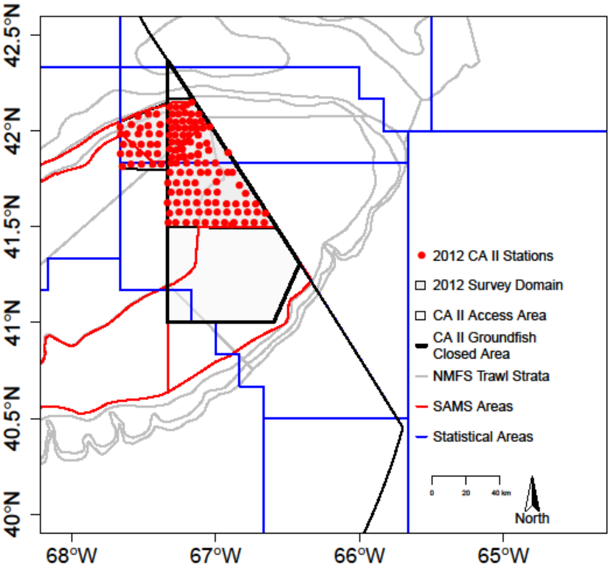

Figure 5. VIMS 2012 survey domain (light gray) and stations sampled (red circles). The map also includes the CAII scallop access area, CAII groundfish closed area, NMFS trawl survey strata, Scallop Area Management Simulator areas (SAMS) for 2019, and NMFS statistical areas.

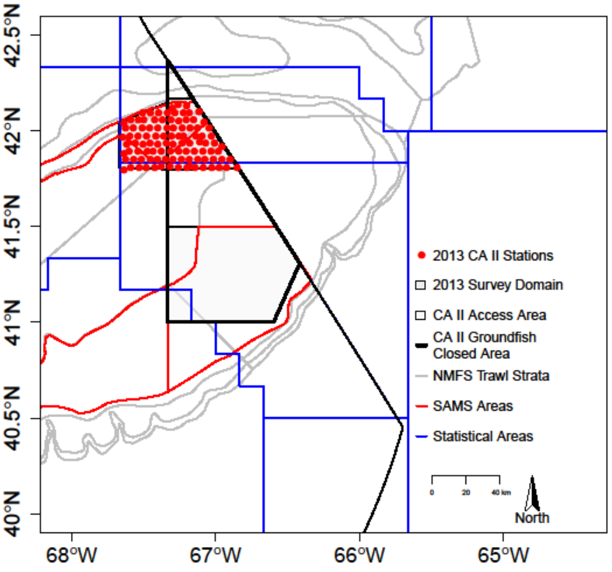

Figure 6. VIMS 2013 survey domain (light gray) and stations sampled (red circles). The map also includes the CAII scallop access area, CAII groundfish closed area, NMFS trawl survey strata, Scallop Area Management Simulator areas (SAMS) for 2019, and NMFS statistical areas.

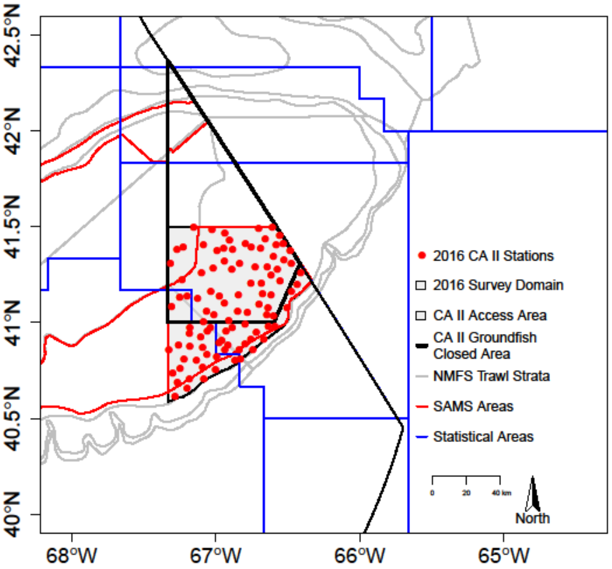

Figure 7. VIMS 2016 survey domain (light gray) and stations sampled (red circles). The map also includes the CAII scallop access area, CAII groundfish closed area, NMFS trawl survey strata, Scallop Area Management Simulator areas (SAMS) for 2019, and NMFS statistical areas.

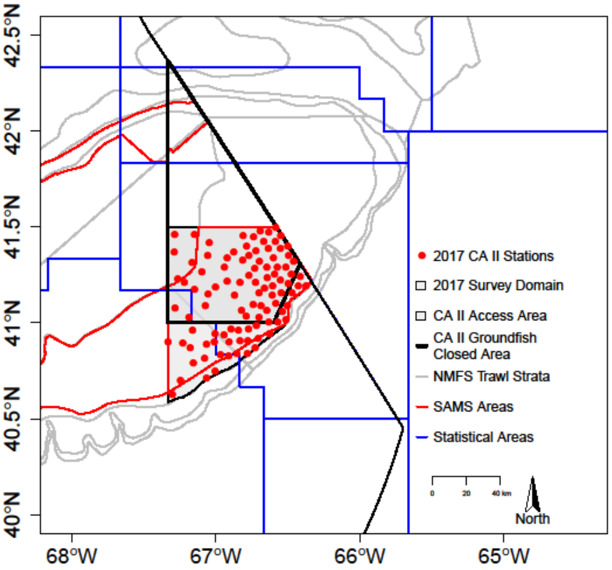

Figure 8. VIMS 2017 survey domain (light gray) and stations sampled (red circles). The map also includes the CAII scallop access area, CAII groundfish closed area, NMFS trawl survey strata, Scallop Area Management Simulator areas (SAMS) for 2019, and NMFS statistical areas.

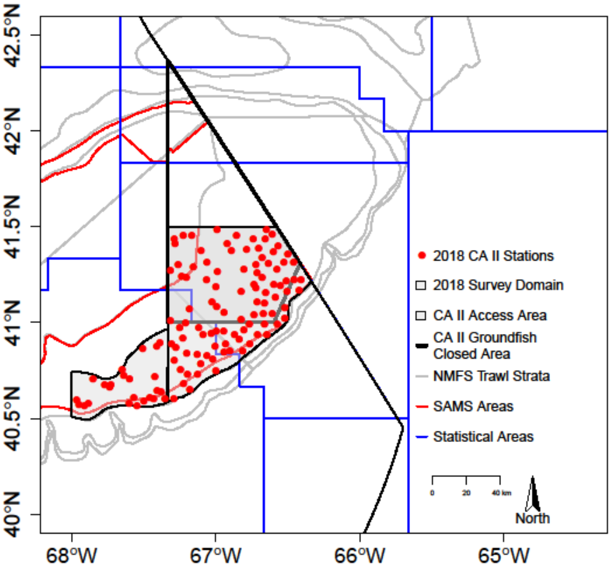

Figure 9. VIMS 2018 survey domain (light gray) and stations sampled (red circles). The map also includes the CAII scallop access area, CAII groundfish closed area, NMFS trawl survey strata, Scallop Area Management Simulator areas (SAMS) for 2019, and NMFS statistical areas.

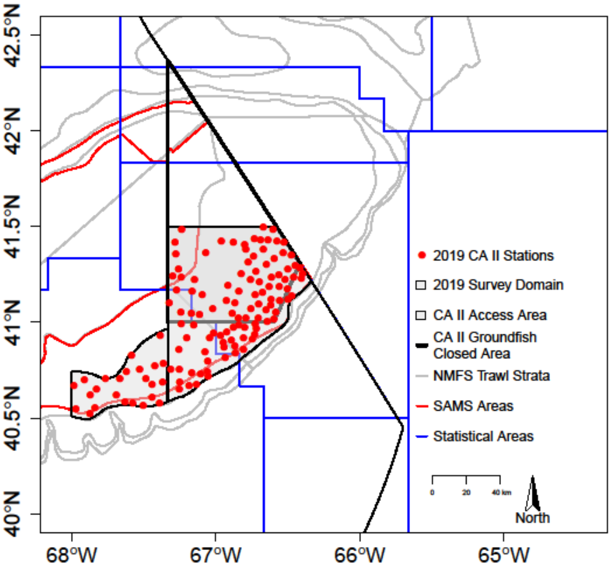

Figure 10. VIMS 2019 survey domain (light gray) and stations sampled (red circles). The map also includes the CAII scallop access area, CAII groundfish closed area, NMFS trawl survey strata, Scallop Area Management Simulator areas (SAMS) for 2019, and NMFS statistical areas.

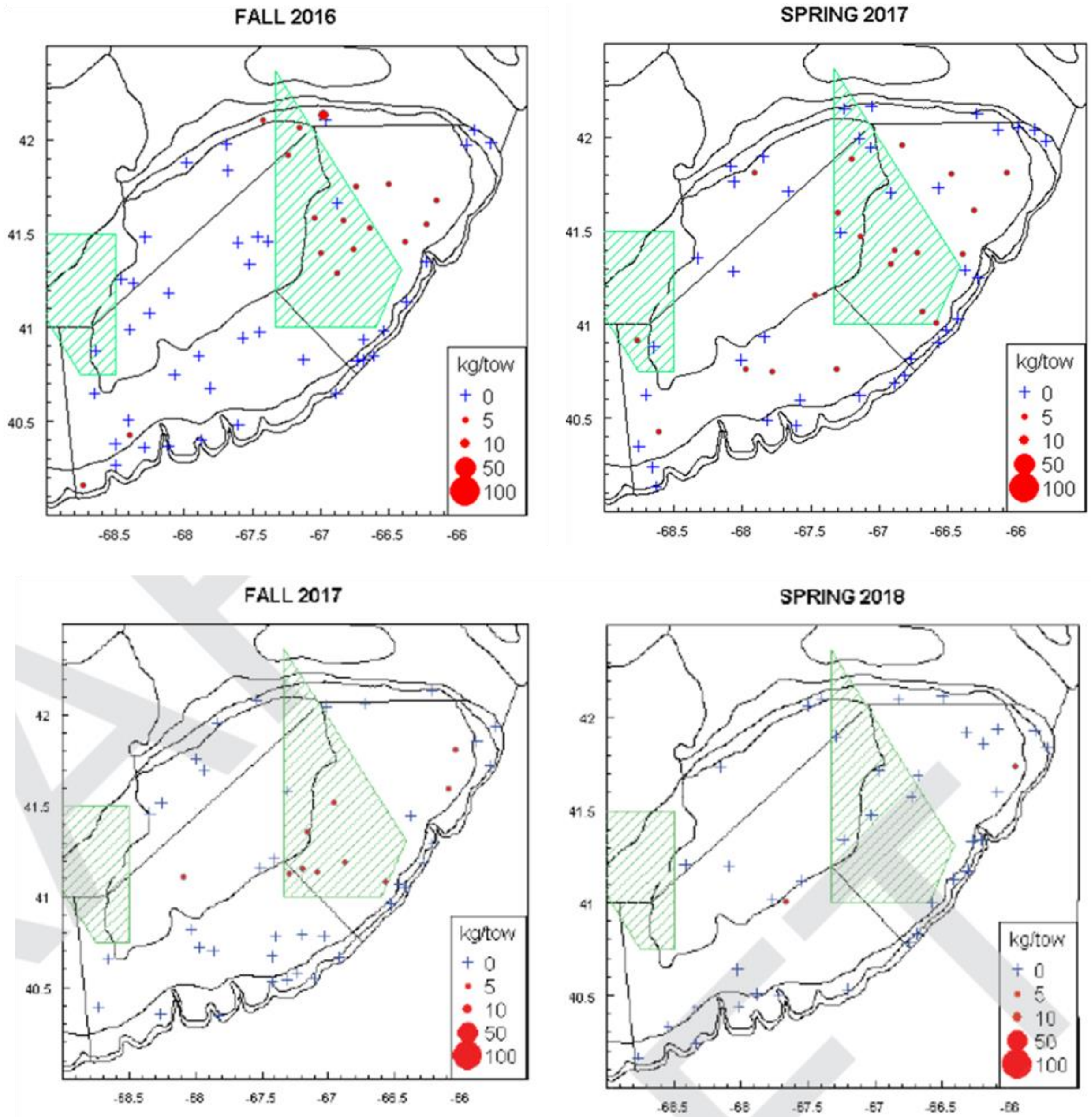

Figure 11. NMFS Fall 2016, Spring 2017, Fall 2017, and Spring 2018 survey catches of Yellowtail Flounder (Legault and McCurdy, 2017; Legault and McCurdy, 2018).

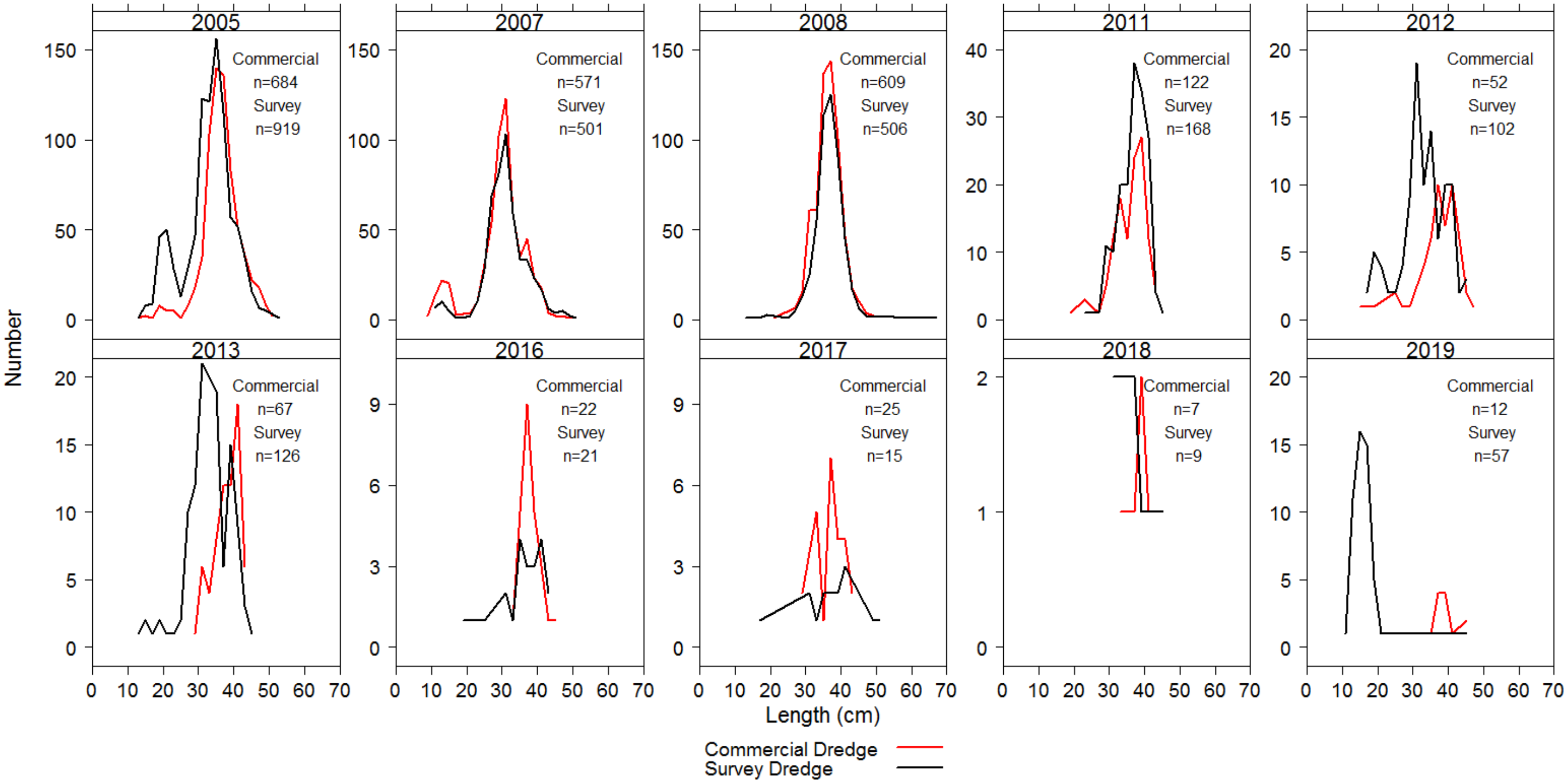

Figure 12. Length frequency distributions of Yellowtail Flounder measured during the VIMS surveys for the survey and commercial gears by year. Number of Yellowtail Flounder caught in either dredge by year is also provided in each panel.

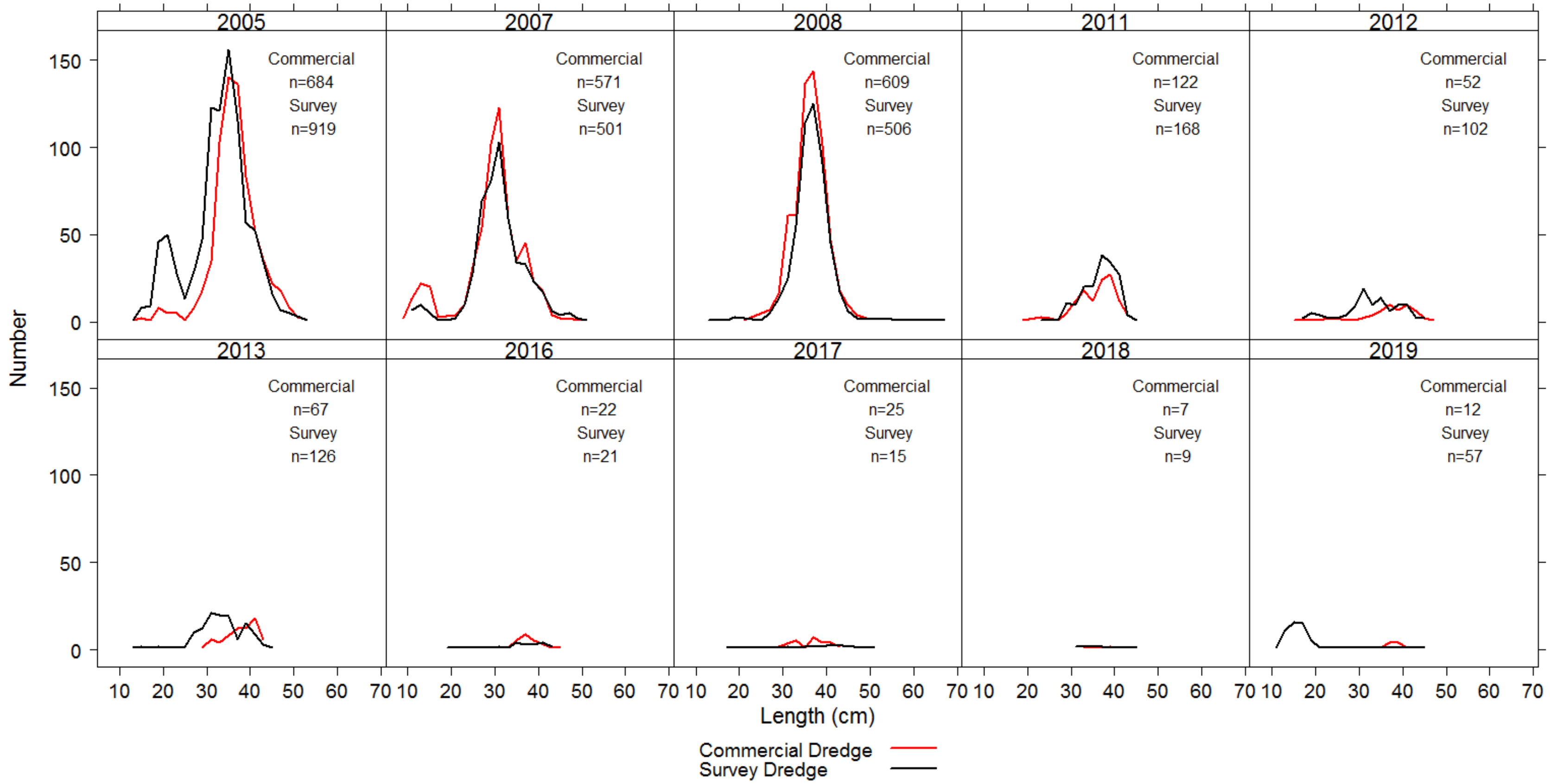

Figure 13. Length frequency distributions of Yellowtail Flounder measured during the VIMS surveys for the survey and commercial gears by year with the y axis on the same scale. Number of Yellowtail Flounder caught in either dredge by year is also provided in each panel.

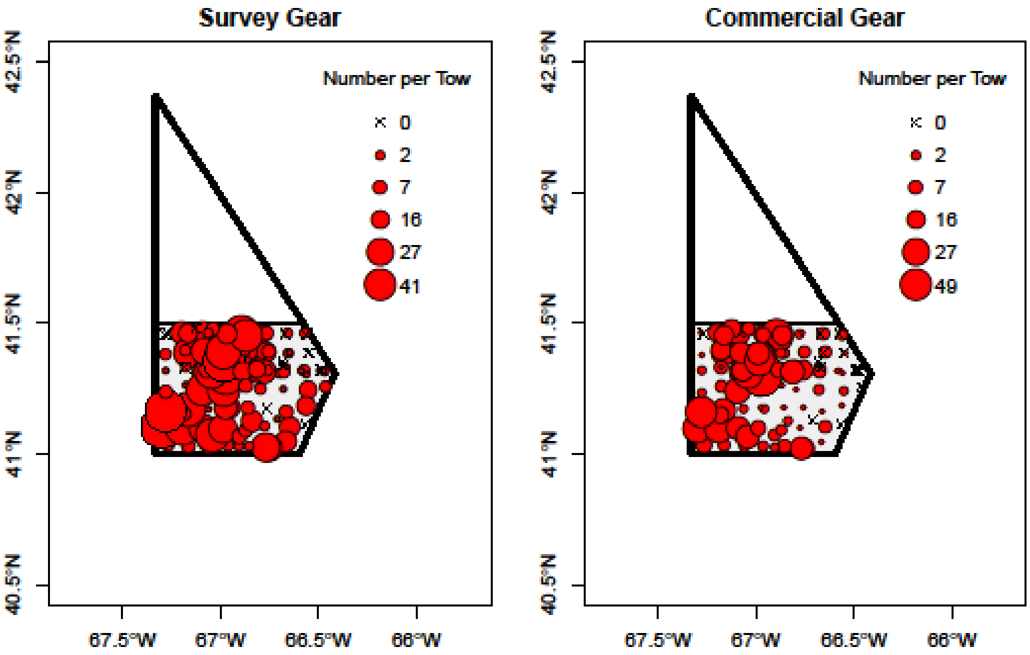

Figure 14. Spatial distribution of the number of Yellowtail Flounder caught in the VIMS 2005 survey by gear.

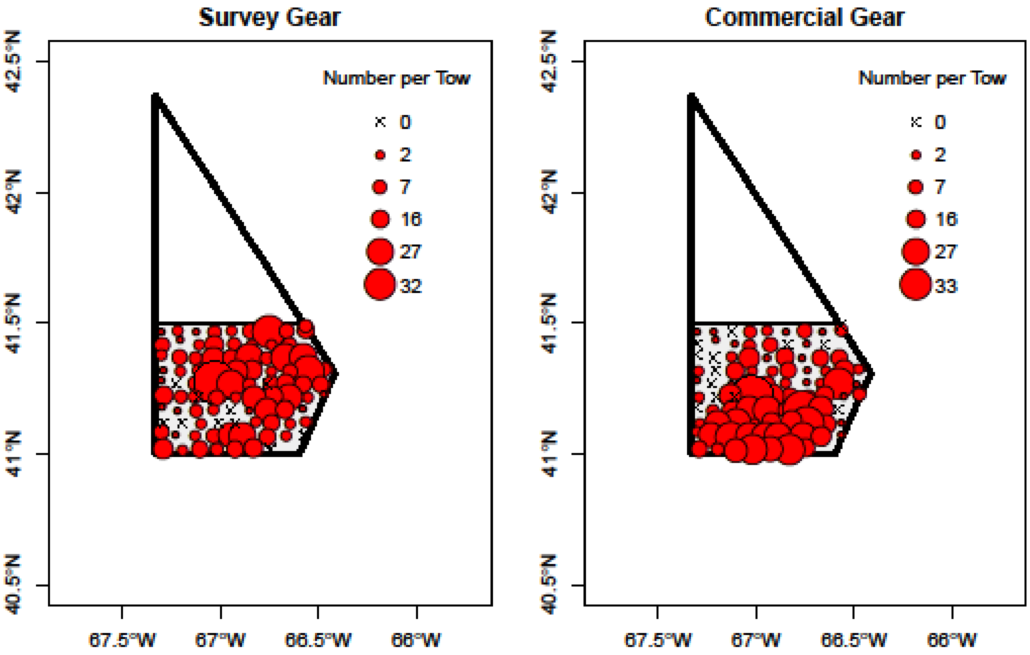

Figure 15. Spatial distribution of the number of Yellowtail Flounder caught in the VIMS 2007 survey by gear.

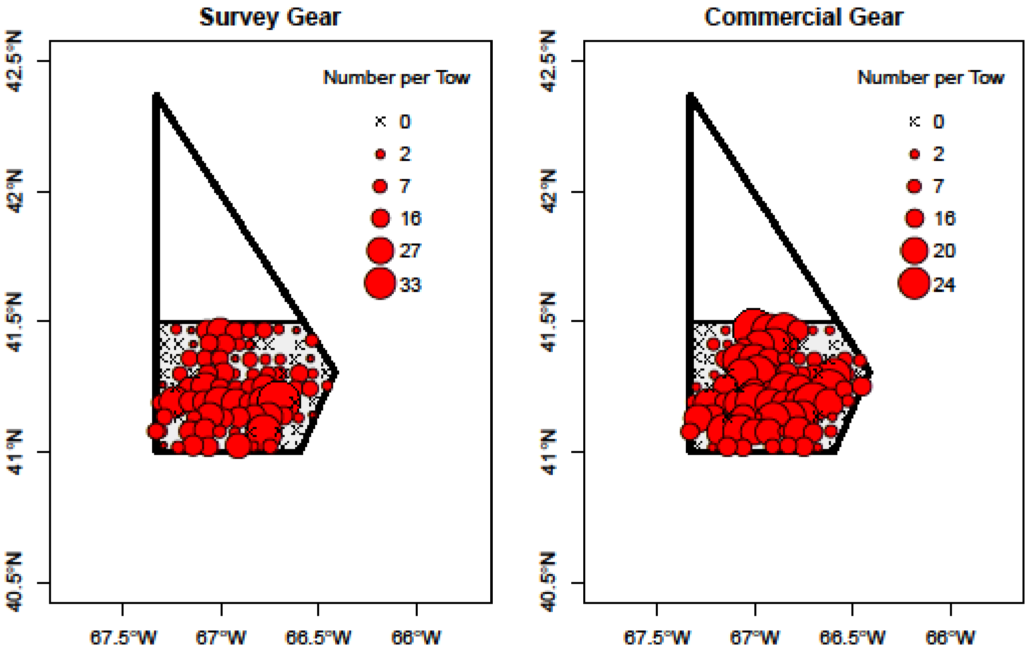

Figure 16. Spatial distribution of the number of Yellowtail Flounder caught in the VIMS 2008 survey by gear.

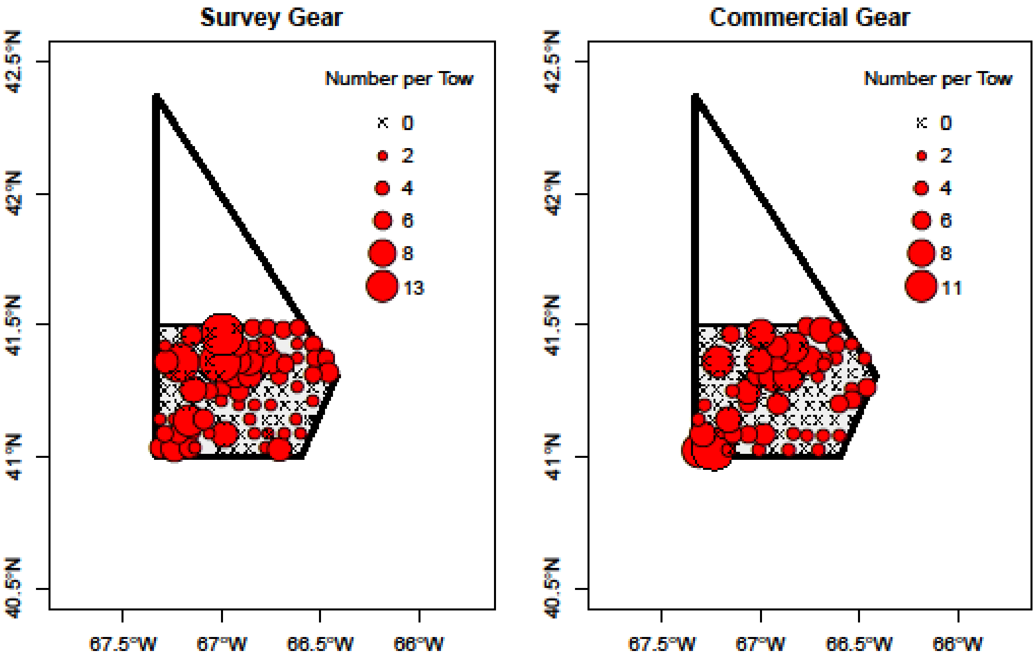

Figure 17. Spatial distribution of the number of Yellowtail Flounder caught in the VIMS 2011 survey by gear.

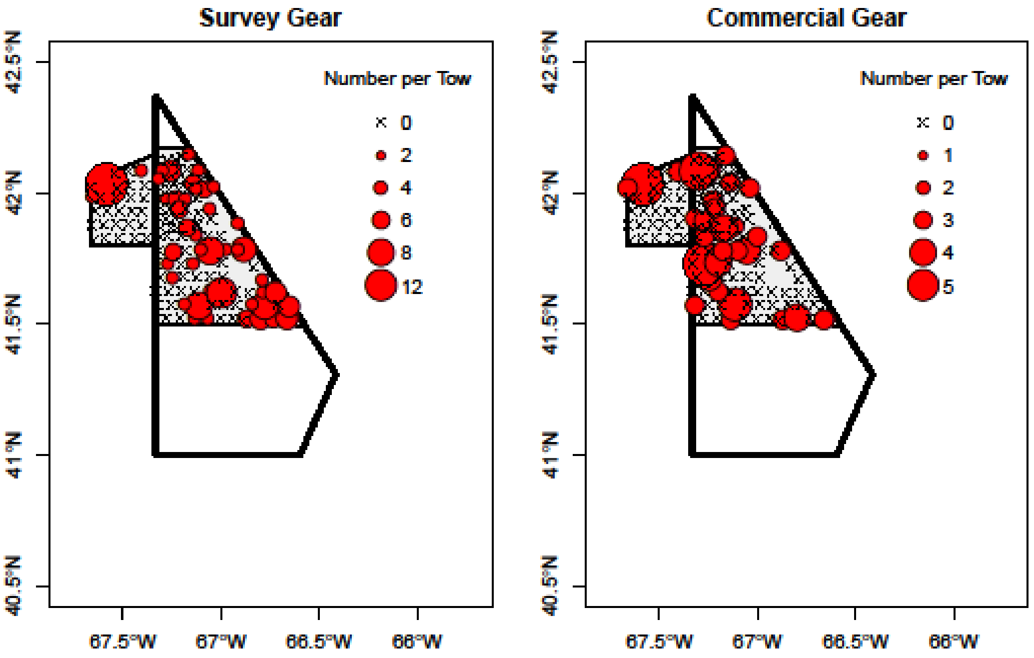

Figure 18. Spatial distribution of the number of Yellowtail Flounder caught in the VIMS 2012 survey by gear.

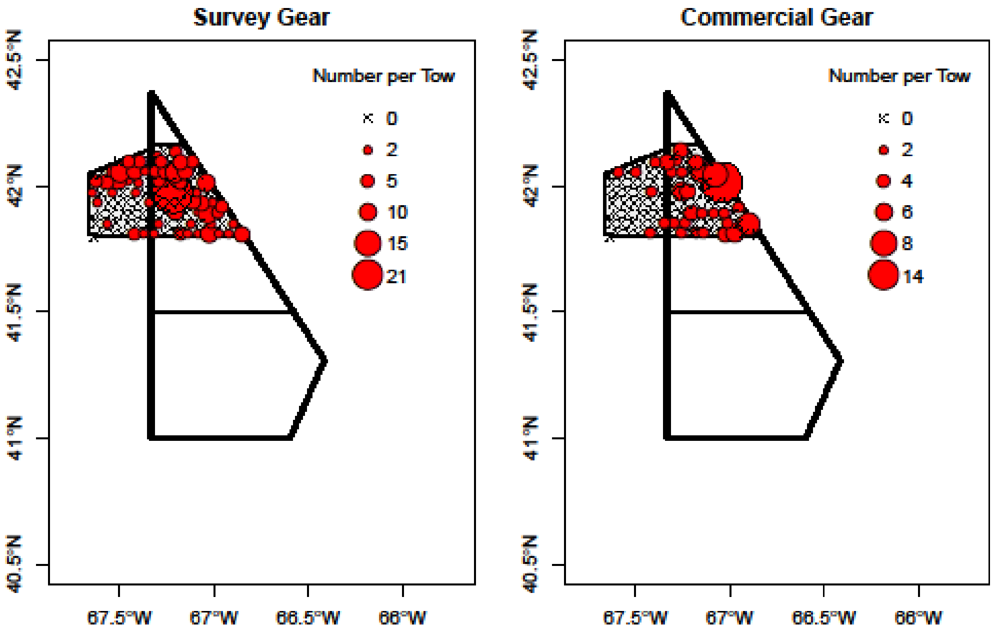

Figure 19. Spatial distribution of the number of Yellowtail Flounder caught in the VIMS 2013 survey by gear.

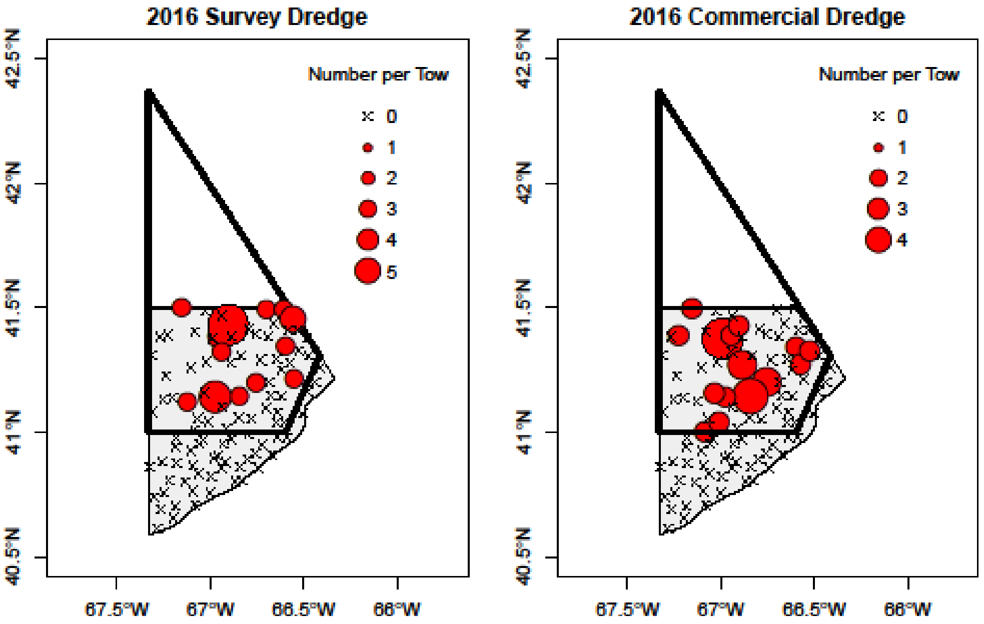

Figure 20. Spatial distribution of the number of Yellowtail Flounder caught in the VIMS 2016 survey by gear.

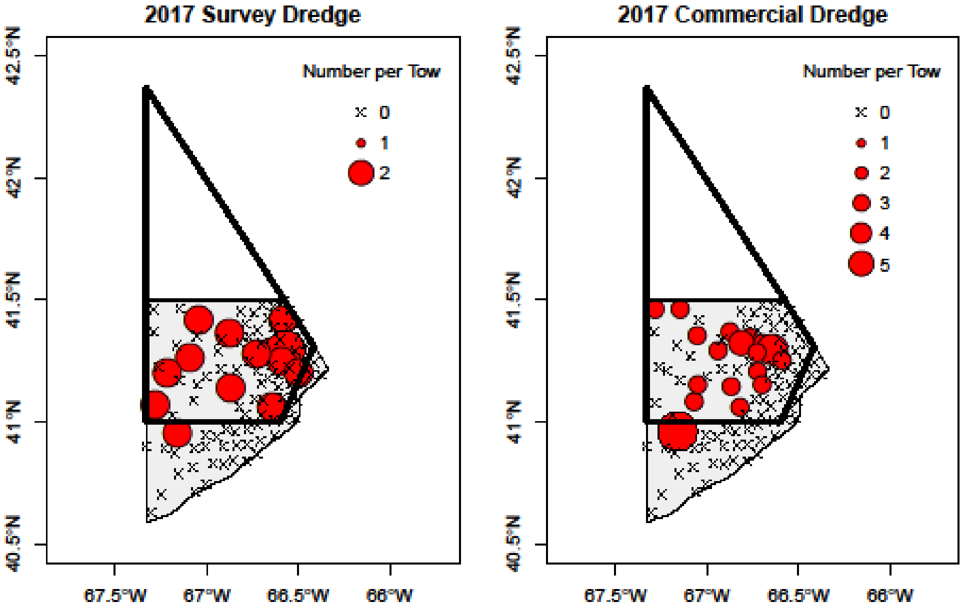

Figure 21. Spatial distribution of the number of Yellowtail Flounder caught in the VIMS 2017 survey by gear.

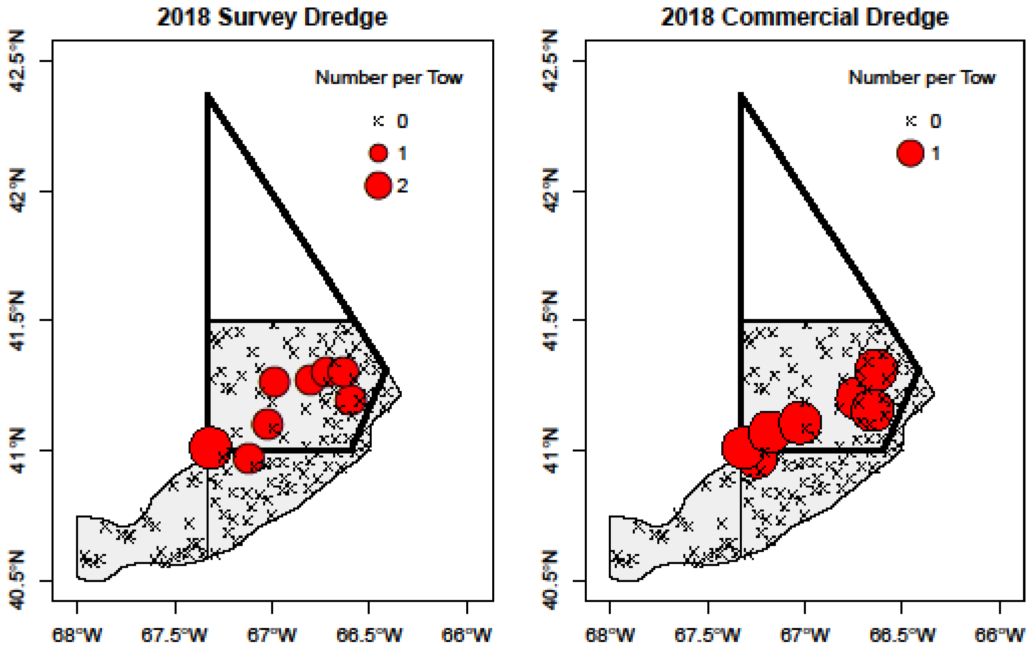

Figure 22. Spatial distribution of the number of Yellowtail Flounder caught in the VIMS 2018 survey by gear.

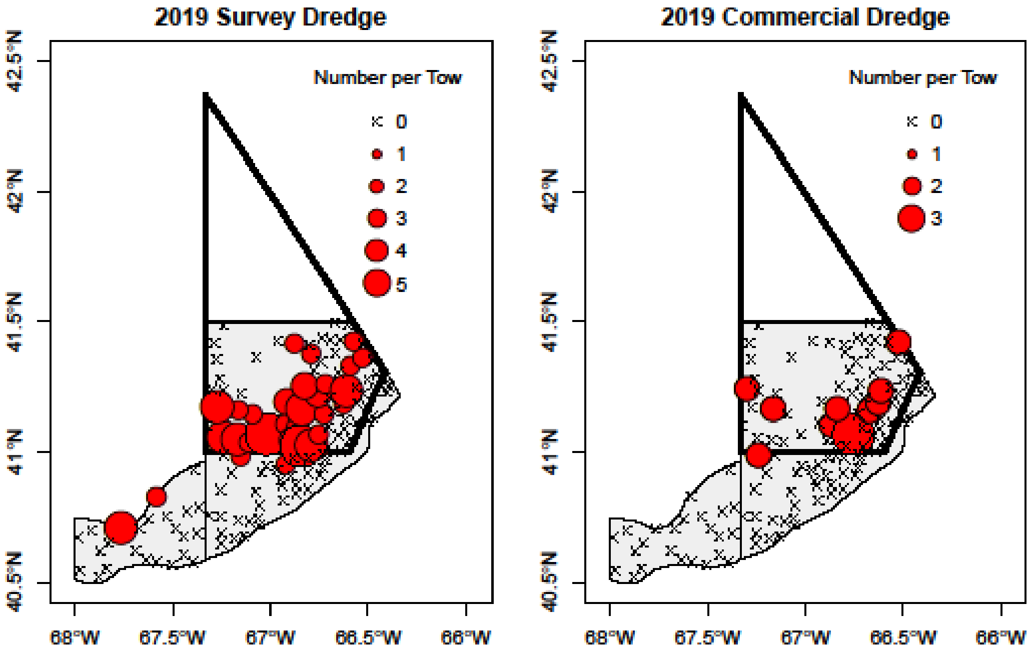

Figure 23. Spatial distribution of the number of Yellowtail Flounder caught in the VIMS 2019 survey by gear.