Technical Reports

Massachusetts Division of Marine Fisheries
Technical Report TR-67

Early Opening Experimental Fishery for Silver Hake/ Whiting in Small Mesh Area 1 and the Western Raised Footrope Exemption Area

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Ronald S. Amidon, Commissioner
Massachusetts Division of Marine Fisheries
David E. Pierce, PhD, Director

Executive Summary

Times and areas where small mesh codends can be used to fish for whiting (silver hake) have not changed since the 1990s although fish migrations have shifted. Fishermen asked the Massachusetts Division of Marine Fisheries (DMF) to help test early openings of Small Mesh Area 1 (SMA1) in Ipswich Bay and the Western Raised Footrope Exemption (WRFE) area in Cape Cod Bay because they observed whiting appearing earlier than before. Using funds from the Groundfish Disaster Aid Program, DMF organized experimental fisheries with sea samplers onboard commercial fishing vessels in SMA1 in 2016 and 2017, and in the WRFE area in 2016. The mandatory raised footrope trawl (RFT) used by each vessel was inspected by DMF before fishing started. Areas were opened fourteen days (two weeks) early.

In both SMA 1 and the WRFE, the experimental fishery was limited to a smaller, subset area chosen by fishermen. In 2016 in the WRFE subset area, one vessel fished for two days and six tows. The whiting price was too low and catches were too small with too many spiny dogfish. Fixed gear such as lobster pots also made fishing difficult. The experimental fishery was not continued into 2017.

The experimental fishery in SMA1 had more participation. In 2016 in SMA1, five vessels fished 29 trips and 89 tows. In 2017, five vessels (with one vessel different from 2016) fished 26 trips and 87 tows. Catches were mostly whiting, red hake, herring (in 2017), and butterfish (2017). Main discards were haddock, lobster, American plaice, yellowtail flounder, and spiny dogfish (in 2016). Added together, the groundfish discards were higher than 5% of the kept catch in both years, mostly due to haddock. Most of the haddock caught were below the minimum legal size.

Observer data from the normal SMA1 exempted fishery that occurs each year were similar to the experimental fishery for species and amounts. Discard to kept catch proportions were usually lower in the exempted fishery, but direct comparisons are complicated by differences in data collection.

Exceeding 5% in groundfish discards makes continuing an early opening of SMA1 difficult. However, some of the discarded fish stocks (haddock, American plaice (dab)) are healthy and underutilized. Gulf of Maine yellowtail flounder is overfished with overfishing occuring with a high utilization rate.

It may be possible to reduce bycatch by working with fishermen. Some vessels caught either more or less bycatch, which could be due to small differences in the RFT, in tow location, or other factors. The date, time of day, or the order of the tow did not affect discards. Further, new gear modifications could be developed and tested.

Fishermen are still interested in an early opening of SMA1. The data collected during the experimental fishery can help weigh the fishing benefits and bycatch risks.

Introduction

During development of the Commonwealth's Groundfish Disaster Aid Program, fishermen expressed persistent interest in modifying the timing of openings of small-mesh exemption areas, species specific exempted fisheries that allow vessels to use smaller than the minimum codend mesh sizes permitted under Regulated Mesh Area regulations, to target silver hake/whiting *Merluccius bilinearis* (Greater Atlantic Regional Fisheries Office, 2015). They saw changes in typical migration patterns and/or availability over time. The whiting fishery, as a source of income for small trawlers in the New England region, Massachusetts in particular, has increased in importance in recent years as landings of other fish, especially regulated multispecies groundfish, have declined (New England Fishery Management Council (NEFMC), 2017a).

The northern silver hake stock is currently not overfished and overfishing is not occurring (NEFMC, 2014). The stock in the GOM exceeds its biomass targets and annual catch limits have again received an increase for 2018-2020 (NEFMC, 2017a & 2017b; National Oceanic and Atmospheric Administration (NOAA) 2018). Despite this, landings are at a near historical low. Further access to the stock could provide a greater and sustainable opportunity to the ailing groundfish trawl fleet.

Interest in evaluating the performance of the exempted fisheries has also been prioritized by the NEFMC's Small-mesh Multispecies Committee, with a possible goal of increasing their effectiveness based on distribution and productivity of target and bycatch species. To modify exemptions the Council needs "…information on where small mesh fishing may occur with the least possible impact on species usually caught with large mesh gear." (Amendment 4 to the Northeast Multispecies Fishery Management Plan (FMP)). Current sea sampler program coverage is not adequate to assess the impact

of potential changes in exempted areas. By program design, federal sea sampler data is collected only during times of permitted fishing activity. Therefore, sea sampler data of trawlers using small-mesh is not collected outside the exempted fishery open seasons and possible adjustments to the timing of this fishery are hindered by lack of data on possible catch and bycatch. The need for timely information on all catch (kept and discarded) was highlighted at a Whiting Exempted Fishing Permit Workshop (2/18/2016) held by the National Marine Fisheries Service (NMFS) Greater Atlantic Regional Office (GARFO).

Purpose and Goals

The goal of this project was to utilize a portion of the Groundfish Disaster Aid Program funds to conduct an experimental small-mesh fishery (primarily targeting silver hake) in the Gulf of Maine. To inform possible area/time amendments to current exempted fishery regulations, data would be collected on catch and bycatch in small-mesh exemption areas outside of currently prescribed times by assigning sea samplers to interested commercial fishing trawlers.

Methods

Funding

As part of its approved spending plan for Bin 3 of the Groundfish Disaster Aid Program, the Massachusetts Division of Marine Fisheries (DMF) allocated $50,000 of federal grant funds to look at the times and areas when exempted small mesh fishing for silver hake was allowed in the Gulf of Maine. Specifically, funding was used to cover sea sampler and analytical costs associated with this project. The work was initially planned to begin in the summer of 2016.

Study Area & Participation

Areas and timing were selected by contacting regional fishermen using multiple methods, including at workshops, via email and listserv, DMF web posting, and by phone, over several months, and asking them to complete a pre-qualification form (with a due date of 3/4/16). This form requested preferential ranking among all small-mesh exempted areas along the coast of Massachusetts, as well as the preferred temporal adjustment (e.g. opening earlier or extending later). Prior participation in whiting trawl fisheries and a home port in Massachusetts were not prerequisites for participation.

Based on available resources, we chose the two areas of greatest interest, Small Mesh Area 1 (SMA1) and the Western Raised Footrope Exemption (WRFE) area. The final experimental areas were selected as subsets of the full exemption areas based on the preferred fishing grounds of the fishermen and avoidance of the Whaleback Cod Spawning Protection Area in SMA1.

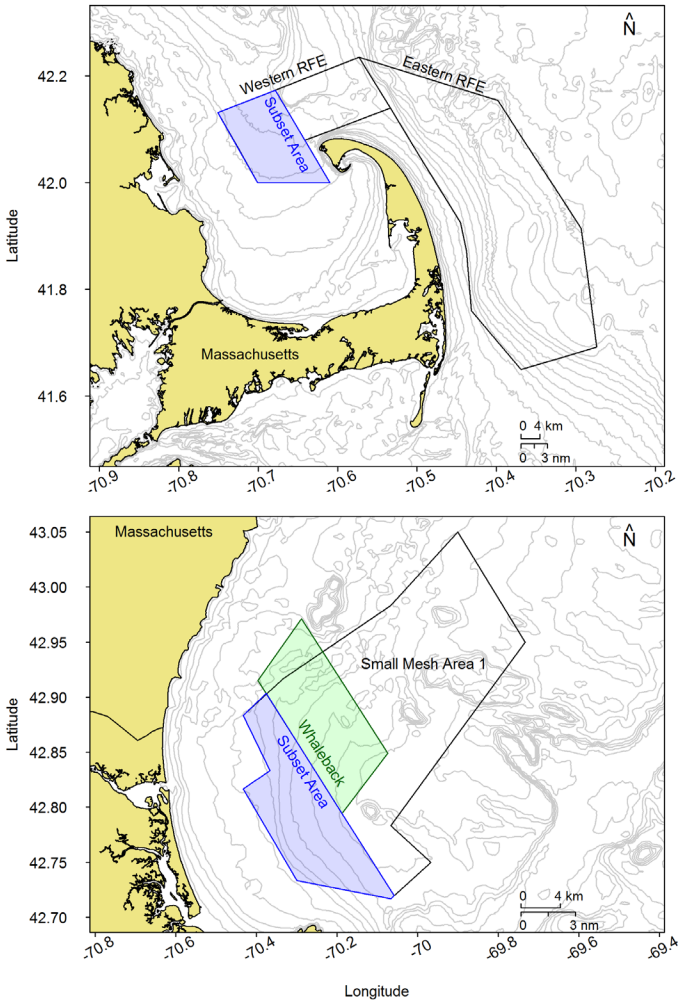

Figure 1. Plots of the subset experimental fishing areas (blue polygons) within the full exemption areas (outlined in black) for the WRFE (top) and SMA1 (bottom). The green polygon shows the Whaleback Cod Spawning Protection Area.

Based on indicated preferences, access was sought in 2016 for a two week window prior to the normal opening date for each area's exempted fishery (July 1–14 for SMA1 and August 18–31 for WRFE area). Fishermen active in the SMA1 exempted whiting fishery requested a two-week earlier opening of the fishery to test their belief that the timing of the whiting migration has shifted earlier. Interested vessels were assigned to the two areas based on a combination of factors including balancing fishing effort, personal area preference, prior experience, vessel size (and holding capacity), and proximity to home port. All vessels that expressed interest and

that qualified for Bin 3 Groundfish Disaster Aid were invited to participate.

Work was repeated the following year, 2017, within the subset area of SMA1 only (Figure 1). No experimental fishery was conducted in the WRFE area in 2017. Once again, pre-qualification forms were circulated (with a due date of 4/30/17) and vessels were assigned to work within SMA1 during the same period following the same protocols.

Permitting

Exempted fishing permits (EFPs) were granted by NMFS on July 1, 2016 and June 29, 2017 for the 2016 and 2017 experimental fisheries, respectively. As in the traditional exempted fishery, retention of regulated multispecies groundfish (Atlantic cod, haddock, pollock, redfish, ocean pout, windowpane flounder, yellowtail flounder, winter flounder, witch flounder, American plaice, Atlantic halibut, wolfish, and white hake)[1] was prohibited. For the remainder of this document, groundfish refers to these 13 large-mesh species unless otherwise specified.

After submitting a permit request to the Stellwagen Bank National Marine Sanctuary, DMF was advised by the Sanctuary office that a permit was not required but requested that DMF voluntarily avoid archaeological resource areas.

At-sea Study Design

Participant's nets were examined by DMF personnel prior to fishing for compliance with raised footrope trawl (RFT) requirements (Greater Atlantic Regional Fisheries Office, 2015) including codend mesh measurements (Fonteyne, 2005). Each vessel was offered a maximum of six trips within the two week window of the assigned experimental fishery based on funding limitations, sea sampler availability, and reasonable fishing effort control. Captains and vessel owners were asked to distribute their trips (three trips per week) in order to demonstrate catches over the entire time period. Vessels coordinated trips with DMF so that sea samplers could be assigned. DMF worked with NMFS Northeast Fisheries Observer Program (NEFOP) staff to develop modified small-mesh fishery subsampling protocols that would capture all necessary data elements. DMF staff conducted training for sea samplers contracted from A.I.S., Inc., and also conducted five sea sampling trips in-kind.

Modified NEFOP small-mesh fishery logs and protocols were used, with a priority on collecting actual weights on discards (Northeast Fisheries Science Center, 2016). If actual weights could not be collected, subsampling of discards using volumetric ratios was implemented. Biological data (lengths, spawning condition) was collected for some kept fish and for priority discards (groundfish and river herring).

Data summary uploads were conducted by sea samplers nightly in order to track trip completion, catches and bycatch in near real-time. Trips were mailed or hand delivered to DMF's Gloucester office for auditing and debriefing with samplers and captains.

Analytical Methodology

We assessed the catches of the two-week earlier, experimental fishery and compared them with the catches in the normal exempted fishery. To gain additional insight into short term changes in target and bycatch abundance and distributions over a short time period, we compared catches in the experimental fishery to an equal length (two-weeks) and adjacent period in the exempted fishery.

For all experimental fisheries, herring species (Atlantic herring (*Clupea harengus*), alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), menhaden (*Brevoortia tyrannus*), and American shad (*Clupeidae*)) were combined as "herring unspecified" since not all tows could be sampled to the herring species level, especially in 2017 when silver hake and Atlantic herring were often targeted simultaneously.

Average catch rates (lb/trip) and 95% confidence intervals for catch of silver hake, red hake (*Urophycis chuss*), butterfish (*Peprilus triacanthus*), and herring were calculated to compare fishing performance in the experimental and exempted fisheries. Catch rates (lb/trip) for the experimental fishery and the first two weeks of the exempted fishery were further compared using t-tests. Kept and discard weights for these species were combined due to variation in discarding reasons (e.g. fish too small for markets vs. regulatory discards).

Discard ratios were used to assess the performance of the experimental fishery; data from unobserved tows were excluded as these data were based on Captains' estimates and did not include discards. A similar methodology has been used in the past to assess potential exempted fisheries (McKiernan et al., 1998). We calculated the ratios using a modification of the Standardized Bycatch Reporting Methodology (SBRM) (Wigley et al., 2012) where the weight of a species or species

1 Atlantic halibut is a regulated groundfish but was not caught.

group is divided by the total weight of kept catch. This discard ratio can be calculated on a fishery, trip, or tow level (Pol, 2017). We chose to analyze at each level due to uncertainty about the appropriate scale for assessment by fishery managers, and to obtain insight into fishery performance. Discard ratios were analyzed at these three levels, and were then examined between vessels (anonymized by a two-digit random number), by date, time of day, and tow number within trips. Discard ratios for all regulated multispecies groundfish and for groundfish without Gulf of Maine (GOM) haddock were compared against a 0.05 threshold, which has been used historically (McKiernan et al., 1998). Discard ratios for groundfish without GOM haddock were calculated given the historical opening of the exempted whiting areas using the 0.05 groundfish bycatch standard was accomplished at a time of low haddock abundance and currently underutilized haddock stocks are at historic high abundance levels.

NEFOP data from vessels using small-mesh codends or liners in the entire SMA1-area during the exempted fishery (July 15–November 15) were obtained and aggregated from the NOAA NEFSC database in compliance with data confidentiality protocols for both years. Tows conducted on these trips targeted silver hake, Atlantic herring, or both. Average catch per trip and groundfish discard ratios for the first two weeks of the SMA1 exempted fishery (July 15–July 28) in both years were separately calculated, along with the remainder of the fishery. We did not determine if the observed trips were a representative subsample of the entire exempted fishery.

Sea sampling data were edited, entered, and audited in Microsoft Excel spreadsheets and a customized relational database in Microsoft Access by DMF personnel. Data visualization and analyses were conducted with the open-access program R, GIS, and Microsoft Excel. Data were partially examined using box and whisker plots (McGill et al., 1978). Box-plots were drawn using the 25th and 75th quantiles as lower and upper limits (interquartile range, IQR), with a bar representing the median. Approximately 50% of observed values are within the interquartile range. Whiskers extend to at most 1.5 times the IQR and end at an observed value. Points beyond the whiskers are greater than 1.5 times the IQR and can be considered outliers (Sokal and Rohlf, 2000). Box widths (when used as a factor) are proportional to the square roots of the sample sizes within each grouping.

Results

Participation & Effort

We received eight responses to our 2016 pre-qualification form. SMA1 and the WRFE area were identified as highest priorities; two-week earlier openings were identified as the preferred temporal adjustment. Five vessels were assigned to SMA1 and four were assigned to the WRFE area. Four out of the five vessels from the 2016 experimental SMA1 fishery participated in 2017; one new vessel was included.

In 2016, a number of RFT nets were found to be non-compliant at the time of examination and in some cases modifications were made at that time to help bring the gear into regulatory compliance. The fishing participants agreed that additional compliance issues would be resolved prior to fishing. Fewer compliance issues were observed prior to 2017 fishing, likely due to gear improvements in 2016 and the acquisition of new RFT gear. Some potential non-compliance issues were still identified prior to the 2017 work and these issues were brought to the attention of the participants.

Five vessels fished in the 2016 experimental SMA1 fishery on 10 different days, completing 29 trips and 89 tows, of which 82 were observed (Table 1 and Figure 2). Vessels fished 5–6 days each. Some effort in SMA1 was restricted by participants due to market and a holiday conflict. Weather also reduced effort. Number of tows per vessel ranged from 13–25 overall and 1–5 per trip. Seven tows on six trips on one vessel in SMA1 were not fully sampled. These tows were the ultimate or penultimate tow of the day and could not be observed due to lack of deck space. Despite assignment of four vessels effort in the WRFE area consisted of only one vessel. That vessel conducted only two trips due to low catch-

Table 1. Summary of effort during experimental fishing.

Area	Opening Dates	Vessels	Trips	Fishing Dates	Tows	Observed	Tow Time (h)
SMA1	1-14 July 2017	5	26	1-13 July 2017	87	87	183.3
SMA1	1-14 July 2016	5	29	2-13 July 2016	89	82	144.8
WRFE	18-31 Aug 2016	1	2	21-22 Aug 2016	6	6	11.9

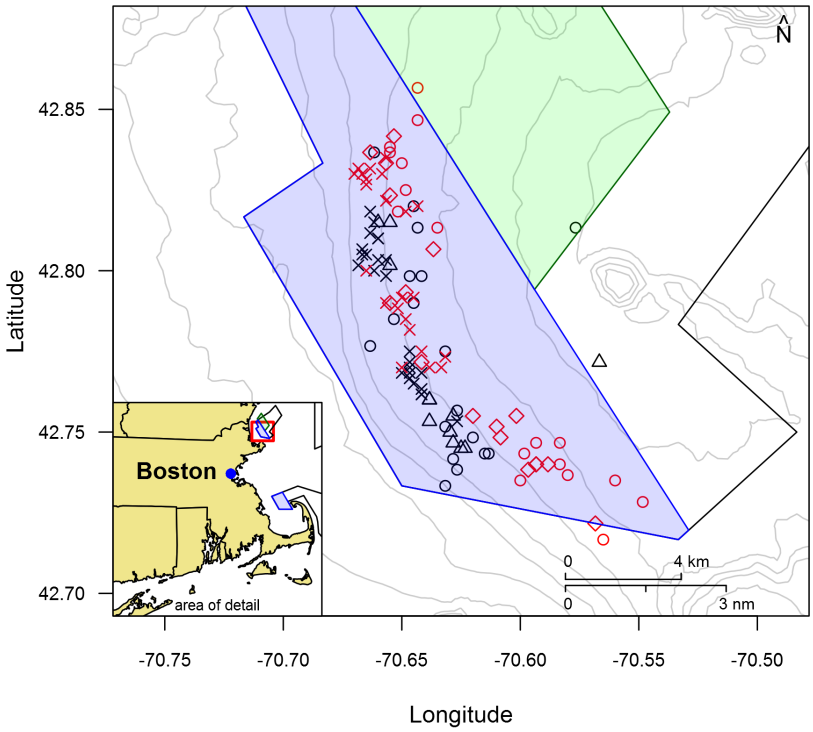

Figure 2. Tow start locations for the subset area (blue polygon) of the experimental SMA1 fishery. Black and red symbols are tows from 2016 and 2017 respectively. Symbol types represent unique vessels. The green polygon shows the Whaleback Cod Spawning Protection Area. Three tows outside of the subset area are likely recording errors.

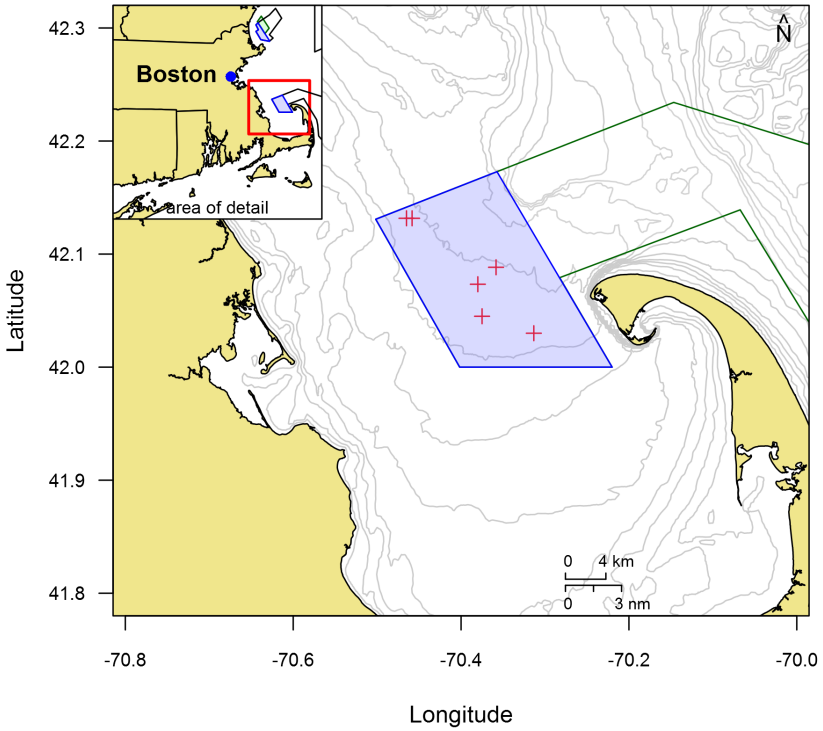

Figure 3. Tow start locations for the subset area (blue polygon) of the 2016 experimental WRFE fishery.

es, the presence of lobster gear, and other fishing opportunities (Table 1 and Figure 3).

Effort for the 2017 experimental SMA1 fishery occurred on 11 different days, which included 26 trips and 87 tows (Table 1 and Figure 2). All tows were observed.

Catches from the 2016 experimental fishery in the WRFE area totaled 5,112 lb including 24 taxa and groups (Table 2). Over 3,750 lb of catch were kept, primarily silver and red hakes, butterfish, spiny dogfish, and herring. Groundfish discards totaled 518.0 lb, of which 66% was haddock. No further analyses of these data were conducted due to low fishing effort.

Total catch in observed tows in the experimental 2016 SMA1 fishery was 257,778 lb from 30 taxa (Table 3), with 208,780 lb of kept catch, consisting primarily of silver and red hakes, and amounts of less than one percent of spiny dogfish and herrings. Total discards were nearly 50,000 lb (19% of the total catch), of which 79% were groundfish species, with haddock contributing 68% of all discards and 86% of groundfish discards.

Table 2. Catches from six observed tows in the 2016 experimental WRFE area fishery, sorted by totals. Total groundfish discards and groundfish excluding haddock discards are also reported.

		Weight (lb)		
Species		**Kept**	**Discard**	**Total**
Silver hake	*Merluccius bilinearis*	2320.0	14.0	2334.0
Red hake	*Urophycis chuss*	565.0	477.0	1042.0
Haddock	*Melanogrammus aeglefinus*		342.0	342.0
Butterfish	*Peprilus triacanthus*	350.0		350.0
Spiny dogfish	*Squalus acanthias*	271.7		271.7
Herring unspecified	*Alosa, Clupea, and Brevoortia sp.*	270.0	211.0	481.0
American plaice (dab)	*Hippoglossoides platessoides*		101.0	101.0
Yellowtail flounder	*Limanda ferruginea*		51.9	51.9
American lobster	*Homarus americanus*		47.2	47.2
Debris, fishing gear			25.0	25.0
Thorny skate	*Amblyraja radiata*		23.3	23.3
Winter flounder	*Pseudopleuronectes americanus*		17.4	17.4
Rock crab	*Cancer irroratus*		6.3	6.3
Monkfish	*Lophius americanus*		6.0	6.0
Ocean pout	*Zoarces americanus*		4.5	4.5
Jonah crab	*Cancer borealis*		3.7	3.7
Fourspot flounder	*Hippoglossina oblonga*		3.3	3.3
Atlantic mackerel	*Scomber scombrus*	2.9		2.9
Shortfin squid	*Illex illecebrosus*	2.6		2.6
Sea cucumber	Holothuroidea		1.8	1.8
Longfin squid	*Doryteuthis pealeii*	1.4		1.4
Longhorn sculpin	*Myoxocephalus octodecimspinosus*		1.3	1.3
Windowpane flounder (sand dab)	*Scophthalmus aquosus*		1.2	1.2
Wrymouth	*Cryptacanthodes maculatus*		0.6	0.6
Groundfish			518.0	
Groundfish excluding haddock			176.0	
	Total	3783.6	1338.5	5122.1

The next highest groundfish discards, American plaice and yellowtail flounder, contributed 7% and 4% of all groundfish, respectively (6% and 3% of all discards, respectively).

Total catch in the experimental 2017 SMA1 fishery was similar to 2016, with 232,710 lb from 36 taxa or groups (Table 4), including 195,318 lb of kept catch, consisting primarily of silver hake followed by red hake, herrings, and butterfish. Discards made up 16% of the total catch. Groundfish species made up 39% of the discards, with haddock contributing 17% of all discards and 44% of groundfish discards. American plaice and yellowtail flounder contributed the next highest percentages of groundfish discards: 25% and 21% respectively (10% and 8%, respectively, of all discards).

Table 3. Catches from 82 observed tows in the 2016 experimental SMA1 fishery, sorted by totals. Total groundfish discards and groundfish excluding haddock discards are also reported.

		Weight (lb)		
Species	**Scientific Name**	**Kept**	**Discard**	**Total**
Silver hake	*Merluccius bilinearis*	154,094.8	22.8	154,117.6
Red hake	*Urophycis chuss*	53,387.7	4,383.2	57,770.9
Haddock	*Melanogrammus aeglefinus*		33,320.9	33,320.9
Spiny dogfish	*Squalus acanthias*	675.0	2,214.2	2,889.2
American plaice (dab)	*Hippoglossoides platessoides*		2,765.1	2,765.1
Yellowtail flounder	*Limanda ferruginea*		1,655.3	1,655.3
American lobster	*Homarus americanus*		1,355.6	1,355.6
Monkfish	*Lophius americanus*		705.8	705.8
Witch flounder (grey sole)	*Glyptocephalus cynoglossus*		661.7	661.7
Herring unspecified	*Alosa, Clupea, and Brevoortia sp.*	622.5	867.6	1,490.1
Torpedo ray	*Tetronarce nobiliana*		305.0	305.0
Atlantic cod	*Gadus morhua*		198.4	198.4
Ocean pout	*Zoarces americanus*		162.1	162.1
Little skate	*Leucoraja erinacea*		127.2	127.2
Winter flounder	*Pseudopleuronectes americanus*		68.4	68.4
Wrymouth	*Cryptacanthodes maculatus*		59.7	59.7
Fourspot flounder	*Hippoglossina oblonga*		41.5	41.5
Pollock	*Pollachius virens*		19.3	19.3
Butterfish	*Peprilus triacanthus*		14.2	14.2
Longhorn sculpin	*Myoxocephalus octodecimspinosus*		12.5	12.5
Jonah crab	*Cancer borealis*		11.7	11.7
Redfish	*Sebastes sp.*		8.4	8.4
Blackbelly rosefish	*Helicolenus dactylopterus*		5.9	5.9
Shortfin squid	*Illex illecebrosus*		4.8	4.8
Windowpane flounder	*Scophthalmus aquosus*		1.6	1.6
White hake	*Urophycis tenuis*		1.5	1.5
Spotted hake	*Urophycis regia*		1.3	1.3
Rock crab	*Cancer irroratus*		1.2	1.2
Lumpfish	*Cyclopterus lumpus*		1.1	1.1
Longfin squid	*Doryteuthis pealeii*		0.3	0.3
Groundfish			38,862.7	
Groundfish excluding haddock			5,541.8	
	Total	208,780.0	48,998.1	257,778.1

Table 4. Catches from 87 observed tows in the 2017 experimental SMA1 fishery sorted by totals. Total groundfish discards and groundfish excluding haddock discards are also reported.

		Weight (lb)		
Species	**Scientific Name**	**Kept**	**Discard**	**Total**
Silver hake	*Merluccius bilinearis*	107,278.5		107,278.5
Red hake	*Urophycis chuss*	35,523.0	8,639.0	44,162.0
Herring unspecified	*Alosa, Clupea, and Brevoortia sp.*	43,508.6	7,771.5	51,280.1
Butterfish	*Peprilus triacanthus*	8,156.0	736.0	8,892.0
Haddock	*Melanogrammus aeglefinus*		6,422.6	6,422.6
American lobster	*Homarus americanus*		4,090.9	4,090.9
American plaice (dab)	*Hippoglossoides platessoides*		3,605.4	3,605.4
Yellowtail flounder	*Limanda ferruginea*		3,091.6	3,091.6
Atlantic mackerel	*Scomber scombrus*	665.5	297.0	962.5
Witch flounder (grey sole)	*Glyptocephalus cynoglossus*		902.9	902.9
Monkfish	*Lophius americanus*		682.5	682.5
Shortfin squid	*Illex illecebrosus*	186.1	43.8	229.9
Fourspot flounder	*Hippoglossina oblonga*		175.7	175.7
Winter flounder	*Pseudopleuronectes americanus*		161.3	161.3
Ocean pout	*Zoarces americanus*		133.9	133.9
Wrymouth	*Cryptacanthodes maculatus*		126.7	126.7
Atlantic cod	*Gadus morhua*		118.9	118.9
Winter skate	*Leucoraja ocellata*		79.7	79.7
White hake	*Urophycis tenuis*		78.0	78.0
Fishing gear debris			50.0	50.0
Longhorn sculpin	*Myoxocephalus octodecimspinosus*		49.1	49.1
Little skate	*Leucoraja erinacea*		39.2	39.2
Spiny dogfish	*Squalus acanthias*		22.0	22.0
Pollock	*Pollachius virens*		17.7	17.7
Blackbelly rosefish	*Helicolenus dactylopterus*		15.0	15.0
Redfish	*Sebastes sp.*		12.9	12.9
Surf clam	*Spisula solidissima*		7.0	7.0
Jonah crab	*Cancer borealis*		5.5	5.5
Atlantic wolffish	*Anarhichas lupus*		4.0	4.0
Lumpfish	*Cyclopterus lumpus*		3.0	3.0
Smooth skate	*Malacoraja senta*		2.1	2.1
Windowpane flounder	*Scophthalmus aquosus*		2.0	2.0
Thorny skate	*Amblyraja radiata*		1.7	1.7
Sea raven	*Hemitripterus americanus*		1.5	1.5
Rock crab	*Cancer irroratus*		1.0	1.0
Sea scallop	*Placopecten magellanicus*		0.8	0.8
Groundfish			14,551.2	
Groundfish excluding haddock			8,128.6	
	Total	195,317.7	37,391.9	232,709.6

Groundfish discards declined by 63% between years, primarily due to lower catches of haddock (81% decline). All flatfish catches increased in 2017, usually by large percentages. American plaice and yellowtail flounder increased by 30% and 87% respectively.

Butterfish and herring catches from SMA1 in 2017 were much higher than in 2016, likely due to regulatory changes in 2017 that allowed for increased landings of herring, which are often caught along with butterfish (Tables 3 and 4).

Catch Per Trip

Silver hake were caught at similar average rates in the experimental fishery and in the first two weeks of the normal exempted fishery in 2016 (t=0.26, df=39, p=0.79) and in 2017 (t=0.82, df=39, p=0.63; Table 5). In both years, the average silver hake catch/trip in the exempted fishery appeared to decline after the first two weeks.

Red hake showed a different comparison. In 2016, red hake catch rates were similar in the experimental fish-

Table 5. Catch (lb) per trip for major targeted species plus haddock and 95% confidence intervals based on the t-test in the SMA1 experimental fishery (top table) and from observed trips in the exempted fishery (lower tables in blue). The exempted fishery is further subdivided into the entire season (July 15–Nov 15), effort during the first two weeks (July 15–July 28), and the remainder after the first two weeks (July 29–Nov 15). Catches include both kept and discards.

Catch/Trip for SMA1

	2016 Experimental Fishery			2017 Experimental Fishery		
Species	**Trips**	**Catch/Trip**	**95% CI**	**Trips**	**Catch/Trip**	**95% CI**
Silver hake	29	5,314.4	(3,984.9; 6,643.9)	26	4,126.1	(2,997.2; 5,255.0)
Red hake	29	1,992.1	(1,347.0; 2,637.2)	26	1,698.5	(1,329.6; 2,067.4)
Butterfish	4	3.5	(-0.2; 7.2)	25	355.7	(222.8; 488.6)
Herring	22	67.7	(41.8; 93.6)	26	1,972.3	(1,488.0; 2,456.6)
Haddock	29	1,149.0	(741.7; 1556.3)	26	247.0	(88.5; 405.5)

	2016 Exempted Fishery			2017 Exempted Fishery		
	Trips	**Catch/Trip**	**95% CI**	**Trips**	**Catch/Trip**	**95% CI**
Species	**2-weeks**			**2-weeks**		
Silver hake	12	5,754.2	(1,171.8; 10,336.6)	24	5,448.7	(2,219.7; 8,677.7)
Red hake	12	2,269.7	(1,225.8; 3,313.7)	23	989.6	(530.1; 1,449.1)
Butterfish	9	103.1	(10.7; 195.5)	20	81.8	(29.9; 133.7)
Herring	12	125.1	(0.4; 249.9)	24	1,630.9	(789.4; 2,472.4)
Haddock	12	425.3	(108.8; 741.8)	24	196.1	(21.8; 370.4)
Species	**Remaining**			**Remaining**		
Silver hake	13	3,084.1	(350.7; 5,817.5)	44	2,121.0	(1,407.0; 2,835.1)
Red hake	13	1,014.4	(-34.7; 2,063.6)	43	959.0	(561.7; 1,356.3)
Butterfish	4	18.9	(-1.4; 39.2)	36	161.2	(77.5; 244.9)
Herring	13	123.7	(20.7; 226.6)	44	2,752.6	(1,476.3; 4,028.8)
Haddock	13	253.5	(-46.3; 553.3)	38	126.0	(51.8; 200.2)
Species	**All Fishery**			**All Fishery**		
Silver hake	25	4,365.7	(1,891.7; 6,839.8)	68	3,295.5	(2,057.0; 4,534.0)
Red hake	25	1,617.0	(883.9; 2,350.1)	66	969.7	(672.9; 1,266.4)
Butterfish	13	77.2	(23.1; 131.4)	56	132.8	(76.4; 189.3)
Herring	25	124.4	(50.3; 198.4)	68	2,356.7	(1,485.2; 3,228.2)
Haddock	25	336.0	(142.0; 530.0)	62	155.1	(64.8; 245.4)

Table 6. Groundfish discard ratios for SMA 1 in 2016 (left) and 2017 (right) and for the experimental fishery (top table) and exempted fishery (lower tables). The exempted fishery is further subdivided into the entire season (July 15–Nov 15), effort during the first two weeks (July 15–July 28), and the remainder after the first two weeks (July 29–Nov 15). Discard ratios, at tow, trip and fishery level, are shown for all groundfish stocks and for groundfish excluding haddock. Effort is the number of observations; means and standard deviations (SD) are for the discard ratios. Mean discard ratios highlighted in pink fail to fall under the 0.05 threshold. "No. >=0.05" describes the number of discard observations that failed to fall under the 0.05 threshold.

Discard Ratio for SMA1

	2016 Experimental Fishery						2017 Experimental Fishery					
Level	Effort	Mean Groundfish	SD	No. >= 0.05	Mean Groundfish without haddock	SD	No. >= 0.05	Effort	Mean Groundfish	SD	No. >= 0.05	Mean Groundfish without haddock	SD	No. >= 0.05
Fishery	1	0.190	-	1	0.030	-	0	1	0.074	-	1	0.042	-	0
Trip	29	0.192	0.110	29	0.023	0.013	2	26	0.069	0.087	10	0.039	0.063	3
Tow	82	0.200	0.156	76	0.025	0.022	10	87	0.077	0.113	34	0.040	0.074	16

	2016 Exempted Fishery						2017 Exempted Fishery					
Level	Effort	Mean Groundfish	SD	No. >= 0.05	Mean Groundfish without haddock	SD	No. >= 0.05	Effort	Mean Groundfish	SD	No. >= 0.05	Mean Groundfish without haddock	SD	No. >= 0.05
	2-weeks							2-weeks						
Fishery	1	0.060	-	1	0.010	-	0	1	0.041	-	0	0.016	-	0
Trip	13	0.066	0.066	5	0.011	0.010	0	24	0.045	0.068	7	0.016	0.021	3
Tow	46	0.074	0.080	21	0.017	0.035	3	78	0.110	0.568	19	0.021	0.030	12
	Remaining							Remaining						
Fishery	1	0.070	-	1	0.010	-	0	1	0.035	-	0	0.015	-	0
Trip	13	0.055	0.104	2	0.010	0.011	0	45	0.031	0.051	9	0.013	0.020	3
Tow	17	0.048	0.092	3	0.008	0.011	0	129	0.037	0.069	27	0.018	0.037	10
	All Fishery							All Fishery						
Fishery	1	0.062	-	1	0.011	-	0	1	0.037	-	0	0.016	-	0
Trip	26	0.058	0.086	7	0.011	0.010	0	69	0.036	0.057	16	0.014	0.020	6
Tow	63	0.067	0.084	24	0.014	0.031	3	207	0.065	0.353	46	0.019	0.035	22

ery and the first two weeks of the exempted fishery (t=0.72, df=52, p =0.47; Table 5). But in 2017, red hake catch rates were significantly higher in the experimental fishery (709 lb/trip, t=2.51, df=48, p=0.01). Red hake catch rates appeared to decline quite a bit between years during the exempted fishery (all periods) and only slightly in the experimental fishery between 2016 to 2017.

Butterfish catch rates also showed no significant difference between the experimental fishery and the first two weeks of the exempted fishery in 2016 (t=1.62, df=11, p=0.13) but with low sample sizes (Table 5). Like red hake, there was a significant difference between the fishery periods in 2017 (274 lb/trip, t=3.63, df=53, p=0.001). Butterfish catch rates in the experimental fishery changed dramatically between years, with a 100x increase in 2017. In the exempted fishery, butterfish catch rates appeared to increase overall from 2016 to 2017; during the first two weeks catch rates appeared to remain somewhat similar or to decline.

Herring catches also changed dramatically in the experimental fishery between years, with an increase in mean rate of 29x, and a similar increase was observed in the exempted fishery across all periods (Table 5). Catch rates between the experimental and first two weeks of the exempted fishery were not significantly different either in 2016 (t=1.28, df=32, p=0.21) or 2017 (t=0.74, df=48, p=0.46). Within each year, herring catches during the first two weeks of the exempted fishery remained similar to the later period and over the entire exempted fishery.

Haddock catch rates in the experimental fishery in 2016 appeared to be anomalous (Table 5). Catch rates in the experimental fishery compared to the first two weeks of the exempted fishery were significantly higher (723.7 lb/trip, t=2.23, df=39, p=0.03); in 2017, the difference was not significant (t=0.47, df=48, p=0.66; Table 5). Observed rates declined as the exempted fishery progressed in both years (Table 5).

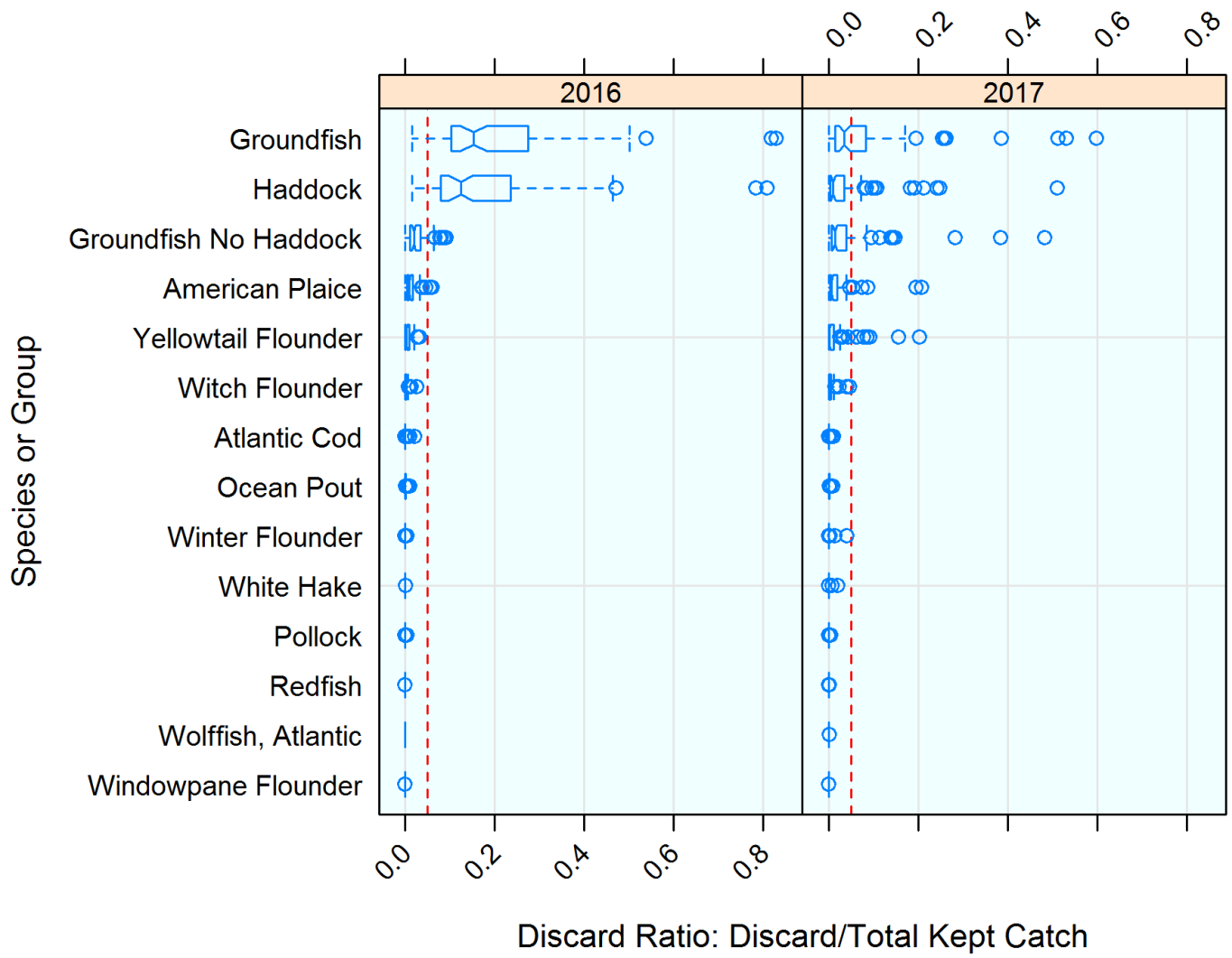

Figure 4. Box and whisker plot of discard ratios (at the tow level) for individual groundfish species encountered in the experimental 2016 (left) and 2017 (right) SMA1 fishery. Also included is the discard ratio for all groundfish and all groundfish excluding haddock. The red dashed line is the 0.05 threshold. Notches in boxplots represent approx. 95% confidence intervals.

Bycatch Ratios

Groundfish discard ratios for the SMA1 experimental fishery were higher than 0.05 in both years (2016: 0.190; 2017: 0.074; Table 6 and Figure 4). Recalculation of discard ratios with haddock catches removed (the primary groundfish discard) reduced bycatch ratios below the 0.05 threshold in both years (2016: 0.030; 2017: 0.042).

Groundfish and groundfish-without-haddock discard ratios averaged across trips (n=29 in 2016; n=26 in 2017) only slightly changed these ratios (Table 6). All trips in 2016 (ratio: 0.192, 29 of 29 trips) exceeded the 0.05 threshold, with many fewer in 2017 (ratio=0.069, 10 of 26 trips). In 2016, without the contribution of haddock, only 2 of 29 trips met or exceeded the threshold, and the average discard ratio was 0.023, less than half the threshold level. In 2017, without the contribution of haddock, 3 of 26 trips exceeded the 0.05 threshold, and the average discard level of 0.039 was again lower than the threshold.

At the tow level (n=82 in 2016; n=87 in 2017), the average groundfish discard ratios for the fishery overall were slightly higher than at the trip level (2016: 0.200; 2017: 0.077; Table 6). Nearly every tow in 2016 (76 of 82) exceeded the threshold. In 2017, only 34 of 87 tows had discard ratios higher than 0.05. Once again, recalculation without the contribution of haddock had a strong impact on the discard ratios: only 10 of 82 tows

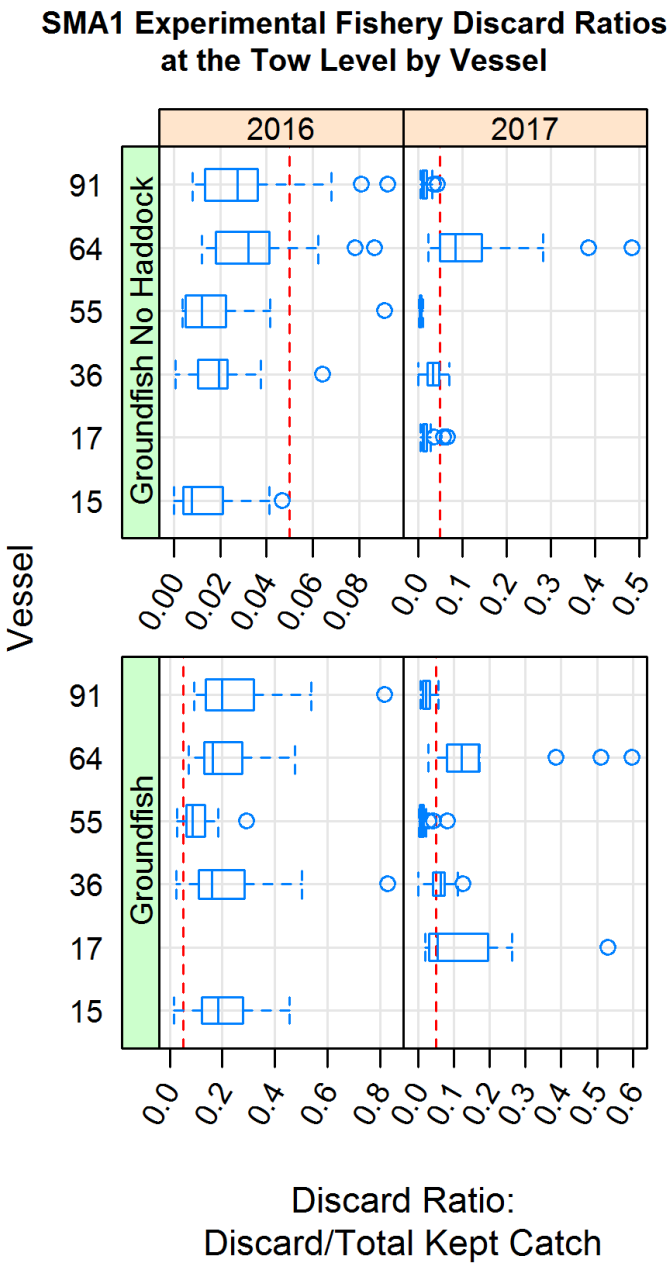

Figure 5. Box and whisker plot of discard ratios (at the tow level) by vessel for total groundfish (bottom) and groundfish excluding haddock (top) in the 2016 (left) and 2017 (right) SMA1 experimental fishery. The red dashed line is the 0.05 threshold.

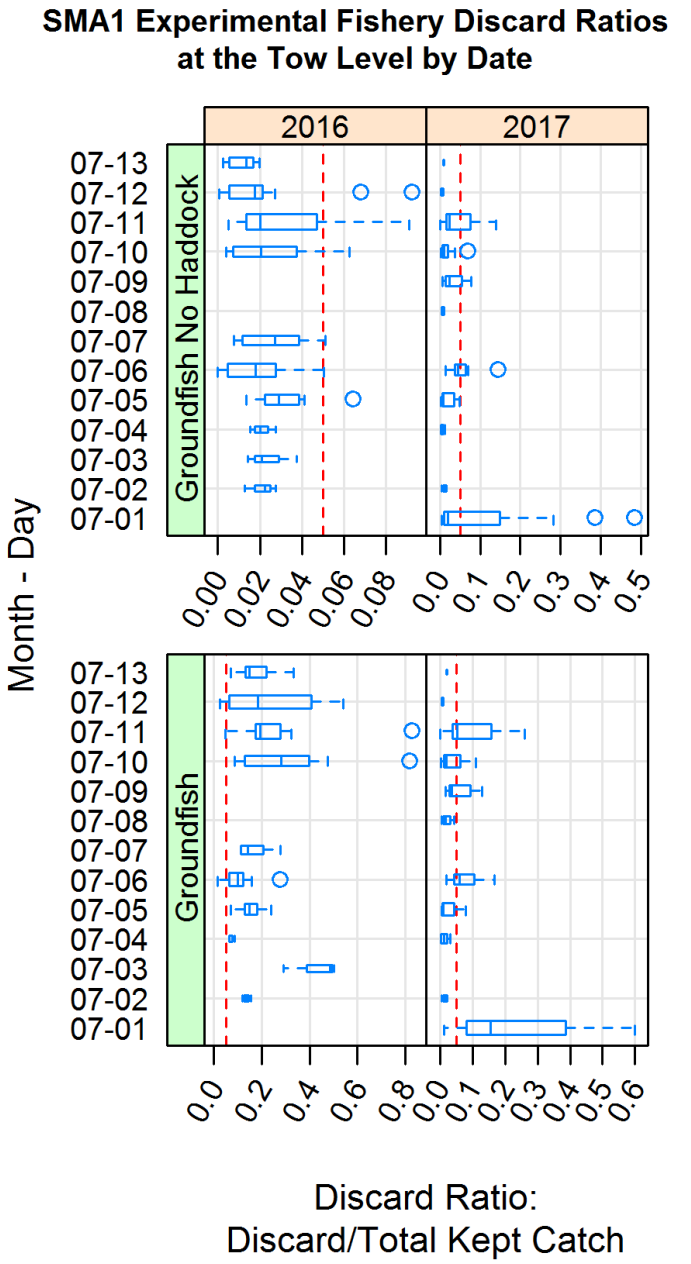

Figure 6. Box and whisker plot of the discard ratios (at the tow level) by date (month-day) for total groundfish (bottom) and groundfish excluding haddock (top) in the 2016 (left) and 2017 (right) SMA1 experimental fishery. The width of the boxplot reflects the sample sizes. The red dashed line is the 0.05 threshold.

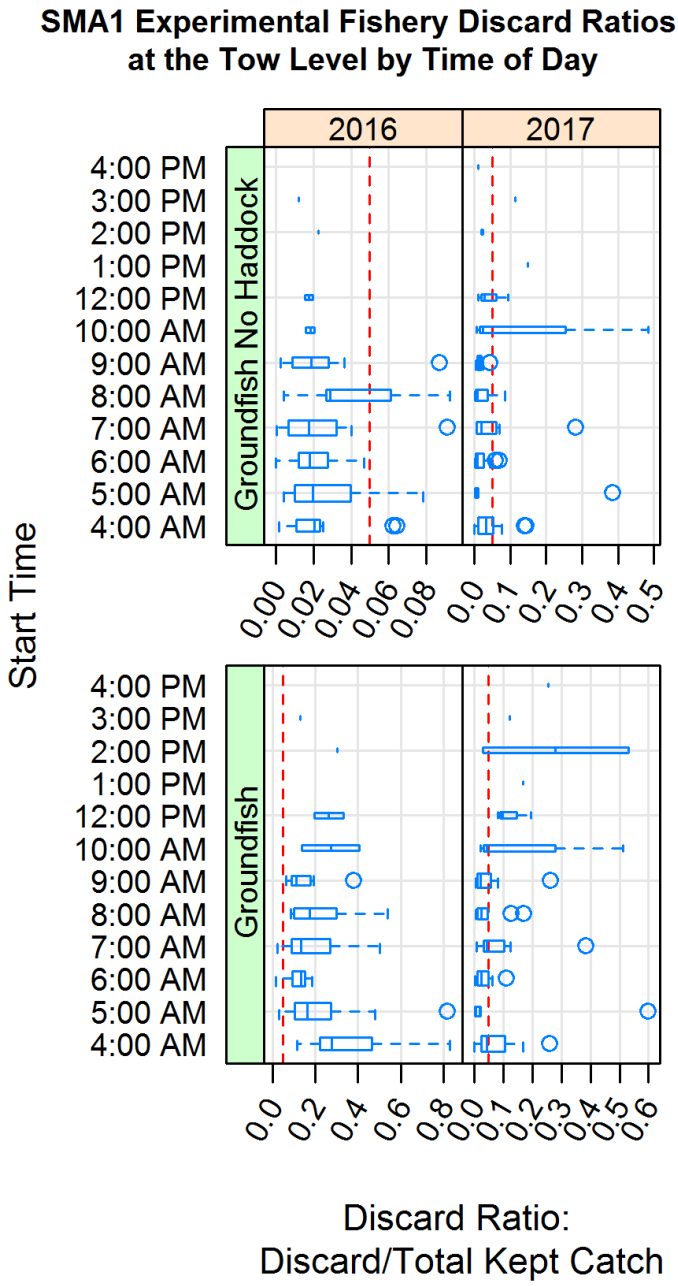

Figure 7. Box and whisker plot of the discard ratios (at the tow level) by time of day for total groundfish (bottom) and groundfish excluding haddock (top) in the 2016 (left) and 2017 (right) SMA1 experimental fishery. The width of the boxplot reflects the sample sizes. The red dashed line is the 0.05 threshold.

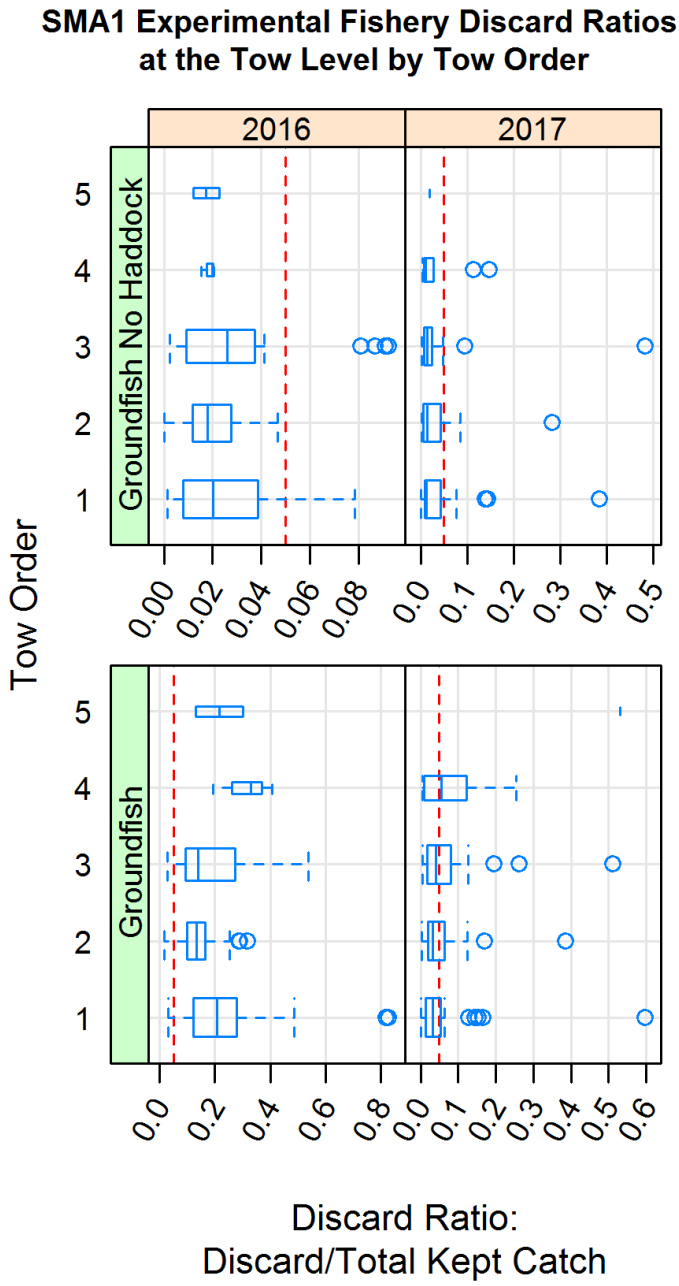

Figure 8. Box and whisker plot of the discard ratio by sequential tows (per trip) for total groundfish (bottom) and groundfish excluding haddock (top) in the 2016 (left) and 2017 (right) SMA1 experimental fishery. One tow was excluded as it occurred on the second day of the only multi-day trip. The width of the boxplot reflects the sample sizes. The red dashed line is the 0.05 threshold.

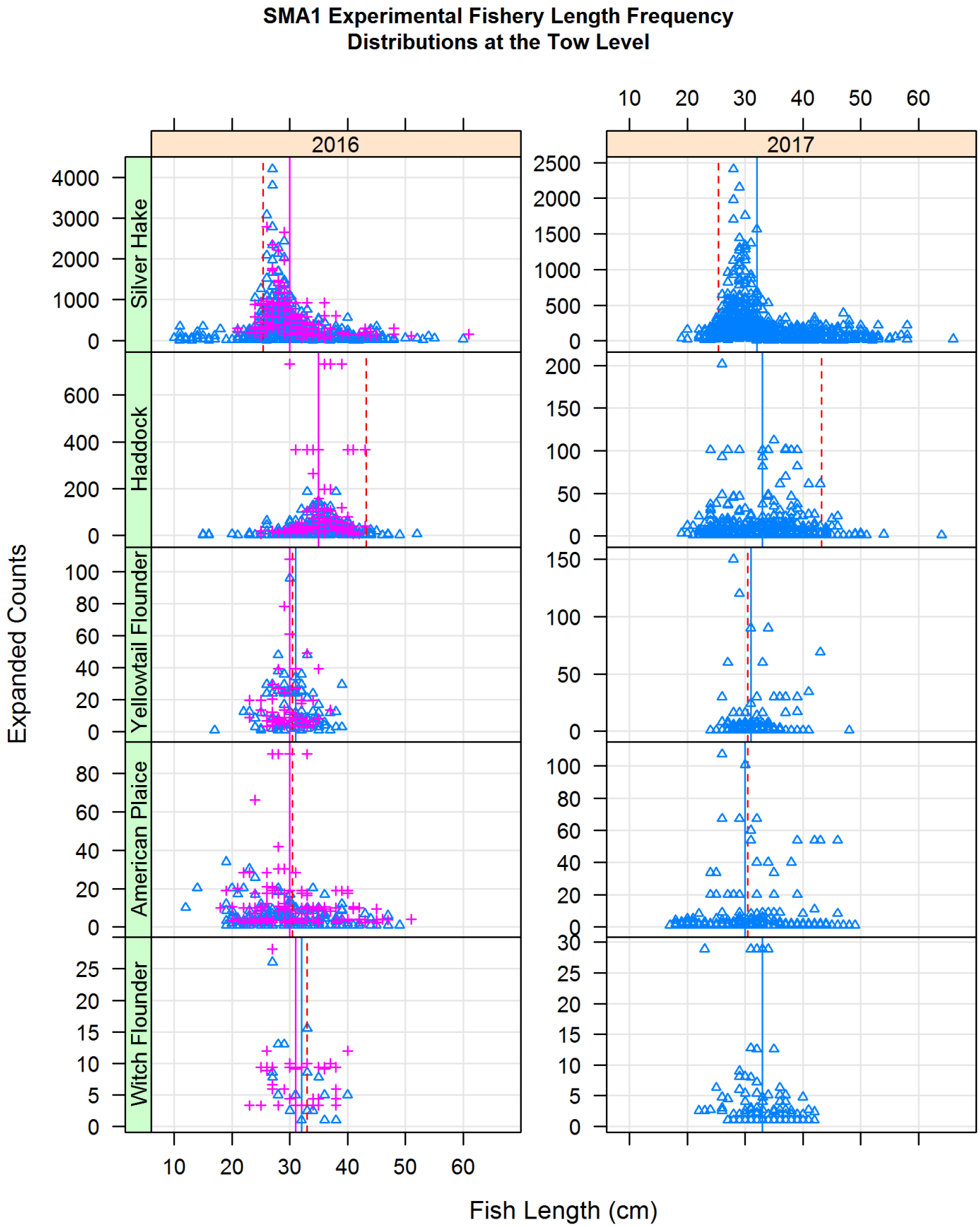

Figure 9. Expanded length frequencies of silver hake and four groundfish species measured in the 2016 (left) and 2017 (right) SMA1 experimental fishery. Blue triangles and pink plusses represent tows using a 2.5 in and 3.0 in codend mesh respectively. Corresponding colored vertical lines illustrate panel medians; where one line is seen in 2016, the median lines overlap. No 3.0 in codend meshes were used in 2017. Red dashed lines are the legal minimum sizes, except for silver hake, where the line is arbitrarily placed at the equivalent of 25.4 cm (10 in).

(ratio=0.025) in 2016 and 16 of 87 tows (ratio=0.040) in 2017.

In the exempted fishery in SMA1 in 2016, sea sampler data indicated groundfish bycatch ratios lower than in the experimental fishery, but also above the 0.05 threshold on the fishery (0.062), trip (0.058; 7 of 26 trips), and tow (0.067; 24 out of 63 tows) levels (Table 6). Removing haddock catches reduced these ratios to levels below the 0.05 threshold with no trips and only 3 tows exceeding the threshold. Bycatch ratios in the two weeks immediately following the experimental fishery in 2016 did not differ greatly from the overall exempted fishery but were lower than in the prior two weeks of the experimental fishery. The three tows that exceeded 5% groundfish discards (without the haddock contribution) during the exempted fishery were all in this time period.

In 2017, the groundfish discard ratios at the fishery and trip (n=69) level were below 0.05 for the entire exempted fishery and in the first two weeks (Table 6). At the tow level, the discard ratio was higher than the threshold - 0.065 overall, and 0.110 in the first two weeks. Discard ratios in 46 of 207 tows were higher than 0.05, with 19 of 78 in the first two weeks. Removing haddock catches in the exempted fishery reduced discard ratios below the 0.05 threshold and resulted in 6 trips and 22 tows exceeding the threshold, with 3 of those trips and 12 of those tows in the first two weeks.

Median groundfish discard ratios by vessel at the tow level during the 2016 experimental SMA1 fishery all surpassed the 0.05 threshold (Figure 5). Once haddock were excluded from the groundfish discard ratios, all vessels' median results dropped below the threshold. In 2017, only three vessels had median discard ratios over the threshold; one vessel still had a median discard ratio over the threshold once haddock was removed. The same vessel had the highest median groundfish without haddock discard ratio in both years, due to combined flatfish catches.

We also examined groundfish discard ratios during the experimental SMA1 fishery at the tow level by date (Figure 6), time of day (Figure 7), and sequential tow number per trip (Figure 8). In all cases, no clear trends emerged due to the above factors for either year.

Lengths

Sufficient lengths were collected during the SMA1 experimental fishery from five species to permit examination of results. Length frequencies of counts for silver hake (expanded from subsamples) indicated a broader size range, with more small fish (under approx. 20 cm), in 2016 than 2017 (Figure 9). Use of a 3.0 in codend mesh (rather than the 2.5 in mesh size) in 2016 by one vessel did not appear to affect the median size to any great degree for any investigated species but did appear to eliminate smaller fish of most species, particularly silver hake. Nearly all haddock were below the minimum landing size of 40.6 cm (16 in); use of the 3.0-in. mesh appeared to truncate the size distribution of haddock observed with this gear.

Discussion

Silver hake, red hake, and herring appeared to be abundant and available in SMA1 during both years of the experimental fishery, with markets willing to accept the earlier product. Catch rates during the experimental fishery for silver hake were generally similar to those observed in the first two weeks of the normal exempted fishery, and for red hake in 2016. Both experienced whiting fishermen and new participants expressed and maintained interest over both years of the experimental fishery. Consequently, it appears that an earlier opening to the exempted fishery would be exploited by several fishermen.

Bycatch of groundfish in the SMA1 experimental fishery was consistently above a discard threshold of 0.05 as measured at every level (fishery, trip, tow) in both 2016 and 2017 (Table 6). Haddock drove these groundfish bycatch levels in both years (Tables 3 and 4) and most of the haddock caught were below minimum landing size and all were discarded, likely with a high mortality rate (Figure 9). After haddock, American plaice and GOM yellowtail flounder were the groundfish species caught in the greatest amount. Approximately equal proportions of both plaice and yellowtail flounder caught in the experimental fishery were above and below the minimum landing size.

While we found no evidence that haddock could be avoided in 2016, different patterns emerged in 2017. In 2016, haddock was the primary cause for the 0.05 groundfish bycatch threshold to be exceeded across all vessels of the experimental fishery (Table 5 and Figure 5), for all dates (Figure 6), for all hours of the day (Figure 7), and without regard to tow order (Figure 8). In 2017, two vessels had mean groundfish discard ratios below 0.05 (Figure 5). Examination of tow start locations suggested these vessels did not begin tows in the southern portion of the experimental fishery. This spatial distinction may be considered for further analysis. Additionally, the first day's discard ratio was by far the highest of

the 2017 experimental fishery (Figure 6); in the following three days, the ratio was lower than 0.05. Removing haddock from the discard ratios did not change this result. It is likely that most participants learned from the first day's catches, or from each other, how to avoid bycatch of groundfish species. Whether avoidance was from choice of fishing grounds, timing, or other adjustments is not known.

Generally, bycatch trends were similar in the experimental and exempted fisheries (Table 6). During 2016, groundfish discard ratios in the exempted and experimental fisheries are similarly above the 0.05 threshold. Notably, after the first two weeks, the discard ratios during the exempted fishery are above 0.05 just on the fishery and trip levels. In 2017, the experimental and exempted fisheries are less similar. Discard ratios above the 0.05 threshold are seen in the experimental fishery again at every level, but only at the tow level during the exempted fishery (overall and first two weeks). The 2017 tow level similarity is likely due to large outlier tows of bycatch, mainly haddock and flatfish, whose impacts are reduced in the trip and fishery levels.

Bycatch levels of haddock also were consistent in both the experimental and exempted fisheries, with greater similarity in the first two weeks of the experimental fishery. No other groundfish species was caught at high levels in the SMA1 experimental fishery (Tables 3 and 4).

But the experimental and exempted fisheries cannot be easily compared since it is not known if observer coverage was representative of the exempted fishery as a whole. Further, the experimental fisheries were limited to a subset of the entire exemption areas which may not be characteristic of the entire exempted areas. Also it should be noted that comparing performance of the RFT historically and to present day using the five percent threshold is not straightforward. The method for calculating the threshold has evolved. During field sampling of commercial use of the RFT and during gear comparison trials in the 1990s, it was calculated as the proportion of the total weight of all groundfish bycatch divided by the sum of both the kept and discard weights during a tow (McKiernan, et al. 1998). The method used in our analysis is more conservative as the denominator is reduced by excluding the weight of discards, increasing the bycatch ratio. The bycatch ratio definition was ambiguous with respect to level of precision (fishery, trip, or tow level) (McKiernan et al. 1998, NOAA 1996), but was eventually clarified (50 CFR 648; FR 61(106): 27737-8) with added flexibility of implementation. Additionally, species that constitute current regulated groundfish varied from those that were previously defined or reported (Carr et al. 1995; NOAA. 2010).

Further complicating comparisons is a shift in the catch composition of observed trips from the exempted fishery between years due to management changes from the Atlantic States Marine Fisheries Commission (ASMFC). ASMFC's Atlantic herring fishery management plan (FMP) determines the number of days that vessels can land >2,000 lb of herring from Management Area 1A (inshore Gulf of Maine), which encompasses SMA1. With the approval of Addendum I in May 2017 (Atlantic States Marine Fisheries Commission. 2017), ASMFC relaxed landing-day restrictions for bottom trawl vessels, allowing them to land herring seven days per week. This increased opportunity, and the abundance of captured herring in SMA1, led to a large increase in targeted herring tows and landings in 2017 (Table 5). Of the 69 NEFOP sampled trips queried, roughly half landed more Atlantic herring than silver hake, suggesting that tows from these trips had multiple target species. The much larger 2017 butterfish catch is likely also explained by the management change that occurred, as butterfish are often captured around herring, and/or a greater availability of the stock; butterfish recruitment into the fishery is highly variable year-to-year (Adams, 2017). Further butterfish landings in 2017 were likely limited by the 600-lb trip limits (average catch/trip was 355.7 lb in the experimental fishery and 132.8 in the exempted fishery) (Greater Atlantic Regional Fisheries Office, 2015) (Table 5). Increased landings of these species added to the total kept catch and therefore, reduced the bycatch discard ratios for those tows and trips, as well as the fishery.

Some evidence for suboptimal gear performance or handling was observed. One vessel in particular (#64) caught the most groundfish bycatch overall during both years of the experimental SMA1 fishery, including the most flatfish by far—approximately twice as many of the flatfish from this vessel compared to the others were caught in 2017 (data not shown). Additionally, other bottom tending species, such as lobsters and monkfish were also captured in the greatest quantities by vessel #64 during those times. The RFT was designed to avoid these species based on their bottom-tending behaviors. The RFT gear used by vessel #64 was inspected in both years, and was considered within tolerances of the specifications (the vessel's footrope length was slightly greater than the headrope length + 20 ft); traditionally, some allowance has been made for extra length in the headrope to adjust height of the footrope off-bottom. However, the notable differences in flatfish catches and other bottom tending species from this vessel suggest

greater issues with some aspect of the net's use. This vessel may offer an opportunity for support, outreach and education to improve the performance of their version of this net.

Differences in performance between vessels, despite adherence to a single, mandated gear configuration highlights a likely vessel effect and the role of captain's knowledge. Two vessels were able to stay under the 0.05 ratio in 2017 (Figure 5), and one vessel in 2017 was responsible for 12 of 14 tows and all trips where the groundfish discard ratio was higher than 0.05 (data not shown). This vessel's performance in 2016 was not notably different from the other vessels, however. In 2017, it appeared that two vessels had found some way to avoid haddock and other bycatch. Vessel effects combine all differences in experience, tow location, and gear, and appears to provide indication of substantial differences, and may be worthy of further investigation.

However, substantial catches of haddock in the experimental and exempted fisheries are likely not due to poor gear performance or handling. The RFT was developed, tested, and approved for use in the exempted fisheries when the spawning stock biomass of GOM haddock was at a low point, in contrast to the current healthy status of the stock (Palmer, 2017). In field testing of the RFT and a standard whiting net in 1997, catch rates for haddock were below 7 lb/hr in 72 tow-pairs, and no difference in haddock catch was observed between nets (p=0.11) (DMF, unpublished data). Based on known haddock behavior in the fishery (Carr and Caruso, 1992), we would expect haddock catches to remain relatively unaffected by the RFT. We anticipate further consideration of the impact of changes in stock status among the multispecies fishery on bycatch reduction of the RFT via a scientific manuscript.

Conclusion

Insufficient data were collected in the WRFE area to make any conclusions. Lack of interest in either year suggests that any change in this area's opening date is of little interest to the fleet. The prevalence of fixed gear and low price were cited as obstacles to further fishing. No further action is recommended in this area.

In SMA1, alteration of the timing of the opening of the area would be taken advantage of by the fishing fleet. In all likelihood, an earlier opening would lead to levels of groundfish bycatch above the five percent threshold, and higher than in the normal exempted fishery. Some of the discarded fish stocks (haddock, American plaice (dab)) are healthy and underutilized. GOM haddock biomass is 706% of the target and the 2016 fishing mortality rate is only 30% of the overfishing threshold (NEFSC, 2017). American plaice was at 99% of biomass target in 2016 with an exploitation rate at 1% of the overfishing proxy (Terceiro, 2016). An earlier opening may not jeopardize the health of these stocks. However, for some species, an earlier opening might jeopardize meeting fishing mortality objectives. GOM yellowtail flounder is overfished with overfishing occurring and subject to a high utilization rate (Northeast Fisheries Science Center, 2015).

Bycatch reduction devices, such as grids, can effectively separate species. A gear solution to haddock bycatch involving a grid likely would cause loss of herring and large silver hake catches. If loss of herring is acceptable, an escape cut in the top of the net could provide an alternative solution—herring and haddock are known to seek escape upward while silver hake seem less inclined or apt (Main and Sangster, 1982; Chosid, et al., 2011). Developing and testing a gear modification would require additional time and effort.

Some evidence was found that bycatch could be lowered by altering choices by vessel captains. Further investigation, outreach and education on gear use or gear modification may help to reduce bycatch for the fishery as a whole. As a result, an opening for the exempted whiting fishery in SMA 1 earlier than the current July 15th date may be possible after assessment of potential impacts on the multispecies complex of the GOM. The dataset acquired during the experimental fishery is a valuable resource for that assessment.

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