Marine Policy 66 (2016) 75–82

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

A cost-effective discards-proportional at-sea monitoring allocation scheme for the groundfish fishery in New England

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ARTICLE INFO

Article history:
Received 17 November 2015
Received in revised form
29 December 2015
Accepted 31 December 2015
Available online 22 January 2016

Keywords:
Fisheries
At-sea monitoring
Groundfish
Discards
Cost-effective management

ABSTRACT

Discards can account for a large proportion of a fishery's total catch and have a significant impact on the condition of stocks, so many fisheries implement management measures to estimate discards, including at-sea monitors. Currently, at-sea monitors for the United States Northeast multispecies (groundfish) fishery, located in the northwest Atlantic Ocean, are allocated to meet a 30% coefficient of variation (CV30) standard to estimate the discards of 22 groundfish stocks by sector, gear type, and broad stock area on a trip basis. CV30 is a relative standard deviation precision measurement that deploys observers at an equal coverage rate across strata, regardless of their volume of landings or discards. As a result, at-sea monitors have not been cost-effectively allocated to observe the majority of the catches and discards or the catches and discards of highly utilized stocks to ensure accurate accounting of annual catch entitlement (ACE) utilization. Although some sectors and gear types are responsible for a relatively large percentage of landings and discards, they are allocated observers at the same coverage level as those that discard less. This has resulted in a disparity between monitoring effort and groundfish landings and discards, and the incentive to reduce discards is now misaligned with the utilization of ACE. Given that at-sea monitoring funding is limited and that the industry will soon have to bear this cost, this analysis proposes a discards-proportional observer allocation scheme that weights stocks with high ACE utilization rates more heavily. Results show that, in FY 2013, this allocation method could have reduced observer sea days by 1892 days, resulting in a $1.3 million total cost savings for the industry, while still observing the same amount of weighted discards as under current monitoring standards. This proposed approach could also provide an incentive to reduce discards for sectors faced with disproportionate and daunting at-sea monitoring costs.

1. Introduction

1.1. Background

In 2010, the groundfish fishery transitioned from days-at-sea to sector-based catch share management. Under this system, annual catch entitlement (ACE) is allocated to sectors—groups of voluntarily affiliated vessels—based on the catch history of the sector's members. The sector bears responsibility for allocating ACE to its member vessels. ACE may then be traded and leased within and between sectors. As of Fishing Year (FY) 2013, there were 19 sectors in the fishery, four of which functioned as lease-only sectors that did not conduct fishing activities [12].

Vessels fishing in sectors are required to carry at-sea observers on a portion of their trips to monitor their discards and ACE utilization. Discards account for about 18% of total catch in United States fisheries, and insufficiently monitored and regulated discards can play a substantial role in fisheries depletion [3,9]. In the groundfish fishery, discards include both non-target species and groundfish discarded due to minimum size restrictions or other regulations. Previous research has suggested that the ratio of discards of both groundfish and non-groundfish species to groundfish landings is roughly 1.79 [9]. This analysis focuses on discards of groundfish species that accounts for ACE utilization; in Fishing Year 2013, discards accounted for 0.3%-29.7% of the total catch of each groundfish stock and 0.2–11.1% of the ACE for each stock. The majority of these discards are not directly measured, but an estimated quantity of discards by stock is counted against a sector's ACE [8]. At-sea monitoring of a portion of trips is necessary to estimate discard rates, monitor the utilization of ACE as the

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http://dx.doi.org/10.1016/j.marpol.2015.12.029

fishing season progresses, and limit the adverse effect of poorly estimated discards on fisheries sustainability and profitability.

The stated objective for this at-sea monitoring (ASM) program in Amendment 16 to the Northeast Multispecies Fishery Management Plan is to "verify area fished, catch, and discards by species, by gear type" [2]. Observers are randomly assigned to vessels within strata determined by sector, gear type, and area fished on a trip basis, at a constant coverage rate determined by the National Marine Fisheries Service (NMFS) for each fishing year. The current monitoring coverage rate is calculated based on the CV30 precision standard (see Section 1.3); the rate selected is the lowest required to meet the CV30 for each of the 22 stocks in the groundfish fishery or, at a minimum, to ensure that 80% of discards by weight can be estimated with a CV of 30% or lower [8].

Since implementation of sector management, the cost of at-sea monitoring coverage has been paid by the National Oceanic and Atmospheric Administration (NOAA), but multiple efforts have been undertaken to shift the program to industry funding. While Framework Adjustment 48 to the Northeast Multispecies Fishery Management Plan (FW 48) deferred industry funding of ASM in FY 2013, the industry is expected to cover the salary costs of at-sea monitors—roughly $710 per observed day—beginning in Winter 2015, and will still be required to meet CV30 standards for monitoring [4]. For many fishermen in New England groundfish sectors, this expense could signal financial ruin for their fishing businesses. In fishing year (FY) 2013, the total expected ASM cost to be paid by sectors would have been $2.7 million if the infrastructure and overhead costs for administration of the program were covered under the Northeast Fisheries Observer Program (NEFOP), but no observer salaries were paid by NOAA [4,7]; this is equivalent to more than 4.8% of the $55.2 million groundfish landings value by sectors in FY 2013 [12].

The New England Fishery Management Council (NEFMC) revised certain elements of the groundfish monitoring program through Framework Adjustment 48 to the Northeast Multispecies Fishery Management Plan; these measures were voted on during the December 2012 meeting and were implemented by the National Marine Fisheries Service (NMFS) in FY 2013. Throughout summer and fall of 2012, the groundfish Plan Development Team (PDT) vetted setting observer coverage rates proportional to discards across vessel category, but this alternative analysis was not completed in time for further consideration in FW48.

In anticipation of the shift to industry funding of ASM, discussion regarding the program resumed in April 2015. At its April meeting, the New England Fishery Management Council requested that the agency estimate the costs of the ASM program relative to industry revenues and initiate action to address the economic viability of the groundfish fleet in light of these costs. In June 2015, the Council voted in favor of several motions related to ASM. First, the Council requested an agency emergency action suspending the ASM program; second, it asked NMFS to conduct an analysis of the effectiveness of the program; and third, it tasked the PDT to investigate ways to improve its efficiency and cost-effectiveness. The analyses requested by the Council provide a timely opportunity to consider and improve the cost-effectiveness of the program and ensure that efficient distribution of observer coverage can support the concurrent goals of economic viability and accurate discard estimates.

In response to this discussion, the PDT's meetings in May–August 2015 focused on possibilities for evaluating and revising the ASM program, including the analysis presented here. Options noted by the PDT included altering the method by which CV30 is used to determine the coverage rate, prioritizing coverage based on stock status or ACE utilization, and redesigning and restratifying the system to be proportional to landings and discards.

This analysis attempts to identify the distribution of monitoring effort by estimating the average landings and discards that were observed on each observer sea day among different vessel categories (sector and gear) to determine whether these categories could serve as appropriate strata for developing an alternative cost-effective allocation scheme for ASM observer coverage.

1.2. Previous research

Discussion of ASM coverage distribution within a fleet is not abundant in fisheries literature. Most studies focus primarily on the total observer coverage rate rather than its distribution across vessel sizes, gear types, and other categories. [11] gives an extensive overview of effective monitoring programs. Guiding principles for setting overall observer coverage levels include a formal threat assessment and/or a cost-benefit analysis and consideration for the needs of industry. Guiding principles for program costs include shifting the burden of responsibility to the industry, which is intended to incentivize vessel operators to fish cleaner. Furlong and Martin [6] focus on the optimal level of observer coverage in a fishery through which maximum net benefits are realized; the benefits of reduced illegal and underreported fishing are weighed against the costs of observer coverage. Allard and Chouinard [1] show the importance of a cost-efficient strategy in enforcing regulations against discarding. Rossman [18] highlights the importance of differentiating observer coverage and relative bycatch of marine mammals for each stratum in the Northeast and Mid-Atlantic bottom trawl and gillnet fisheries. Those vessels responsible for higher marine mammal mortality, particularly for threatened species, are deemed a priority in receiving observer coverage.

ASM costs have been a major concern for the groundfish industry since the implementation of sectors over four years ago, as indicated in Section 1.1. This discards-proportional approach, suggested by Sun,was presented to the PDT as an alternative allocation scheme to improve the situation in 2012. An updated study was also presented at the Massachusetts Marine Fisheries Institute Monitoring Workshop on February 24–26, 2013 and was cited by former NEFMC Council member David T. Goethel in public comments on the Draft Standardized Bycatch Reporting Methodology (SBRM) Amendment.

In addition, the University of Massachusetts Dartmouth's School for Marine Science and Technology (SMAST), in partnership with the Northeast Sector Service Network (NESSN), examined the utility of a fixed discard rate for the groundfish fleet based on analysis of NEFOP data collected in 2010–2011 [16]. Discard to kept ratios (D:K) and coefficients of variation (CV) across strata for two gear types, four species and three stock areas were analyzed to examine the utility of using 2010 NEFOP data to predict discard rates for 2011. Results indicated no significant differences in discard rates between 2010 and 2011 for three of the four species analyzed in all stock areas. Numerical differences in the discard rates between the years may have been the result of changes in fishing behavior related to adaptation to the catch share management system.

This analysis expands on these previous studies in demonstrating that, in addition to an optimal level of observer coverage within a fishery, there is also an optimal way to disperse those observers among fleet members to effectively enforce quota controls while minimizing costs.

1.3. The CV30 standard

Currently, coverage rates for the ASM program are set to meet a CV30 standard for discard measurements (a coefficient of variation of 30%). The CV30 standard is a precision measurement calculated as the ratio of the sample standard error to the sample mean. This criterion, which must be met for each stock, is combined with efforts to reduce observer bias and improve accuracy to determine an observer coverage rate for the fishery. This target coverage rate is applied to each tier (defined by stock area, gear, and sector) in the fishery; within a tier, observers are assigned to vessels randomly by the pre-trip notification system (PTNS) [17].

The CV30 standard was first developed for the 2008 Standard Bycatch Reporting Methodology (SBRM) Omnibus Amendment, prior to the implementation of the sector management system and development of the ASM program. The standard was originally applied to the Northeast Fisheries Observer Program (NEFOP), which is designed to more broadly monitor the condition of the stocks, gather biological information, and support the stock assessment process. The at-sea monitoring program, meanwhile, is designed to monitor sector ACE utilization as the fishing season progresses. On implementation of Amendment 16, which expanded the sector system to nearly the entire groundfish fleet, the existing CV30 standard was applied to the ASM program to allow the two monitoring programs to complement each other in meeting monitoring requirements. The NEFOP and ASM programs function similarly, then, despite their quite different fishery management functions [8].

Since implementation, numerous problems related to application of the CV30 standard to the ASM program have arisen. The groundfish PDT has repeatedly noted that the standard may not be appropriately addressing the goal of accurately determining sector catch and ACE utilization. In addition, the program is not cost-effective—more observed trips are necessary to measure a small amount of discards with the required level of precision, but measuring these small amounts precisely does not serve the goal of accurately determining sector quota utilization. Despite these challenges, the agency has generally continued to support use of the CV30 standard for relative ease of implementation and complementarity with NEFOP [8].

Currently, the CV30 standard results in at-sea observation of about 20% of trips, landings, and discards. However, by targeting those vessels that land and discard the most, fewer trips could carry an observer while observing the same volume of landings and discards. In addition, to more accurately observe the discards of highly-utilized species for which catch is likely to be near the total allocation, a weighting scheme based on the expected utilization rates of each stock can be employed. This model is similar to Rossman's [18] proposed method for observing bycatch of marine mammals in the Northeast and Mid-Atlantic bottom trawl and gillnet fisheries by prioritizing coverage of vessels with high bycatch. Differential coverage rates for various vessel categories have also been implemented in the observer program for the Alaskan groundfish and halibut fisheries; in this program, the largest vessels maintain a 100% observer coverage rate, mid-sized vessels are randomly assigned observers to meet a partial coverage rate, and the smallest vessels are not observed [14].

2. Methods

2.1. Data

This analysis uses data from NOAA's Data Matching and Imputation System (DMIS) dataset in Fishing Year 2013 to determine variability in landings, discards, and observer coverage. Data were classified by each of fifteen sectors and five gear types (large mesh gillnet, extra-large mesh gillnet, handline, longline, and otter trawl). Trips taken by vessels fishing outside sectors (in the common pool) and vessels smaller than 30′ were excluded from analysis because these vessels are only subject to NEFOP coverage (8% in 2010–2014; 4% in 2015), not ASM coverage. Trips taken with three gear types—fish pots, Ruhle trawls, and haddock separator trawls—were excluded because the small number of these trips created confidentiality issues. The Northeast Coastal Communities Sector was not explicitly excluded, but its lack of groundfish landings by vessels larger than 30′ in FY 2013 means it does not appear in results. Trips employing multiple gear types were assigned the gear used for a majority of the trip rather than being double-counted. A total of 9406 trips are included in this analysis.

The number of sea days was calculated in accordance with the definition provided in contracts with northeast observer service providers [13]. The first and last calendar day the vessel leaves port are prorated by quarter days (six-hour intervals), and any interim days are counted as one sea day. This billing structure was first implemented in contracts signed in mid-FY 2012, replacing a system that prorated only the last day of a multi-day trip. Although some observer providers may still have been using previous contracts in early FY 2013 and so may not have fully switched to the new billing system, the majority of observed sea days in FY 2013 were likely calculated according to the quarter-day system.

2.2. Observer coverage

Observer coverage rates in the jth category of trips (based on sector or gear type) were calculated as follows: a dummy variable was assigned to each trip, where i indexes the groundfish trips in the jth sub-category.

$$Observer_{ij}=\begin{cases}1, & \text{when trip } i \text{ was observed}\\ 0, & \text{otherwise}\end{cases} \quad (1)$$

The mean of the $Observer_{ij}$ dummy indicates the observer coverage rate by trip in that category. This is equivalent to dividing the number of observed trips by the total number of trips. The estimated coverage rate of groundfish landings was then calculated, with the variable L_{ij} being the round weight of all groundfish landed on the ith trip of the jth sub-category.

$$P_j^L=\frac{\sum_{i=1}^{N} Observer_{ij}\bullet L_{ij}}{\sum_{i=1}^{N} L_{ij}} \quad (2)$$

The coverage rates by sea days and by discards were calculated in a similar manner. Coverage rates are defined as the percentage of trips that carried an observer on board, the percentage of sea days fished with an observer on board, the percentage of total groundfish landings that were observed, and the percentage of total groundfish discards that were observed. The distribution of discards, landings, and observed sea days across sectors and across gear types were also calculated as the percentage of the total that was within each category.

2.3. Reallocation simulations

Four scenarios were simulated to investigate the potential effects of reallocating observer coverage at variable rates across sectors. Observed sea days were reassigned to sectors at rates directly proportional to those sectors' contribution to total discards (Scenarios 1 and 2) or weighted discards (Scenarios 3 and 4; see description of weighting scheme in Section 2.4). In one set of scenarios (1 and 3), the same amount of total observed sea days is maintained, but the days are reallocated to observe more discards; in the other set of scenarios (2 and 4), the same amount of discards are observed, but coverage is reallocated to reduce the total number of observed sea days.

Table 1
Groundfish annual catch entitlement, catch (landings+discards), and utilization rate (UR) by stock. The predicted utilization rate is calculated as the 2012 catch divided by the 2013 ACE for a given stock; the standardized utilization rate is the ratio of the expected utilization rate of a given stock to the expected utilization rate of pollock.

Stock	2012 ACE (mt)	2012 Catch (mt)	2013 ACE (mt)	2013 Catch (mt)	2013 Actual UR	2013 Predicted UR Based on 2012 Catch	Standardized Relative Weight Based on UR of Pollock
CC/GOM Yel. Fl.	1,021	954.3	466	376.5	80.8%	204.8%	4.10
GB Cod East	159	67.4	90	33.3	37.0%	74.9%	1.50
GB Cod West	4,524	1,593.0	1,776	1,540.6	86.7%	89.7%	1.80
GB Haddock East	6,861	365.9	3,742	578.8	15.5%	9.8%	0.20
GB Haddock West	27,363	1,197.1	26,111	2,977.1	11.4%	4.6%	0.09
GB Winter Fl.	3,367	1,930.9	3,506	1722.0	49.1%	55.1%	1.10
GB Yellowtail Fl.	364.1	215.2	152.6	55.8	36.6%	141.0%	2.82
GOM Cod	3,619	2181.1	812	732.0	90.1%	268.6%	5.38
GOM Haddock	648	245.1	185	169.2	91.5%	132.5%	2.65
GOM Winter Fl.	690	258.0	688	167.6	24.4%	37.5%	0.75
Plaice	3,223	1,601.4	1,395	1,391.6	99.8%	114.8%	2.30
Pollock	12,530	6,394.7	12,802	4,878.4	38.1%	50.0%	1.00
Redfish	8,291	4,423.4	10,092	3,996.2	39.6%	43.8%	0.88
SNE/MA Yel. Fl.	607	425.6	487.5	281.9	57.8%	87.3%	1.75
White Hake	3,257	2,446.8	3,822	2,039.8	53.4%	64.0%	1.28
Witch Fl.	1426	981.0	599	638.9	106.7%	163.8%	3.28
SNE Winter Fl.	N/A	104.8	1,074	670.4	62.4%	N/A	5.38
N. Windowpane	N/A	129.5	N/A	237.3	N/A	N/A	5.38
S. Windowpane	N/A	95.9	N/A	86.0	N/A	N/A	5.38
Ocean Pout	N/A	35.4	N/A	27.3	N/A	N/A	5.38
Halibut	N/A	57.4	N/A	53.8	N/A	N/A	5.38
Wolffish	N/A	30.0	N/A	17.1	N/A	N/A	5.38
Grand Total	**77,950**	**25,733.9**	**66,800**	**22,671.6**	**33.4%**	**38.0%**	

2.4. *Definition of weighted discards*

Landings and discards by sector members are counted against a sector's ACE for each stock; the ASM program is intended to monitor this total catch to provide accurate estimates and prevent overages. Table 1 indicates great variability in the ACE utilization rate for groundfish stocks—stocks such as Georges Bank haddock and Gulf of Maine winter flounder were not heavily utilized in FY 2013, while others, such as plaice, witch flounder, and Gulf of Maine cod and haddock, were fished nearly at their limits. For the purpose of monitoring ACE utilization and preventing catch overages, catches approaching limits should be observed more closely, and so a weighting scheme was introduced for the discards in this analysis to allocate more observer sea days to observe highly utilized stocks. Stocks were weighted by their expected utilization rate in FY 2013, defined as their total catch in FY 2012 divided by their catch limit in FY 2013, which was standardized by the expected utilization rate of pollock. Stocks with no allocated sector ACE (in FY 2012/2013, these included wolffish, halibut, ocean pout, Southern New England winter flounder, and Northern and Southern windowpane flounder) were assigned the same weighting as the most highly-weighted stock. The resulting weights are shown in Table 1.

3. Results and discussion

3.1. *Overview of groundfish activity*

Table 2a,b shows data for FY 2013 groundfish trips by sector and gear type, respectively. In FY 2013, a total of 9406 groundfish trips landed a total of 43,781,542 pounds of groundfish. These figures are slightly lower than the 42,200,000 pounds of landings and 10,056 trips reported in the 2013 NMFS groundfish fishery

Table 2a
Number of trips, sea days, landings, and discards for groundfish trips in FY 2013 by sector.

Sector	Trips	Sea Days	Observed Trips	Observed Sea Days	Groundfish Landings (lbs)	Groundfish Discards (lbs)	Observed Discards (lbs)	Weighted Discards (lbs)	Discard Rate (lbs/sea day)
SHS	1166	5,525	249	1,208	17,647,408	966,322	214,608	1,424,503	175
NE09	463	2,721	99	650	7,929,714	846,172	172,594	1,777,330	311
NE02	1,033	1,707	218	398	5,838,853	262,065	58,591	423,760	154
NE06	98	633	28	149	2,505,171	25,988	4,033	71,001	41
NE08	105	672	24	157	1,549,907	177,951	37,907	511,015	265
NE11	1,104	786	221	165	1,461,009	54,728	12,323	120,688	70
NE13	335	780	72	156	1,384,512	372,256	76,005	1,540,303	477
PCCS	445	617	84	87	1,177,126	46,955	6,868	94,745	76
NE03	1,254	1,195	233	189	1,016,473	58,735	11,543	164,008	49
NE07	242	824	48	151	833,936	96,238	16,656	386,751	117
NE12	207	470	37	99	641,898	30,747	6,512	59,036	65
NE10	613	457	119	78	627,419	58,133	10,782	211,916	127
NE05	841	731	192	167	612,291	128,427	29,241	620,590	176
FGS	1,500	984	263	149	555,825	28,750	5,825	68,189	29
Total	9,406	18,102	1,887	3,803	43,781,542	3,153,468	663,488	7,473,835	174

Table 2b
Number of trips, sea days, landings, and discards for groundfish trips in FY 2013 by gear type.

Gear type	Trips	Sea days	Observed trips	Observed sea days	Groundfish landings (lbs)	Groundfish discards (lbs)	Observed discards (lbs)	Weighted discards (lbs)	Discard rate (lbs/sea day)
OT	4,618	13,292	1,004	2,989	38,160,504	2,911,943	615,396	6,970,595	219
GL	2,708	3,006	548	553	5,012,052	193,138	42,314	357,958	64
GXL	1,941	1,687	306	237	510,941	43,059	5,194	120,782	26
LL	121	100	27	20	87,826	5,247	552	24,308	52
HL	18	17	2	1	10,219	81	32	190	5
Total	9,406	18,102	1,887	3,803	43,781,542	3,153,468	663,488	7,473,835	174

performance report, likely due to this analysis' exclusion of trips and landings by common pool vessels, vessels under 30 ft, and certain gear types, and the fact that it does not double-count trips with multiple gear types [12].

Fishing practices vary significantly between sectors; average sea days per trip range from less than 1 to over 6, different sectors fish in different stock areas, and some sectors catch the majority of their landings with large or extra-large mesh gillnets, while others fish primarily with otter trawls. These variable fishing practices are likely to result in different discard rates.

3.2. Observer coverage rates and distribution of landings, discards, and catch

The current monitoring system's CV30 standard is used to determine a blanket coverage rate for vessels in each tier (determined by stock area, gear, and sector) in the fishery; for fishing year 2013, the coverage target was 14% (22% when combined with NEFOP). The coverage rate by trips and sea days for all sectors and gear types was between 14% and 29% in FY 2013; overall, 20% of trips, 21% of sea days, and 21% of discards were observed.

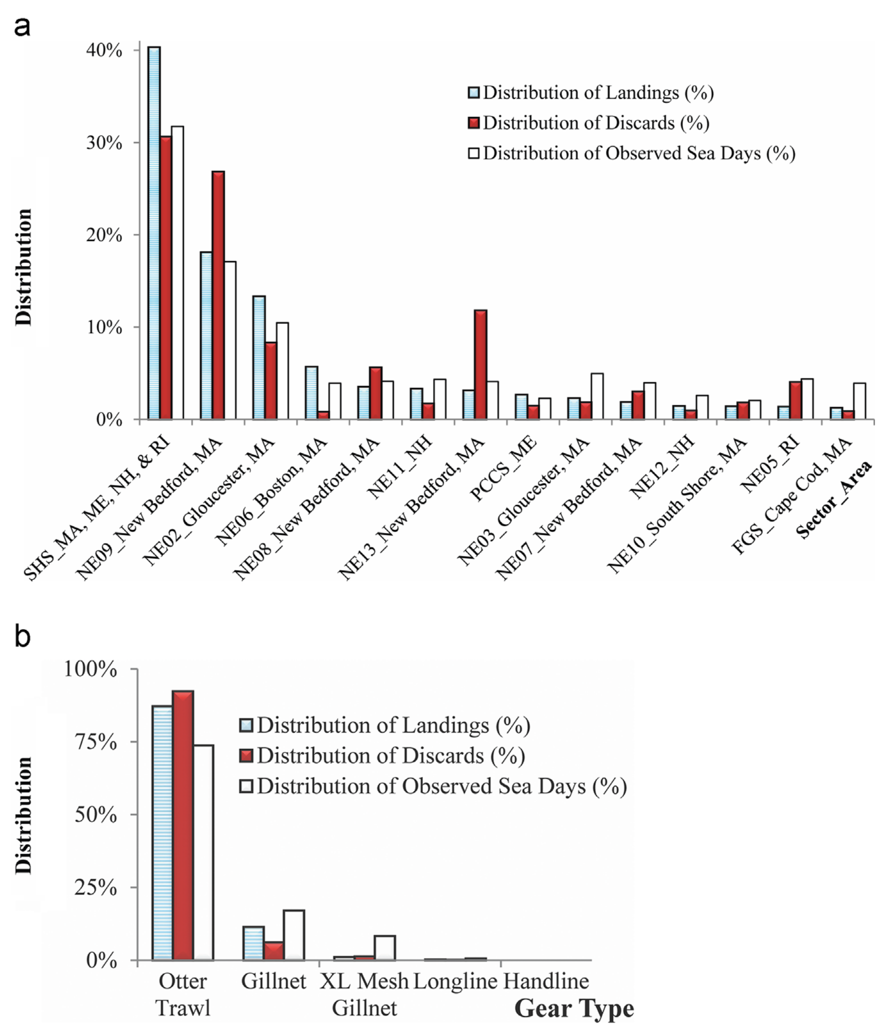

Fig. 1. (a) Distribution of observed sea days, landings, and discards during groundfish trips in FY 2013 by sector. (b) Distribution of observed sea days, landings, and discards during groundfish trips in FY 2013 by gear type.

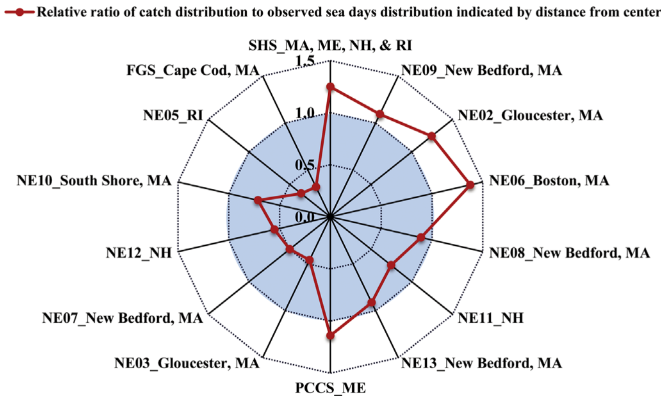

Fig. 2. The ratio of the distribution of catch to the distribution of observed sea days for each sector, indicated by distance from the center of the circle. The sectors that fall inside the shaded unit circle are observed at high rates in proportion to their contribution to total catch; those that fall outside the circle are observed at low rates in proportion to their contribution to total catch.

These similar rates of coverage across sectors and gear types result in a distribution of observer coverage that is not proportional to the distribution of total discards (Fig. 1a,b). In 2013, the three sectors (SHS, NE09, and NE02) with the highest landings and discards accounted for 72% of groundfish landings and 66% of discards, but only 59% of total observer days were used to monitor. Similarly, otter trawl gear accounted for 87% of total groundfish landings and 92% of discards but 79% of observed sea days (Fig. 1a, b). This disparity between monitoring effort and groundfish landings and discards is generally present for all gear types in various sectors.

Vessels fishing with otter trawls produce more discards per trip than other fishing activity categories. The average discards that could be observed in in one observer sea day in 2013 on an otter trawler would take an average of 9 observer sea days deployed on an extra-large mesh gillnet vessel to observe. Similarly, the average discard that could be observed in one observer sea day in 2013 on a vessel from the sector with the most discards per day would take an average of 16 sea days to observe on a vessel from a sector with the least discards per day. This discrepancy is not being accounted for when assigning observer sea days to various vessel categories.

Fig. 2 further indicates that observer rates are out of proportion to the scale of various sectors' operations. This figure indicates the ratio of the distribution of catch to the distribution of observed sea days for each sector (for example, the Sustainable Harvest Sector (SHS) accounted for 39.7% of total catch and 28.8% of total observed sea days in FY 13; the resulting ratio of catch distribution to observer coverage distribution is 1.25). The Fixed Gear Sector (FGS) is the most over-observed relative to its catch, while Northeast Sector 6 (NE06) and Port Clyde Community (PCCS) are under-observed relative to their catch but the scale of their landings is smaller than SHS, NE09 and NE02 sectors, as indicated in Fig. 1a.

As evidenced by this disproportionate observer coverage, the CV30 standard applied to ASM is neither cost-effective nor equitable for trips with low landings and discards, largely those by small dayboat gillnetters. It also lowers the degree of accuracy for overall catch estimates of highly utilized groundfish stocks by focusing unnecessary observer effort on trips that account for a small percentage of total discards and total catch.

This mismatch suggests two avenues through which effective allocation of coverage (and its associated costs) could improve the at-sea monitoring program: first, the same expenditures could be used to observe more landings and discards; second, the same industry-wide observed landings and discards could be achieved with less monitoring effort and at a reduced cost. The first avenue could be approached by allocating observers proportional to the weighted landings or discards of each vessel category; the second by further limiting observers to observe the same amount of weighted discards as under the current monitoring standards. The higher the discard, the higher the coverage rate that would be assigned—a discards-proportional monitoring approach.

The following simulations are based on the premise that the optimal allocation of observer effort should be proportional to the amount of discards or weighted discards recorded in each sector. Sea days are identified as the basic unit of observing effort in this simulation.

3.3. *Allocation based on unweighted discards across sectors*

Simulated observed sea day scenarios for groundfish trips in FY 2013 are shown in Table 3; additional detail is provided in Tables A1 and A2. Scenario 1 re-allocates the 3803 observed sea days in FY 2013 according to the unweighted discards recorded in each sector in FY 2013. Without increasing the overall monitoring effort, the percentage of discards observed increases to 28.8% (Table A1) from the actual average observed discards of 21.0%.

Scenario 2 achieves the same volume of discards observed in FY 2013 (663,488 lbs in Table 2a) while reducing the total observed sea days (Table 3). The reduction of overall observed sea days is achieved by increasing monitoring coverage for two sectors by up to 172 days, while decreasing monitoring for all other sectors. The overall observed sea days are reduced by 1024 sea days from 3803 to 2779.

Table 3
An overview of discard-proportional discard allocation schemes. Scenarios 1 and 2 reallocate observer days according to unweighted discards; Scenarios 3 and 4 reallocate observer days according to weighted discards. Scenarios 1 and 3 maintain the same number of observed sea days, while Scenarios 2 and 4 maintain the same weight of observed discards.

	Non-weighted		**Weighted**	
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
Δ in % discards observed	36.8% increase	No change	98.9% increase	No change
Δ in total observed sea days	No change	1024 day decrease	No change	1892 day decrease
Δ in total ASM cost	No change	$0.7million decrease	No change	$1.34 million decrease
Δ in sector ASM costs (without cost sharing)	ASM cost rises by $512k across three sectors, reduced for the remainder	ASM cost rises by $190k across two sectors, reduced for the remainder	ASM cost rises by $859k across six sectors, reduced for the remainder	ASM cost rises by $169k for one sector, reduced for the remainder
Δ in sector ASM costs (with cost sharing)	ASM cost rises by $395k across five sectors, reduced for the remainder	ASM cost rises by $7k for one sector, reduced for the remainder	ASM cost rises by $395k across five sectors, reduced for the remainder	ASM cost reduced for all sectors

3.4. Allocation based on weighted discards across sectors

The weighted discard simulation is presented in Table A2 with scenarios 3 and 4 corresponding to scenarios 1 and 2 in Table A1, respectively. In these scenarios, observer days were allocated according to the weighted discards by each sector, where stocks that are expected to be more heavily utilized are weighted more strongly (see Section 2.3). Scenario 3 re-allocates the 3803 observed sea days in FY 2013 shown in Table 1a. Without increasing the monitoring effort, the percentage of weighted discards observed increases to 40.5% in FY 2013 (Table A2) from the weighted observed groundfish discard of 20.0% in FY 2013. This increase would aid fishery managers and scientists in accurately evaluating the impact of discards on ACE utilization and groundfish stocks.

Scenario 4 shows how to achieve the same percentage of weighted discards observed in FY 2013, which is estimated at 20.0%, while reducing the total observed sea days (Table 3). The reduction of overall observed sea days is achieved by increasing monitoring for one sector by 238 sea days and reducing the observed days for all other sectors, for an overall reduction in observed sea days of 1892 from 3803 to 1911.

3.5. Costs of monitoring

Based on the most recent estimates available, the overall cost of an ASM sea day is $927.76. The cost for an at-sea monitor can be separated into two components: at-sea and infrastructure. Potentially beginning in Fall 2015, the industry will be responsible for at-sea monitoring costs, while NOAA will pay infrastructure costs. Most recently, NOAA and the Council have estimated the at-sea salary portion of monitoring costs at $710, while the infrastructure component was estimated at $217.76 [4,15].

At a cost of $710 per ASM sea day, the industry could have saved $727,040 in FY 2013 by allocating ASM based on the volume of discards across sectors, as shown in Table 3 under scenario 2. If ASM were allocated proportional to the discards of each sector weighted by the stock utilization rate, the industry could save $1,343,320, as shown in Table 3 under scenario 4. Significant monetary resources could be saved while observing the same amount of discards through a discards-proportional allocation scheme.

3.6. Costs by sector and cost sharing

Allocating at-sea monitoring differentially will inevitably raise concerns about the distribution and equitability of costs by sector. Under scenario 1 (current level of monitoring effort allocated by discard rate), costs would increase for three sectors by up to $262,700 and decrease for all others; under scenario 2 (current level of observed discards with monitoring allocated by discard rate), costs would increase by up to $122,120 for two sectors and decrease or stay the same for all others. Under scenario 3 (current level of monitoring effort allocated by weighted discard rate), costs would increase for six sectors by up to $445,880; under scenario 4 (current level of observed discards with monitoring allocated by weighted discard rate), costs would increase for one sector by $168,980 (Table A3).

A discard-proportional method of allocating the costs of at-sea monitoring, then, will benefit some sectors but result in increased costs for others. In general, the burden of increased cost will fall on those sectors with the greatest discard rates per sea day.

One potential method to distribute the monitoring burden could be for the industry to develop a cost sharing scheme between sectors. This program could be analogous to Iceland's catch fee system, where all vessels pay a fee to fish proportional to their allotted quota in each year; these fees in part support monitoring and other management costs [10]. Similarly, in the Alaskan groundfish fishery, vessels subject to partial observer coverage pay a 1.25% fee on landings of groundfish and halibut to fund the observer program [14].

For the Northeast groundfish fishery, sectors could pay monitoring fees directly proportional to their landings; sectors would be free to develop their own systems to collect these fees from member vessels. These fees would then cover the cost of the at-sea monitoring program for the fleet as a whole, with coverage allocated proportional to discards. This cost-sharing scheme is simulated for each of the four scenarios in Table A3.

This cost-sharing scheme would more evenly distribute changes in monitoring costs under a discard-proportional monitoring scheme, and so might be more appealing to many sectors. It is important to consider, however, whether a cost-sharing scheme in which costs paid by each sector are proportional to their landings might limit incentives to reduce discards and might place an unreasonable burden on sectors with high landings but low discards. If sectors pay their own monitoring costs and monitoring coverage is allocated proportional to discards, each sector will have an incentive to limit its discards to reduce its operating costs. Sharing costs according to landings will remove this incentive, and so sectors may not make as substantial an effort to limit their discards or to fish less utilized stocks. For example, under scenario 2, if cost-sharing is implemented, the only sector with increased costs under this scenario accounts for just 1% of total discards in FY 2013 (Table A3).

3.7. Regulatory requirements

Monitoring costs will be one of the major factors affecting groundfish sector viability moving forward, particularly with the impending transition to industry funding. A discard-proportional monitoring allocation may help reduce these costs and protect sector viability if necessary regulatory changes can be implemented. Currently, coverage rates must meet the CV30 precision goal unless NEFMC removes the CV30 language in Amendment 16. Therefore, this approach may need to be used as one component of a monitoring program that allows precision requirements to be covered by NEFOP or another approach unless these regulations are revised.

CVs measure precision of discard rates, or the percentage they vary around an average. However, while the discard rates may be showing this precision around their mean in each stratum, the estimates of ACE discarded may still be inaccurate—their central value may be far from the true discard rate. Therefore, the approach proposed in this paper primarily addresses the accuracy of the monitoring program, which has not been addressed by the Council or NMFS, rather than the precision.

There is a compelling need to have a comprehensive evaluation of the strata for assigning observers. If more observers were assigned to observe trips with high rates of landings and discards, then the monitoring program could more cost-effectively ensure that the fishery does not exceed its ACLs, and more accurate data could be integrated into stock assessments and other analyses that utilize catch and discards.

4. Conclusion

The goals of the ASM program include (1) improving documentation of catch, (2) reducing the cost of monitoring, (3) incentivizing reducing discards, (4) providing additional data streams for stock assessments, (5) enhancing safety of the monitoring program, and (6) performing periodic reviews of the program's effectiveness [5]. A discards-proportional method of allocating observer coverage will be an improvement over the status quo in reaching these goals and objectives.

This allocation scheme meets Goal 1 for the monitoring program, *improve documentation of catch,* because it increases accuracy of catch estimates over the existing program by observing a greater portion of the fishery's discards. The proposed ASM scheme also meets monitoring Goal 2, *reduce the cost of monitoring*, by observing more discards with the same amount of monitoring effort and associated costs. It supports monitoring Goal 3, *incentivize reducing discards*, since sectors that have a lower relative volume of discards would be assigned lower coverage levels. The status quo does not reward sectors with low discard rates. While the current precision standard is not specifically addressed by this program, it may be used in conjunction with the current CV30, or an alternate precision standard could be developed and implemented to meet monitoring goals.

The existing CV30 standard and resulting flat ASM coverage rates across categories are not cost-effective and are poorly suited to the objectives of the at-sea monitoring program. Reallocating observer coverage proportional to discards would enhance the program's ability to reach its objectives while reducing the financial burden on struggling groundfish sectors.

Acknowledgments

This project is one component of a larger "Evolution of Groundfish Sectors Business Model" project supported by the Cooperative Institute for the North Atlantic Region (CINAR) National Oceanic and Atmospheric Administration (NOAA, USA) Grant NA090AR4320129; Amendment #107 (Task II) in cooperation with the Social Sciences Branch at the Northeast Fisheries Science Center, NOAA, USA, and also partly funded by several other NOAA grants through Gulf of Maine Research Institute (GMRI). The data in this analysis was compiled from the individual trip level DMIS dataset, which was acquired by GMRI through a data access agreement for the sector viability project, which restricts access of these confidential data to the GMRI staff directly working on the project, except in aggregated form. Since ASM costs are closely associated with sector viability, GMRI was given permission to use the DMIS dataset for this monitoring analysis. The author thanks comments from Jessica Joyce, Mary Hudson, Michelle Brown, and Mark Hager in the Community Team at GMRI and help from William Bowman, Tess Petesch, and Greg Ardini as interns at GMRI.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.marpol.2015.12.029.

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Glossary

ACE: Annual catch entitlement, the right for a sector to catch a given weight of certain stock of fish in a certain year, calculated as the sum of all sector members' potential sector contributions (PSC) under Amendment 16.;
ASM: At-sea monitoring, a program for the Northeast multispecies fishery that places observers on selected fishing trips to monitor discard rates and ACE utilization.;
CV30: A coefficient of variation of 30%, the target level of precision for discard rate (the ratio of discards to landings per trip by strata) that determines the coverage rate for the ASM program.;
Discards: Fish caught by fishermen that are under legal size or not allowed to be landed, so are discarded at sea rather than being brought to port.;
Fishing year: A fishing year for the groundfish fishery runs from May 1-April 30; for example, FY 13 spans May 1, 2013–April 30, 2014.;
Groundfish fishery: The Northeast multispecies(groundfish) fishery is managed by the New England Fishery Management Council using a variety of management tools, including days-at-sea, special management programs, and sectors. Groundfish includes 15 species/22 stocks of cod, haddock, Pollock, flounders, and other bottom-dwelling fish defined at http://www.greateratlantic.fisheries.noaa.gov/nero/fishermen/images/Multispecies/index.html.;
NEFMC: The New England Fishery Management Council, which regulates the groundfish fishery with oversight from the National Oceanic and Atmospheric Administration (NOAA). The council includes committees like the Plan Development Team (PDT) and Scientific and Statistical Committee (SSC).;
NEFOP: The Northeast Fisheries Observer Program, which places observers on selected fishing trips to gather biological information about the status of groundfish stocks.;
PTNS: The pre-trip notification system, which randomly assigns at-sea observers to vessels on groundfish trips within certain strata.;
SBRM: The standardized bycatch reporting methodology, a Fishery Management Plan element required by the federal Magnuson-Stevens Fishery Conservation and Management Act, which provides guidelines for observer programs and coverage.;
Sector: All vessels with a Federal limited access Northeast (NE) multispecies permit are eligible to join a groundfish sector. A sector is defined as a group of at least three distinct persons holding limited access vessel permits under the fishery management plan through which the sector is being formed, who have voluntarily entered into a contract and agree to certain fishing restrictions for a specified period of time, and which has been granted a quota in order to achieve objectives consistent with the applicable FMP goals and objectives. Sectors in the NE multispecies fishery are intended to provide fishermen with more flexibility and more direct responsibility for managing the resource. Sector members are generally linked by similar fishing practices or location..