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The design and performance of an automated observer deployment system for the Northeastern United States groundfish fishery

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ABSTRACT

Historically, a dock intercept process was used to deploy observers in the Northeastern United States groundfish fishery. In this process, the selection of which fishing trips received observer coverage was manually accomplished using pre-defined specifications established by the National Marine Fisheries Service's Northeast Fisheries Science Center. In May 2010, the management of the northeast groundfish fishery underwent major changes affecting the magnitude and complexity of observer deployment. These changes included: (a) a shift from input controls to a quota based catch-share system; (b) an approximate four-fold increase in the level of observer coverage; and (c) introduction of a new class of trained observers. The manual dock intercept process was insufficient to adequately address these new provisions and an automated observer deployment system, the Pre-Trip Notification System (PTNS), was implemented in the Northeastern United States groundfish fishery on 1 May 2010. The PTNS uses a self-adjusting probability-based, tiered selection process to randomly assign observer coverage across the groundfish fleet on a proportional basis for the purpose of monitoring discards. In this paper, we discuss the general design and performance of the PTNS over the first three years of use with a specific focus the self-adjusting properties of the system, and the impacts of vessel compliance.

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1. Introduction

At-sea fisheries observers have historically been deployed in the Northeastern United States large-mesh groundfish fishery using a dock intercept process. Fishing trips were manually selected for coverage by observer service providers (companies contracted to provide observer coverage) using pre-defined sea day schedules in conjunction with a randomized list of vessels likely to be active in the fishery and personal knowledge of local fleet activity. The sea-day schedules were broadly stratified by month, region and gear type, with target coverage rates designed to meet pre-determined precision requirements for discard estimation (e.g., bycatch estimates with coefficients of variation less than or equal to 30%; Wigley et al., 2007). Since sea-day schedules were established in advance of the fishing season based on anticipated activity, in-season shifts in fishery activity could compromise the efficacy of the specified observer coverage.

In 2010, the management of the northeast U.S. groundfish fishery underwent major changes (NEFMC, 2010), drastically affecting the degree and complexity of observer coverage. These changes included (a) a shift from input controls to a quota based catch-share system managed at the level of fishing sector (similar to harvest cooperatives, Clay et al., 2014); (b) a four-fold increase in the level of observer coverage from approximately 5–8% to 20–30%; and (c) the establishment of a second fishery monitoring program (at-sea monitors, ASMs) that was created in anticipation of a future shift from government-funded to industry-funded monitoring programs. The ASM program was intended to augment the existing observer coverage provided by the Northeast Fisheries Observer Program (NEFOP). Because of the anticipated shift to industry funding the ASM program was designed to operate at a lower cost relative to the NEFOP, largely by reducing the data collection requirements to only those data elements needed to accurately estimate fishery catches.

Deployment of both NEFOP observers and ASMs had to meet the in-season catch monitoring needs of the groundfish fishery catch share program where quota would be tracked by fishing sector, stock area and gear type. There were expected to be 18 active fishing sectors, with the capacity to fish up to five different gears in three different fishing regions for a total of 270 possible sampling strata. In a given fishing year, not all of the 270 strata would be expected to be active since some sectors were likely to only fish

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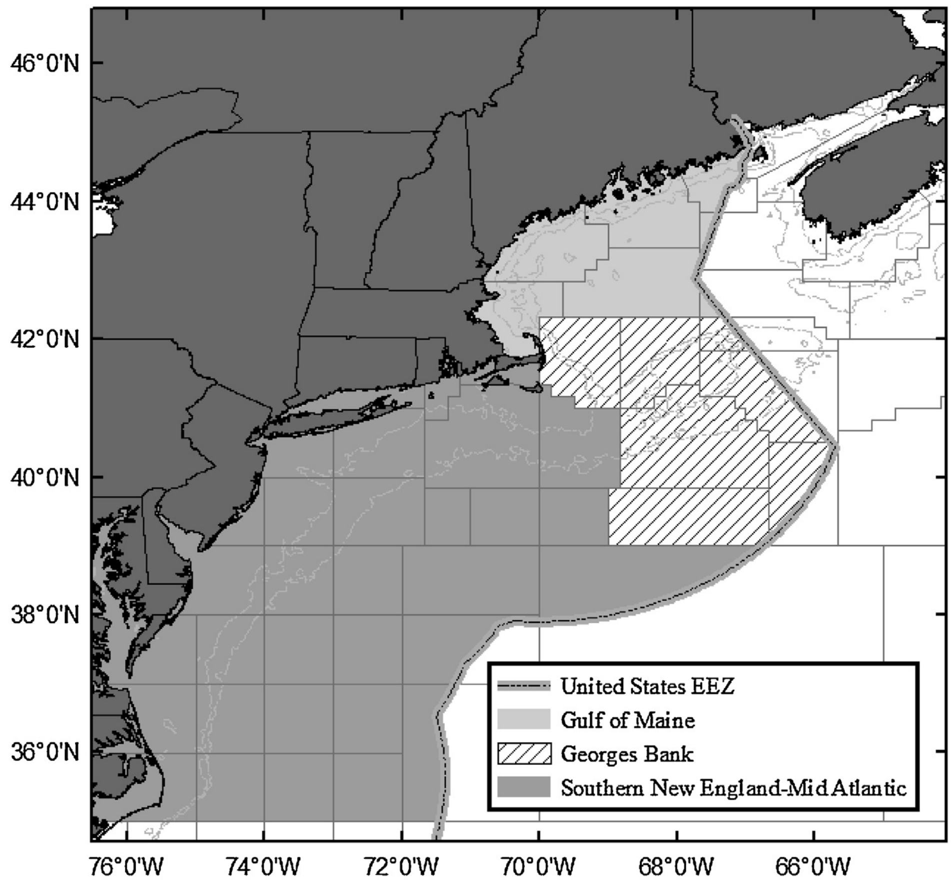

Fig. 1. Map of the offshore waters of the northeast United States showing the three fishing regions within the U.S. Exclusive Economic Zone (EEZ) as defined by the Pre-Trip Notification System. The gridded area delineates the northeast U.S. statistical areas. The 50 m and 100 m bathymetry lines are indicated by thin grey lines.

a single gear type and operate in one region. However, it was not known *a priori* which of the sampling strata would be active. Given the large scale changes to the fishery as a result of sector management, the behavior of the groundfish fleet in prior years would likely be a poor predictor of expected behavior from May 1, 2010[1] and beyond. The efficient and effective support of fine-scale stratification would require the capacity to dynamically identify active strata and deploy observer coverage in these strata in a statistically unbiased manner. This was a marked departure from the sea day schedule approach, in which the stratification scheme was static and the behavior of the fleet was assumed to be similar from one year to the next.

The catch share management system introduced considerable complexity into the manner in which observers would need to be deployed in the groundfish fishery. It was widely recognized that a dock-intercept process would be insufficient to meet the increased demands. A more sophisticated, and dynamic, observer deployment system was needed that would be capable of automatically, and efficiently, allocating observer coverage within the groundfish fishery. The overall purpose of such a system would be to support the stratified random deployment of observers in an unbiased manner in support of groundfish catch monitoring.

With the basic requirements in mind, the National Marine Fisheries Service's (NMFS) Northeast Fisheries Science Center (NEFSC) developed an observer pre-trip notification system (PTNS) that was first deployed in May 2010. While other similar systems have been developed and deployed in North America since 2010 (e.g., NMFS—Alaska Fisheries Science Center developed and deployed their Observer Declare and Deploy System; Faunce et al., 2014) to our knowledge, the PTNS was a first-of-its-kind automated observer deployment system. In this paper we discuss the design and performance of the PTNS over its three year implementation in the groundfish fishery. We focus on this period as it covers the initial design and deployment, system performance review and the subsequent improvements leading to the system currently deployed today. Additionally, we identify areas of possible improvements that would benefit not only the current PTNS, but the design of similar systems around the world.

2. Methods (system design)

Vessels intending to fish in the groundfish fishery are required to notify their intent to take a groundfish trip through the PTNS at least 48 h in advance of sailing. When making an initial trip declaration an authorized vessel representative (e.g., vessel captain, vessel owner, sector manager) must login to the PTNS with the vessel permit number and a personal identification number (PIN). This allows the system to identify the vessel and the groundfish sector to which the vessel belongs. For each trip the following information must be provided: anticipated sail date and time, estimated trip duration, port of departure, the type of gear that will be used on the trip, and the general fishing region (regions shown in Fig. 1). This is the minimum information needed by the PTNS to identify the sampling strata and by the observer service providers to determine whether they have certified observers available to cover the trip.

[1] The northeast United States groundfish fishing year runs annually from May 1 to April 30.

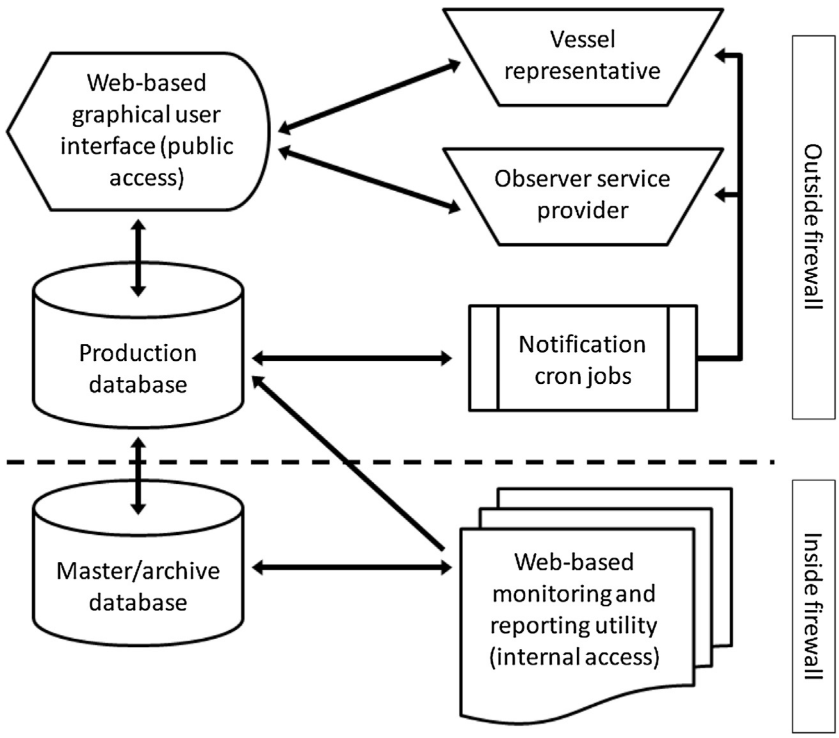

Fig. 2. Data flow processes and major information technology components of the Pre-Trip Notification System.

There are five major components to the PTNS system (Fig. 2). The publically visible component of the PTNS is the web-based graphical user interface. The primary function of the web interface is to allow authorized users to make initial trip declarations as well as to view and edit pending trips. The web interface is also used by observer service providers to manage offered trips (i.e., those preliminarily selected by the PTNS for coverage, but subject to provider acceptance) and report vessel assignments. All data entries and edits made through the web interface write directly to an Oracle® database. The PTNS utilizes two separate Oracle® databases. One database resides outside the NEFSC firewall and serves as the principal production database for the PTNS web interface. The second database is located inside the NEFSC firewall and serves as the master database where all core support tables originate. The master database also serves as a backup of the production system. The fourth component of the PTNS is a set of procedures, or jobs, which are responsible for sending automated email notifications to vessels and providers notifying them of updates to a trip's selection status as it moves through the system. The fifth component of the PTNS is a web-based monitoring utility (i.e., system dashboard). The chief function of this utility is to provide a PTNS system administrator with a near real-time view of system usage and performance and identify aspects of the PTNS that may require in-season adjustments as well as flag potential compliance issues.

2.1. Sampling design

During the preliminary PTNS design phase, several critical sampling design features were identified. We describe the need and basic design of the PTNS with respect to these features but note that this paper is not intended to be an exhaustive list of all of system features; a more detailed description of PTNS development work and design is described in Palmer et al. (2013).

The most important design feature identified was the need to establish a hierarchy in the selection process. Because of the multiple coverage objectives that the PTNS would need to address, it was critical that the relative priorities of each of the objectives were established such that coverage was assigned in order of relative importance. Within the hierarchal structure, individual monitoring objectives were assigned to priority levels, or tiers. For each tier there was an associated type of observer coverage (e.g., NEFOP or ASM). For all tiers with ASM coverage, there were multiple ASM providers to select from. The hierarchal design features of the PTNS are described below:

2.1.1. Sampling unit

The fishing trip is the sampling unit. The PTNS selection process is trip-based such that the target coverage rates are to be evaluated as the ratio of observed trips relative to total trips occurring within a defined stratum. While other sampling frames were considered, such as total fishing effort (e.g., days absent) and total groundfish landings, the difficulty in defining a sampling unit in these terms at the point of notification (i.e., prior to a trip sailing) precluded their use in the PTNS. Fundamentally, if the coverage deployment was unbiased the proportionality of trip-based coverage would be equal to those of other metrics.

2.1.2. Selection tiers

Selection tiers are discrete hierarchal levels within the observer selection process. Many of the selection tiers correspond to explicit monitoring objectives such as baseline NEFOP coverage which applies to all fisheries, coverage for the monitoring of protected species bycatch and ASM monitoring required for the groundfish fishery. In general, the placement of the tiers within the hierarchy is dictated by overall importance relative to resource monitoring. The more important selection tiers are placed at the top of the selection process and a trip moves down through the selection process until selected at a given tier. Once selected, the trip exits the selection process and cannot re-enter. The selection of a trip does not guarantee that an observer is assigned to cover the trip since the trip must still enter the provider assignment and acceptance process post-selection. There are four different types of tiers: 'conditional', 'list', 'probability-based' and 'sea day schedule'. Conditional tiers are not selection tiers, rather trips are issued waivers if they meet certain defined conditions. List tiers refer to those tiers where a vessel was either on the 'list' or not on the 'list'. List tiers exist in two forms: automatic waiver and automatic selection. Probability-based tiers rely on a stratified random selection process to determine whether a trip is selected for coverage—the majority of groundfish trips are handled through the probability-based tiers. Sea day schedule tiers rely on fixed sea day schedules; if a trip is declared into a stratum for which there is still a positive balance on the sea day schedule it would be selected for coverage. The protected species tier was the only tier within the selection process that relied on a sea-day schedule. While the industry-funded ASM tier exists within the PTNS, it has never been turned on since the funding costs for ASM coverage have yet to shift to the industry. The cost of ASM coverage is anticipated to shift to the industry sometime in calendar year 2016, at which point the NMFS funded ASM tier is likely to be shut off.

2.1.3. Observer coverage types

Each selection tier has only a single coverage type. The possible coverage types are: NEFOP coverage, NEFOP-limited (protected species only), NMFS-funded ASM, and industry-funded ASM. The relationship between selection tiers and coverage types is shown in Fig. 3.

2.1.4. Observer providers

An observer service providers is the company contracted to provide fishery observers. Each provider may be contracted to cover multiple coverage types and consequently multiple tiers. For coverage types where multiple providers exist (e.g., ASM), a weighted probability selection process was developed to select two service providers per trip (Palmer et al., 2013). The probability of provider selection would be proportional to the number of certified observers each provider has at the time of the notification. Provider 1 would receive the right of first refusal and if provider 1 declined the trip or failed to accept the trip in a specified amount of time the trip would be offered to provider 2.

Fig. 3 provides a schematic of the progression of a fishing trip as it moves through the PTNS selection process. All of the tiers that would preclude a trip from being selected are at the beginning of the selection process to ensure that only trips eligible for coverage reach the lower selection tiers where positive selection of a trip is possible. The ordering of the four initial tiers (manual waiver, set-only gillnet, do not deploy – safety, do not deploy – coverage) is irrelevant, as trips must pass through all four in order to reach tiers capable of a positive selection.

2.2. Target coverage rates and sea day allocations

One of two primary objectives of the PTNS is to optimize the sea days allocated to the fishery in a given contract year. A sea day represents the duration of observer deployment (time between the start and end of the fishing trip) and annual costs of a fishery monitoring program are based on the number of deployed sea days, not on the number of trips observed. Annually, the PTNS is budgeted a fixed number of NEFOP and ASM sea days for coverage of the groundfish fishery (e.g., NEFSC/NERO, 2012). Sea day budgets are determined external to the PTNS based on considerations that include the desired precision of discard estimates, compliance monitoring needs (i.e., reduction of observer effects; Benoît and Allard, 2009) and funding availability. The allocated sea days represent the total number of sea days the PTNS has available for each year[2]. Prior to the start of the contract year, the sea day budget is translated into an expected coverage rate which is then used as an initial PTNS target coverage rate at the start of the year. Target coverage rates require manual adjustment throughout the year to compensate for changes in trip length, amount of fishing effort (number of trips), estimated effort remaining in the year, number of observers available and overall compliance with PTNS notification requirements. The information needed for a PTNS administrator to make these adjustments is available through the web-based monitoring utility (Fig. 2). Ideally, the allocated seas days will be fully utilized in a manner that will result in near-constant observer coverage rates throughout the fishing year (i.e., no temporal bias).

2.3. Trip selection algorithm

The second primary objective of the PTNS is the stratified random deployment of observers within the groundfish fishery. Specifically, the PTNS needs to be able to distribute the available sea days in an unbiased manner with the coverage proportional to fishing activity within each stratum. The level of stratification applied within the PTNS was designed to be consistent with the in-season discard estimation methods which are based on sector, gear and mesh size (i.e., gear category) and the area fished. With the exceptions noted above (e.g., do not deploy, set-only gillnet, must-deploy, protective species sea day and keep-active tiers), the selection method for the majority of trips entering the PTNS utilizes a probability-based random sampling scheme.

During the initial design phase, other desirable features of the selection method were identified:

1. Ability to achieve a specifiedtarget coverage rate.
2. Some level of 'front-loading' to get in-season information early in the fishing year. While the 'front-loading' aspect was desirable, it had to be accomplished in such a way as to limit the amount of temporal bias in the level of observer coverage.
3. Ideally, the selection criteria should have a self-adjusting capacity so that fine-scale adjustments to the target coverage rates are automatically made based on the realized coverage rates for the stratum in the event that coverage rates are perturbed from the desired target rate.

With these criteria in mind, three different selection methods ('*fixed*', '*incremental*' and '*linear*') were considered and evaluated through simulation (Palmer et al., 2013). The simulation exercises were simplistic, single-tier simulations programmed using SAS software, Version 9 (SAS Institute Inc., Cary, NC, USA). Simulations assumed that all trips entered into the system occurred (no cancellations) and that trips selected for coverage, received coverage (providers could not decline trips). Trips were entered into the simulation one at a time, and each iteration was carried out to 100 trips. Each simulation was run for 500 iterations, and the performance of the method was evaluated based on the mean coverage rate and precision. While the simplistic nature of these simulations may not have captured the nuances of a production system and the limited iterations may not have adequately characterize the true precision, the simulations were sufficient to evaluate the general characteristics of each the methods and offer an objective means with which to identify an optimal method.

Based on the simulation results, the final system design incorporated a '*linear*' method for determining trip selection probabilities. In the linear method, a linear regression is fit between two control

[2] Sea days are allocated annually based on contractual years which run from April 1 to March 31.

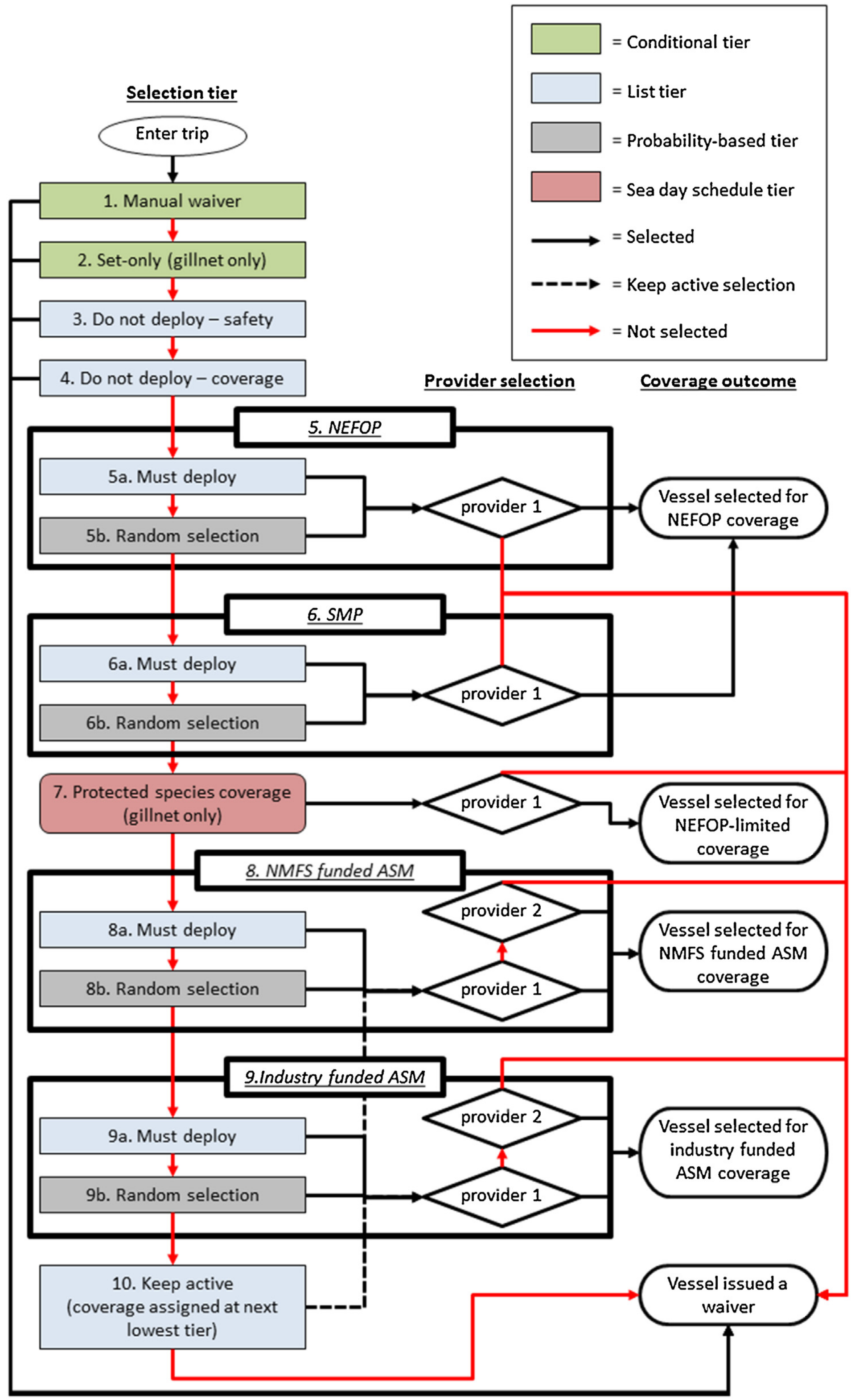

Fig. 3. Schematic diagram illustrating the hierarchal tier selection of the groundfish Pre-Trip Notification System. Acronyms: At-Sea Monitoring (ASM), National Marine Fisheries Service (NMFS), Northeast Fisheries Observer Program (NEFOP), Special Management Program (SMP).

points: a specified maximum selection probability and a target coverage rate (Eq. (1), Fig. 4). The control points represented the fixed behavior of any assignment of observer coverage levels; when a stratum has zero observer coverage, coverage is assigned at the specified maximum selection probability (e.g., 1.0), and when stratum coverage was exactly equal to the target coverage level, trips were assigned coverage at a probability equal to the target coverage rate. The probability of a trip being selected for coverage at all other coverage levels was determined using a simple linear regression. The trip selection probability cannot drop below zero; however,

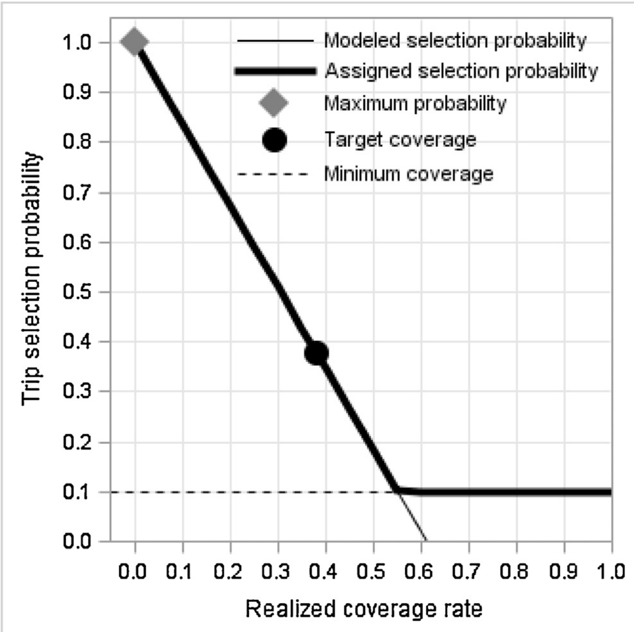

Fig. 4. Schematic illustrating the 'linear' method for determining trip selection probabilities. In the 'linear' method, selection probabilities are determined based on the realized observer coverage rates for each stratum at the time at which the trip is entered into the selection process. The 'linear' method requires specification of three parameters: a maximum probability (probability of selection when realized coverage is equal to zero), a target probability (i.e., target coverage rate), and a minimum coverage rate.

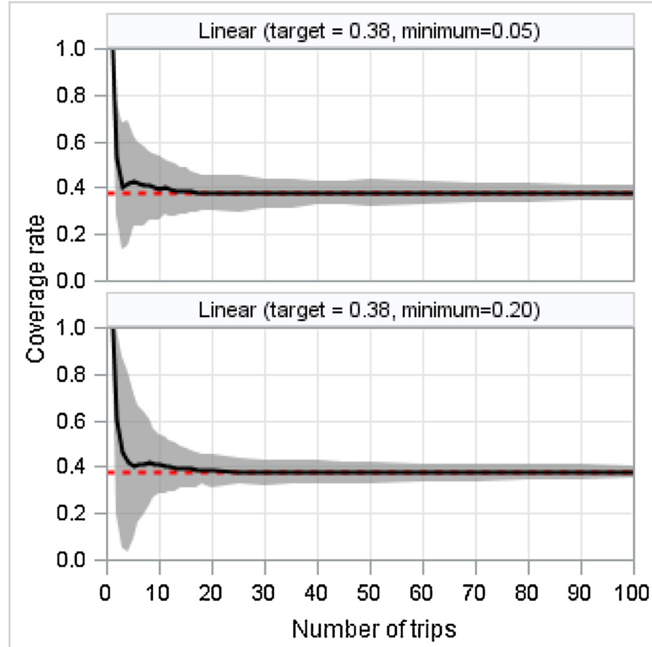

Fig. 5. Comparative performance of the 'linear' selection method with respect to meeting a target coverage rate run at two different minimum coverage threshold levels. Results are based on 500 iterations of a simple single-tier simulation with a specified target coverage rate of 0.38 (dashed line). The mean coverage (solid black line) and 95% confidence intervals (grey band) from all simulation runs is shown.

the system allows a user-specified minimum selection probability to be set which may be desirable for compliance reasons (i.e., even when realized observer coverage levels are high, a vessel operator could expect that there is some probability that the trip will be observed).

$$p = \left[\frac{c_t - 1}{c_t}\right] c_r + c_{max} \text{ unless } c_{min} > \left[\frac{c_t - 1}{c_t}\right] c_r + c_{max}, \text{ then } p = c_{min} \quad (1)$$

where: p is the probability of trip being observed. c_t is the target observer coverage level. c_r is the realized (actual) coverage level when the pre-notification for a trip occurs. c_{max} is the maximum selection probability. c_{min} is the minimum selection probability.

The linear selection method addressed all three desired features identified during the design phase. The lower the specified minimum coverage rate, the faster the system will equilibrate on the target coverage rate and the faster the front-loading biases would be addressed (Fig. 5). While the linear method has zero theoretical probability of having no observer coverage at any point in the fishing year, in practice, this can occur if the observer service provider is unable to deploy an observer on the first trip within a stratum. One benefit of the linear approach is that the probability of selection is based on realized observer coverage—in the event that the first trip within a stratum is not observed, the linear method will assign a probability of 1.0 to the next trip occurring within the stratum until a trip is actually covered. The self-adjusting nature of this selection method allows the system to adjust the selection probabilities based on the realized coverage rates, thereby providing a correction mechanism if realized coverage rates deviate from the target coverage rates. The self-adjusting nature of the linear method works to reduce the overall variance in the stratum coverage.

2.4. Observer avoidance and coverage equitability

When the PTNS was first implemented on May 1, 2010 it contained no mechanism to address the intentional avoidance of observer coverage by vessels. Soon after implementation it became clear that some vessels were avoiding observer coverage by canceling trips scheduled for observer coverage at a rate higher than trips not scheduled for coverage. In August 2010, the PTNS was redesigned to fix this loophole (Palmer et al., 2013). The redesign forced vessels that cancelled trips scheduled for observer coverage to be automatically selected for observer coverage on all subsequent trips until a trip had been covered by an observer (i.e., the vessel entered into temporary 'must deploy' status). The design was intended to reduce intentional avoidance behavior and ensure more equitable coverage across all vessels. The redesign was effective at forcing vessels that were attempting to avoid coverage to carry observers. Unfortunately, the redesign negatively impacted compliant vessels that were not intentionally avoiding observer coverage. These impacts were exasperated during the winter fishing months when 'day-boat' vessels (i.e., small vessels which typically take trips ≤48 h) were forced to cancel a higher proportion of declared trips due to inclement weather. As a result, compliant 'day-boat' vessels ended up experiencing observer coverage well in excess of the target coverage rates in fishing year 2010. A more effective means of addressing observer avoidance that did not penalize compliant vessels was needed.

Prior to the start of the 2011 fishing year, improved methods were developed to deal with observer avoidance behavior without negatively impacting compliant vessels (see Palmer et al., 2013 for a full description of system modifications and simulation work). First, the PTNS was modified so that vessel operators were not informed of the selection status of a given trip until 48 h prior to the trip sail date (the PTNS still made the selection at the time of entry, but notification was delayed). Frequently, 'day-boat' vessel operators would make trip declarations in weekly batches and notify their intent to fish every day in the coming week, not knowing

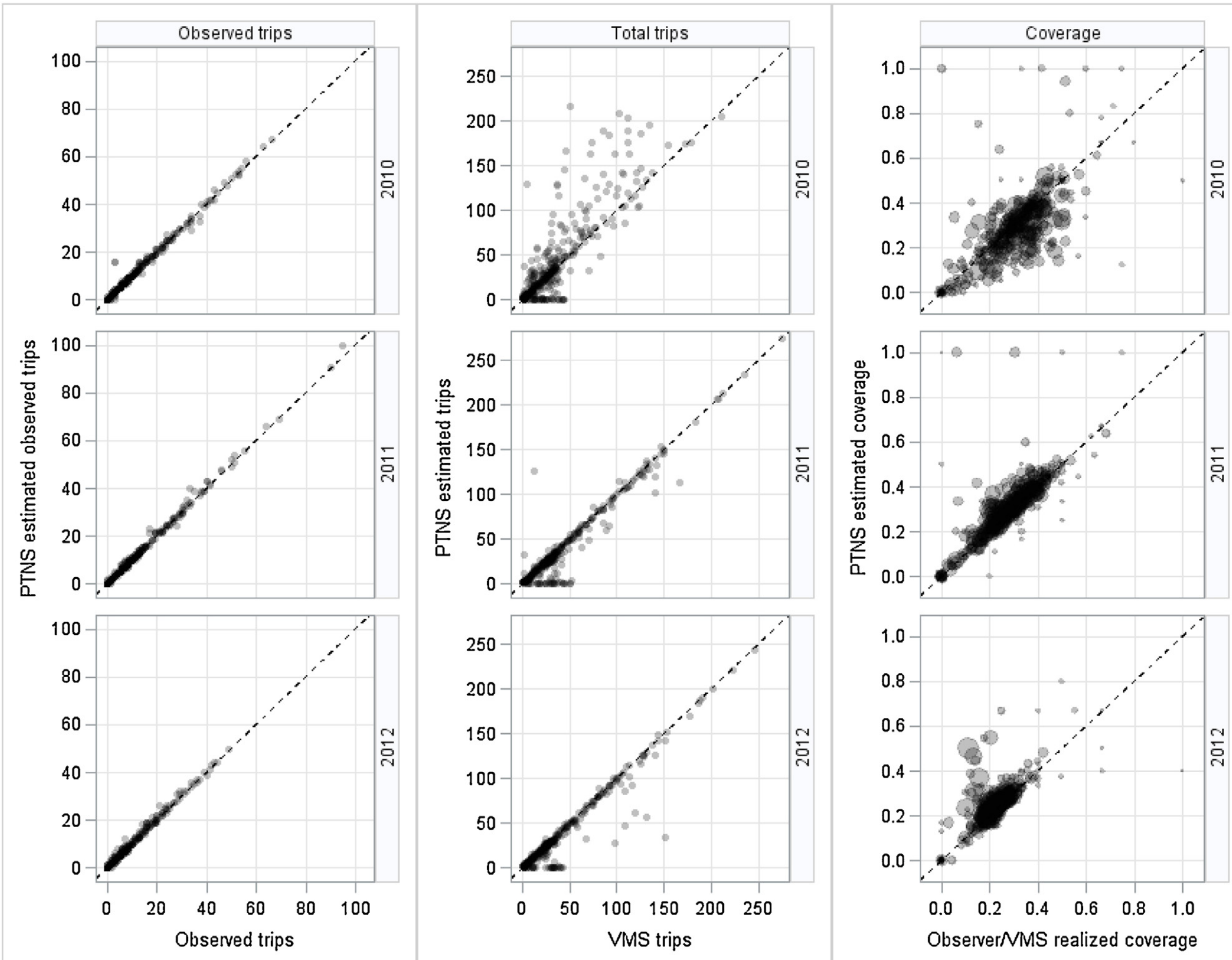

Fig. 6. Comparison of the Pre-Trip Notification System (PTNS) estimate of observed, total trips and coverage rates for an individual vessel to the realized coverage estimated from observer and Vessel Monitoring System (VMS) data. Comparison plots are shown by fishing year. The dashed line indicates the 1:1 identity line. The size of the dots in the coverage plots (right-hand side) is proportional to the number of trips taken by each vessel annually.

which days would offer favorable sea conditions and/or an available crew. Once the operator had a better understanding of sea conditions and crew availability, they would cancel notifications for trips on which they did not intend to sail, a process that was often done in advance of the 48-hour notification requirement. In the initial PTNS design, vessel operators were informed immediately after declaration which trips were scheduled for coverage. This allowed the vessel operators to consider an additional piece of information when deciding which trips to take or cancel; this was particularly true of those vessels looking to avoid observer coverage. With the 2011 redesign, any cancelations made prior to the 48 h period would be done without knowledge of the coverage status; therefore, trips canceled outside of the 48-hour window would not be subjected to automatic coverage on subsequent trips.

Additionally, as part of the 2011 improvements, the PTNS was modified to track individual vessel coverage and identify which vessels were receiving unacceptably low coverage with the levels of acceptably set by the PTNS administrator. From an operational perspective, it was irrelevant whether the low coverage was due to random chance or the intentional avoidance of observer coverage through selective cancelation; below-target coverage on one vessel must be offset with above-target coverage on another vessel within a strata. Vessels identified as having unacceptably low coverage at the time of cancelation would be subject to ‘must deploy’ assignment. All other vessels would receive no penalty for cancelling trips within 48 h of the sail date.

3. Results (system performance)

3.1. Observer coverage rates

A primary objective of the PTNS is to distribute the available sea days in a manner that provides unbiased observer coverage proportional to fishing activity. Evaluating the coverage achievements of the PTNS can be done using either data internal to the PTNS or using external sources (Vessel Monitoring System, or VMS, activity declarations, observer data, dealer weighout data, etc.). From a regulatory perspective, VMS activity declarations offer the only definitive way to classify groundfish versus non-groundfish trips. The optimal performance of the PTNS is contingent on the accuracy of the self-reported information contained within it; most importantly, the PTNS estimates of the realized strata coverage rates. This necessitates that the PTNS data accurately reflects how many total groundfish trips are taken and how many are observed. Unfortunately, there is currently no unique trip identifier to link PTNS trip declarations to the other fisheries-dependent data sources used to monitor the groundfish fishery. Absent a trip identifier, the PTNS cannot communicate directly with the other fisheries-dependent data collection systems to verify the accuracy of its information.

Fig. 7. Comparison of individual vessel coverage rates and the total number of trips taken by an individual vessel. The dashed line indicates the aggregate annual trip based coverage based on total observed trips/total Vessel Monitoring System trips.

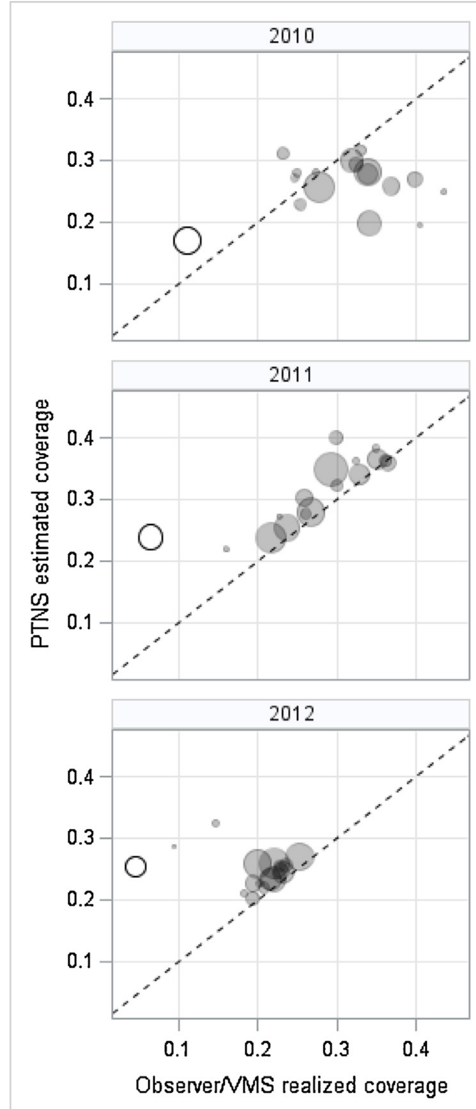

Fig. 8. Comparison of the Pre-Trip Notification System (PTNS) estimated coverage for an individual sector to the realized coverage estimated from observer and Vessel Monitoring System (VMS) data. Comparison plots are shown by fishing year. The dashed line indicates the 1:1 identity line. The common pool (non-sector vessels) is colored white. The size of the dots is proportional to the number of trips within each sector.

While there is no direct communication between the PTNS and other fisheries-dependent systems, the information contained in other data collection systems can be used to externally verify the accuracy of PTNS data and evaluate system performance. External verification methods such as matching on the vessel permit number and sail date are often useful; however, the match between the PTNS declared sail date and actual sail date is inexact and often off by as much as 48 h. Due to the inability to directly match trips, validation is limited to an examination of the total number of trips taken and observed. While not ideal, this allows for a gross examination of PTNS performance.

Overall, the PTNS estimated number of observed trips compares closely with the true number of observed trips on a vessel by vessel basis (Fig. 6). Because the determination of whether a trip was observed is based on information entered by the service providers directly into the PTNS, these data tend to be of a higher quality than the data inputted by the fishing industry since the service providers are contractually obligated to enter this information. There is greater variability between the PTNS estimates of total groundfish trips and those estimated from VMS data, though the variability has decreased with each successive fishing year. The large numbers of vessels above the 1:1 identity line in 2010 indicate those vessels having a high incidence of not canceling PTNS notifications for trips that did not sail (PTNS trip counts > VMS trip counts). Increased efforts by staff from the NEFSC Fisheries Sampling Branch (FSB) to improve the monitoring and manual cancelation of these trips led to the improvements observed in 2011 and 2012. It should be noted that there are no current fishery regulations requiring vessel operators to cancel trips declared into the PTNS but that do not sail even though failure to do so can have large negative impacts on system performance. Vessels falling below the 1:1 identity line represent vessels failing to notify all groundfish trips through the PTNS. Vessel operators failing to notify are in violation of existing fishery regulations. Interestingly, the number of vessels where VMS declared groundfish trips exceeded the number of PTNS notifications has increased over time (137 vessels in 2010, 187 vessels in 2011 and 197 vessels in 2012). While this could indicate declines in general PTNS compliance, the trends could be obscured by improvements in PTNS trip cancelations; for example, non-cancelation of PTNS trips could be offsetting non-notifications.

Overall the PTNS estimates of vessel coverage rates relative to the observer/VMS-based realized coverage rates has improved over time. Additionally, the level of variability in the coverage rates among vessels decreased considerably from 2011 to 2012. Evalua-

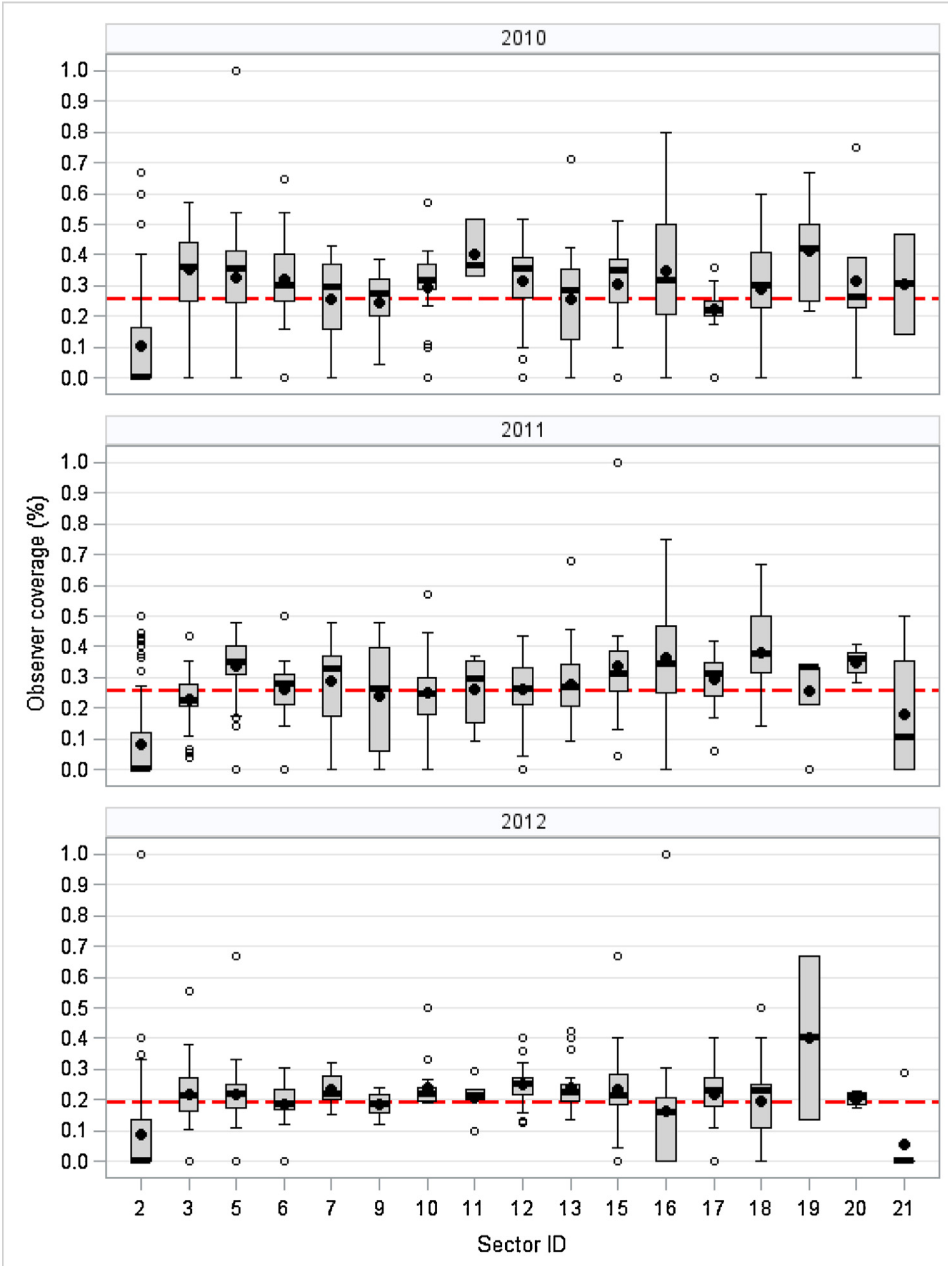

Fig. 9. Box-plot distribution of vessel-level coverage within individual sectors for fishing years 2010–2012. The dashed line indicates the annual mean across all vessels. The solid black line indicates the median, the black circle is the mean, the grey box represents the interquartile range (Q1–Q3) and the whiskers indicate observations within 1.5(IQR).

tion of vessel-level coverage using observer data and VMS activity declarations shows that, overall, vessel coverage was random and uniformly distributed at a given activity level, and, with increasing vessel activity, the coverage converges on the overall mean (Fig. 7). Comparison of vessel-level coverage across fishing years shows the influence of the various system modifications on vessel-level coverage. Overall, the level of variability of vessel-level coverage has declined in each successive fishing year. The reductions in vessel coverage variability from 2010 to 2011 were primarily due to modifications designed to curb observer avoidance. A subsequent reduction in the coverage variability occurred from 2011 to 2012. While there were no system modifications from fishing year 2011–2012 that would have affected the coverage variability, there was more intense monitoring of PTNS performance as well as several manual interventions and outreach activities taken to ensure more equitable coverage across fishing vessels; these are described in depth in Palmer et al. (2013). While improvements have been made over time in the level of agreement between PTNS and externally estimated vessel coverage, there are several vessels in fishing year 2012 that exhibit much higher internal PTNS coverage rates relative to the observer/VMS realized coverage. The most likely explanation for these discrepancies is failure to declare all groundfish trips through the PTNS.

A comparison of the PTNS estimates of sector-level coverage to those obtained externally from observer and VMS activity declarations show similar patterns to the vessel-level comparisons. In fishing year 2010, there was a tendency for PTNS coverage estimates to be lower than the observer/VMS-based estimates for all but four sectors (Fig. 8). As with the vessel-level coverage, the most likely reason for the lower coverage rates estimated internally

Table 1
Summary of the Northeast Fisheries Observer Program (NEFOP) and At-Sea Monitor (ASM) sea day allocation and utilization by fishing year.

Coverage type	Year	Allocated sea days	Utilized sea days	Percent sea days utilized (%)
NEFOP	2010	2208	1863	84.4%
	2011	3386	2694	79.6%
	2012	1338	1320	98.7%
ASM	2010	5991	5761	96.2%
	2011	6814	6909	101.4%
	2012	5225	4887	93.5%

Fig. 10. Sea day utilization, or 'burn', over time (solid black line) relative to the annual allocated sea days (cap, thick dashed line) and a constant burn trajectory (projected, thin dashed line) for both Northeast Fisheries Observer Program (NEFOP) and National Marine Fisheries Service funded At-Sea Monitors (NMFS-funded ASM) for the years 2010 to 2012. Note that the years reflect sea day contract years which run from April 1 to March 30. In 2010, the contract year did not start until the start of the groundfish fishing year on May 1, 2010.

within the PTNS is the non-cancelation of trips that were declared but never sailed. In both fishing years 2011 and 2012, there was greater consistency between the PTNS estimates of sector coverage and those obtained from observer data and VMS activity declarations. This can be directly attributed to improved compliance and monitoring of non-canceled trips by NEFSC staff described earlier. The variability in coverage rates between sectors was considerably reduced from 2011 to 2012. This is consistent with the patterns observed in the individual vessel coverage rates. The decrease in variability reflects directed efforts to ensure equitable observer coverage across all vessels. Examination of the distribution of vessel coverages within individual sectors highlights this point (Fig. 9); the size of the interquartile ranges has decreased over time and there is less spread in the mean and median sector-level coverage rates around the overall mean.

In all years there are one to three sectors where the PTNS had estimated much larger observer coverage rates relative to the realized observer/VMS based coverage (Fig. 8). The cause of these discrepancies is a failure to declare groundfish trips through the PTNS (i.e., non-compliance with the PTNS notification requirement). One sector, the '*common pool*' has had poor reporting compliance across all three years. Efforts have been made to reach out to this component of the fishery; however, the '*common pool*' is not an organized sector, rather it is made up of vessels not affiliated with any of the organized sectors. Consequently, outreach efforts to these vessels have been more difficult.

3.2. Sea day utilization and target coverage rates

In fishing years 2010 through 2012, over 90% of the allocated NMFS-funded ASM sea days were utilized annually, with the sea day utilization marginally exceeding the allocated sea days in 2011 (1% overage; Table 1, Fig. 10). In contract years 2010 through 2012, 80–99% of the NEFOP sea days were utilized. These sea day allocations resulted in the groundfish fishery receiving from 20.8 to 29.3% observer coverage per year with NEFOP coverage making up from 5.5 to 6.7% of the total coverage in any year (Table 2).

The magnitude of the NEFOP sea day under-utilization in 2010 (85% utilization) and 2011 (80% utilization) is undesirable, though the reasons for the under-utilization vary by year. PTNS target coverage rates should be adjusted over time in an effort to optimize the sea day utilization. Modifications to the PTNS target coverage rates impact the relationship between trip selection probabilities and realized observer coverage consistent with the linear selection design of the PTNS. Target coverage rates were not increased for the NEFOP tier until around November, 2010, and only from

Table 2
Estimates of observer coverage rates in the groundfish fishery for fishing years 2010–2012 by coverage type. Acronyms: At-Sea Monitoring (ASM), National Marine Fisheries Service (NMFS), Northeast Fisheries Observer Program (NEFOP), Vessel Monitoring System (VMS).

Fishing year	Tier name	Observed trips	Total VMS trips	Tier coverage	Fraction of annual trips receiving observer coverage
2010	NEFOP	898	13,313	0.067	0.293
	NMFS-funded ASM	2998		0.225	
2011	NEFOP	1005	15,614	0.064	0.260
	NMFS-funded ASM	3047		0.195	
2012	NEFOP	784	14,315	0.055	0.208
	NMFS-funded ASM	2193		0.153	

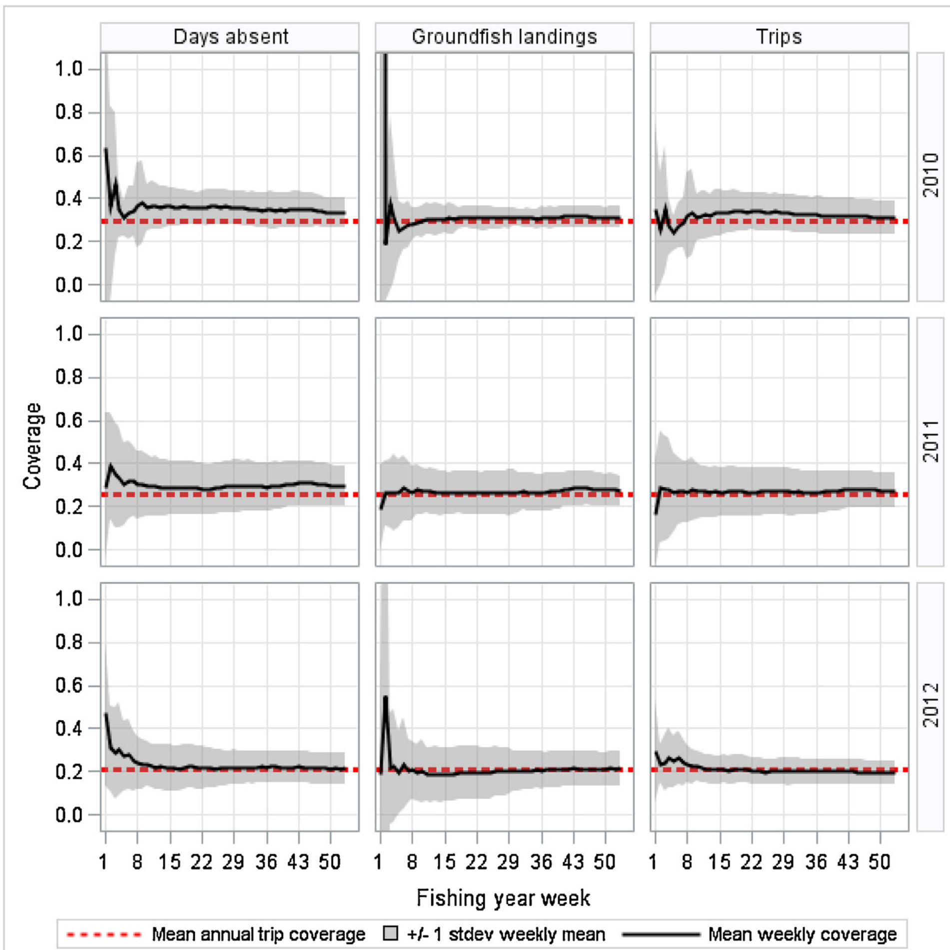

Fig. 11. Mean weekly sector coverage rates over time calculated using three different metrics: days absent, groundfish landings and trips. The dashed line indicates the aggregate annual trip based coverage (across all groundfish trips) based on total observed trips/total Vessel Monitoring System trips.

0.08 to 0.10. The target coverage rates for the NEFOP tier in 2010 should have been increased earlier in the year to better utilize the allocated NEFOP sea days. In 2011, the NEFOP sea day utilization slowed about the same time as in 2010 (approximately June 1). The similarities in timing may be coincidental, or they may relate to the deployment of NEFOP observers in other fisheries. The service provider for NEFOP observers is instructed to offer preference to certain non-groundfish fisheries when demand for observers is high. Increased activity in other fisheries, such as the herring fishery, tends to increase in early summer and may compete with the groundfish fishery when the number of observers is limited. Unlike in 2010, the 2011 NEFOP target coverage rates were continually increased, beginning in early July in an effort to counteract the underutilization of sea days. Unfortunately, the increased target coverage rates had little impact on the utilization rates. The unresponsiveness of the sea day utilization to increases in target coverage rates is symptomatic of there being too few observers to fully utilize the allocated NEFOP sea days.

If the trip-based deployment performed by the PTNS is accomplished in an unbiased manner, coverage should be similar regardless of the metric used to evaluate it. The distribution of sector-level days absent-, groundfish landings- were compared to the aggregate annual (fishing year total) trip-based coverage to determine the uniformity of observer coverage across alternate coverage metrics and evaluate whether there was evidence of temporal bias. Days absent were calculated as the time duration between the trip landing and sail dates measured as fractional days (e.g., a trip sailing at 13:00 and landing the following day at 19:00 would equal 1.25 days absent). Days absent coverage was calculated as the observed days absent divided by the total days absent. Groundfish landings were calculated as the sum of the landings of the twenty regulated groundfish stocks (NEFMC, 2010) with land-

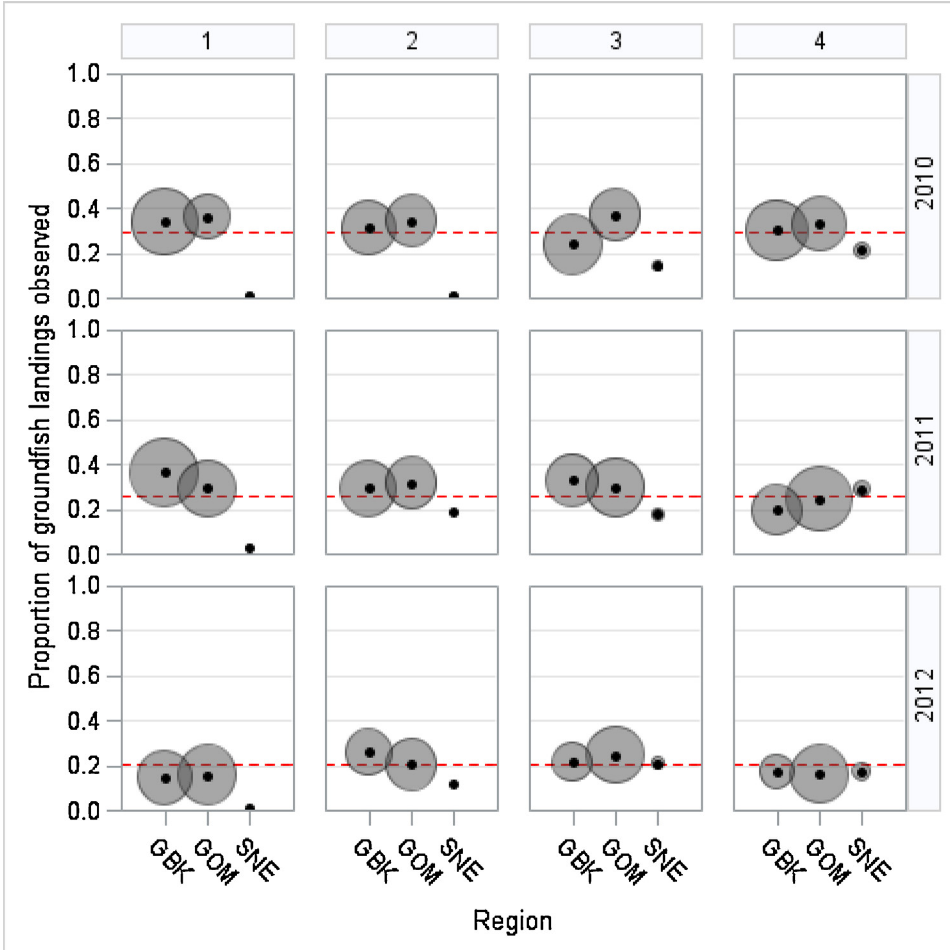

Fig. 12. Proportion of groundfish landings covered by observers by fishing year quarter and region. Regions are defined as: Gulf of Maine (GOM), Georges Bank (GBK) and Southern New England-Mid Atlantic (SNE). Coverage estimates are based on both the Northeast Fisheries Observer Program and at-sea monitoring data and dealer weighout data. The black dots indicate the point estimate and the size of the bubbles is proportional to the relative magnitude of total groundfish landings by quarter and region. The dashed red lines indicate the annual trip-based estimates of observed coverage. Note that fishing years span from May 1st of a given calendar year to April 30th of the following year so quarter 1 covers the months of May–June, etc.

ings coverage calculated as observed groundfish landings divided by total groundfish landings.

Between 2010 and 2012, the aggregate annual trip-based coverage levels were within +/− 1 standard deviation of the weekly mean (mean across sectors) of all three coverage metrics (Fig. 11). The degree of variability in weekly coverage rates over time is consistent with the expectation from the simulation experiments (Fig. 5). As time progresses and more trips enter the PTNS, the variability in the realized coverage generally decreases. Overall, there is little evidence of large-scale temporal biases in the rates. There was little fluctuation of the coverage rates after stabilizing around week 8 of the fishing year, with weekly mean rates similar to the overall annual trip-based coverage. Coverage based on days absent was slightly higher than the annual trip-based coverage in 2010 and 2011. This suggests that observed trips tended to be slightly longer than unobserved trips in these fishing years, though the cause of this pattern is unclear.

3.3. Spatial and temporal coverage patterns

It is critical that the PTNS provides unbiased coverage at the finer spatial and temporal scales that the fishery operates at. Unfortunately, because of limitations in the various data streams, such an analysis is not straight forward. The analysis cannot be conducted at the level of a fishing trip since vessels can fish in multiple areas, or regions, on a single trip. Attempts to estimate spatial coverage based on time spent fishing in a particular area through the use of VMS is problematic given that the proxy methods for estimating fishing effort from VMS polling positions tends to overestimate fishing effort (e.g., Palmer and Wigley, 2009). Dealer weighout data do not provide reliable estimates of time spent fishing per area, but they can provide relatively accurate estimates of the amount of groundfish landed per fishing area. Finer scale spatial and temporal observer coverage patterns were examined by comparing the observed (NEFOP and ASM data) groundfish landings to the dealer weighout landings by fishing region and fishing year quarter. The fishing regions were classified using the same declaration regions utilized in the PTNS (Fig. 1).

Aside from the Southern New England-Mid Atlantic region, there were no consistent patterns in the spatial and temporal coverage between Gulf of Maine and Georges Bank (Fig. 12). Coverages between these two regions were generally similar, and close to the annual trip-based coverage estimates (Table 2). The disparities between regions and across fishing year quarters was slightly greater in 2010 and generally improved over time, consistent with the other PTNS performance metrics that have been examined. The Southern New England-Mid Atlantic region tended to have much lower coverage than the other regions, particularly in quarters one and two. It should be noted that relative to the other two regions, the amount of groundfish landings from the Southern New England-Mid Atlantic region is low. Under coverage of this region will have minimal impacts on the overall monitoring of the groundfish resource, though given that there are Southern New England-Mid Atlantic-specific stocks, undercoverage of trips fishing on these stocks could have large localized impacts.

A closer examination of the Southern New England-Mid Atlantic patterns revealed that there are two factors accounting for the consistent below-average coverage, both of which are related to vessel compliance. First, a large proportion of the vessels fishing in the Southern New England-Mid Atlantic region belong to the '*common pool*' sector. In 2010, more that approximately 46% of the total trips that fished in the Southern New England-Mid Atlantic region were taken by '*common pool*' sector vessels, though this percentage dropped to 31% by 2012. As noted previously, this disorganized sector has a high rate of PTNS non-compliance. Interestingly, the '*common pool*' tends to be most active in the first quarter of the fishing year, which explains some of the temporal trends in the low coverage in the first quarter. Secondly, the majority of groundfish trips which fished in the Southern New England-Mid Atlantic region were delcared monkfish (*Lophius americanus*) trips. These trips are targeting monkfish, but from a regulatory perspective are still considered groundfish sector trips and are subject to PTNS notification requirements. The PTNS compliance rate for trips fishing on declared monkfish trips is lower than that of declared groundfish trips, and particularly the case for '*common pool*' vessels fishing declared monkfish trips (Palmer et al., 2013). The lack of compliance likely stems from vessel operators not understanding that they still have PTNS notification requirements even on the declared monkfish trips. Given these factors, the undercoverage of is the Southern New England-Mid Atlantic region unlikely to have even localized impacts on groundfish resource monitoring aside from the ability to accurately monitor the '*common pool*' quota, which is a very small component of the overall groundfish resource.

4. Discussion

Overall, the PTNS has performed consistent with the system design and was successful in meeting the diverse objectives of a complex observer deployment system. The PTNS utilized over 93% of the nearly twenty five thousand observer sea days it was allocated between 2010 and 2012. Equally important, the sea day utilization was accomplished in a manner that spread observer coverage proportional to fishing effort, resulting in consistent coverage over time and space when evaluated using multiple coverage metrics including days absent and groundfish landings. At a gross level, there is no strong evidence of observer bias, though there are some indications of observed trips being slightly longer in 2010 and 2011. The issue of observer bias (e.g., Benoît and Allard, 2009) requires additional research and is outside the scope of this paper. The deployments of both NEFOP and NMFS-funded ASM observers was done in such a way as to make the resulting discard rates from these two coverage types statistically indistinguishable across a broad range of groundfish species and gear types (Wigley et al., 2011). This is a critical result for the purposes of data inputs for quota monitoring and stock assessments.

The self-adjusting nature of the PTNS linear selection method was effective at reducing coverage variability and, in turn, increasing coverage equitability as additional trips entered the PTNS. Additionally, the self-adjusting nature mitigated many of the coverage rate perturbations induced by external factors such as observer avoidance behavior, observer availability and differential provider acceptance rates. These were the expected characteristics of the PTNS and reflect the importance of simulation work during the design of complex monitoring systems (see Palmer et al., 2013). Some of the real-world complexities of running such a system were not considered in the initial simulations and required system modifications over time to address. These highlight the need to regularly evaluate system performance and identify areas of improvement.

It is one thing to design a system that performs optimally in simple theoretical simulations but extremely difficult to design a system robust to the realities of a production deployment. The PTNS encountered its share of these realities over time, some of which were addressed through system enhancements and others through improved system monitoring and maintenance and outreach to observer service providers. The net results of these efforts were sequential improvements in system performance between 2010 and 2012. Many of the remaining issues can be addressed through minor system improvements in concert with continued improvements in coverage monitoring and outreach activities. We note that while this paper has only provided a summary of PTNS performance through 2012, there have not been significant improvements since then due to staffing and budget constraints—the performance of the system in 2012 is reflective of the current performance of the PTNS. While system improvements may lead to marginal gains in performance, the biggest challenge for the PTNS is compensating for external human factors such as vessel compliance, observer availability and objective provider selection of vessels and trips.

Perhaps the largest external factor affecting optimal performance of the PTNS relates to vessel compliance, both with respect to declaring all groundfish trips and canceling all trips that were declared but never sailed. The optimal performance of the PTNS requires the accuracy of the internal trip count information. While the analyses show that the current system has reasonable accuracy, there continues to be small differences in both the counts of observed trips and total groundfish trips. Compliance among '*common pool*' vessels continues to be a problematic area; fortunately, these vessels catch low amounts of groundfish so there is little impact from the perspective of groundfish catch monitoring. The cancelation of declared trips that did not sail was a large problem in fishing year 2010 but decreased over time, primarily as the result of monitoring and outreach by the NEFSC Fisheries Sampling Branch staff. In fishing year 2012 the non-cancelation of fishing trips had minimal impact on PTNS performance. Both of these issues highlight the need for the PTNS to be able to directly communicate with the other fisheries-dependent data collection systems like VMS activity declarations and observer data through the use of a unique trip identifier. Such communication would facilitate the development of feedback loops allowing the PTNS to auto-correct vessel declarations and maintain accurate accounting of the number of groundfish trips taken.

The ability to utilize all of the sea days allocated to the PTNS is contingent upon having a sufficient number of observers available for deployment. As seen with NEFOP coverage in 2011, an insufficient number of observers can lead to sub-optimal utilization of the allocated sea days. The availability of observers is affected by many factors, including the total number of certified observers in the region, the number of allocated sea days and the competing coverage demands of other fisheries. Additionally, given the front-loading nature of the PTNS, there may be a high demand for observers at the start of the fishing season, though unlike the other factors, this is likely to moderate rather quickly. For service providers, balancing these demands is a difficult task requiring planning and coordination. Having too few observers is problematic from the perspective of coverage deployment, but too many observers can be detrimental to the retention of qualified observers. Maintaining sufficient observers requires a balancing of seasonal coverage demands, employee losses and training sessions for new observers. Continued experience with balancing these demands should improve observer availability in future fishing years.

While external factors pose the biggest challenges to PTNS performance, there are several areas of the PTNS where improvements could be made. The PTNS has required manual interventions to adjust target coverage rates in response to changes in fleet behavior and provider capacity. While this is anticipated, more automated methods should be explored to adjust target coverage rates in response to sea day utilization trajectories and realized observer coverage. Not only will this reduce the extent of manual intervention on the part of the system administrator, it will also help prevent the types of sea day under-utilization similar to what occurred with the NEFOP sea days in 2010. The underutilization had less to do with observer availability and more to do with a lack of responsiveness.

Meeting system requirements, providing flexibility, and minimizing the burden to industry was, and continues to be, a challenge. The trip-based nature of the PTNS works well from the perspective of system design but it has proven to be burdensome for 'day-boat' operators and observer service providers. As discussed previously, many 'day-boat' vessel operators will submit a notification for every day of the week in order to maintain the flexibility to fish around weather and/or crew availability; trips on which they don't sail are then canceled both before and after the provider assignment. With the service provider potentially varying from trip to trip this translates into numerous phone calls, emails and communication with a variety of contacts in a given week and is a source of frustration for both vessel representatives and providers. Industry has expressed a desire to be selected for an entire week worth of trips such that any time the vessel sails during that week, an observer must be on board and communication would only occur with a single provider. Such a proposal presents many challenges, both from an operational and system design view, but also from the perspective of unbiased statistical sampling.

4.1. Expansion to other fisheries

Automated observer deployment systems will likely become more common-place as fishery regulations become more complex in response to industry demands for greater flexibility and as the need for improved accuracy and precision in monitoring fishery catches increases. For example, improvements in bycatch estimation are often necessary to achieve certification under the growing global eco-labelling market (e.g., Marine Stewardship Council; Agnew et al., 2014). While the PTNS was a first-of-its-kind automated deployment system, since the deployment of the PTNS in May 2010, at least one other system has been developed and deployed in North America. The National Marine Fisheries Service's Alaska Fisheries Science Center developed and deployed their Observer Declare and Deploy System (ODDS) for the groundfish and Pacific Halibut *Hippoglossus stenolepis* fisheries on January 1, 2013 (USOFR, 2012). The system has objectives similar to the PTNS in that it attempts to deploy observers in a statistically unbiased manner among a subset of the fleet chosen for trip-based selection.

Though not described in this paper, based on the initial success of the PTNS in the groundfish fishery, the PTNS was expanded to the targeted Long Finned Squid *Doryteuthis pealeii* fishery in January 2011. There are other fisheries in the northeast U.S. with existing observer notification requirements such as the Atlantic Sea Scallop *Placopecten magellanicus* and Atlantic Herring *Clupea harengus* fisheries, which could be incorporated into the PTNS. For vessels participating in multiple fisheries, a single observer notification system could streamline vessel reporting requirements. Additionally, it may also offer efficiencies with respect to system administration and support. While broadening the scope of the PTNS can offer many efficiencies, past experiences with large scale improvements and application to multiple fisheries has shown that large changes to a system of this complexity are not simple and require extensive planning and development time to properly implement.

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References

Agnew, D.J., Gutiérrez, N.L., Stern-Pirlot, A., Hoggarth, D.D., 2014. The MSC experience: developing an operational certification standard and a market incentive to improve fishery sustainability. ICES J. Mar. Sci. 71, 216–225.
Benoît, H.P., Allard, J., 2009. Can the data from at-sea observer surveys be used to make general inferences about catch composition and discards? Can. J. Fish. Aquat. Sci. 66, 2025–2039.
Clay, P.M., Kits, A., Pinto de Silva, P., 2014. Measuring the social and economic performance of catch share programs: Definition of metrics and application to the U.S. Northeast Region groundfish fishery. Mar. Policy 44, 27–36.
Faunce, C., Cahalan, J., Gasper, J., A'mar, T., Lowe, S., Wallace, F., Webster, S., 2014. Deployment performance review of the 2013 North Pacific Groundfish and Halibut Observer Program , NOAA Tech. Memo. NMFS-AFSC-281, 74 p.
NEFMC (New England Fishery Management Council), 2010. Amendment 16 to the Northeast Multispecies Fishery Management Plan. NEFMC, Newburyport, MA.
NEFSC/NERO(Northeast Fisheries Science Center/Northeast Regional Office) 2012. Proposed 2012 Observer Sea Day Allocation. March 23, 2012 (available from: http://nefsc.noaa.gov/fsb/SBRM/2012/Proposed_2012_Observer_Sea_Day_Allocation_3-23-2012_v3pdf).
Palmer, M.C., Wigley, S.E., 2009. Using positional data from vessel monitoring systems to validate the logbook-reported area fished and the stock allocation of commercial fisheries landings. North Am. J. Fish. Manage. 29, 928–942.
Palmer, M.C., Hersey, P., Marotta, H., Shield, G.R., Cierpich, S.B., 2013. The Design, Implementation and Performance of an Observer Pre-trip Notification System (ptns) for the Northeast United States Groundfish Fishery. U.S. Dept. of Comm., Woods Hole, MA, Northeast Fish. Sci. Cent. Ref. Doc. 13–21.
USOFR (U.S. Office of the Federal Register), 2012. Groundfish Fisheries of the Exclusive Economic Zone Off Alaska and Pacific Halibut Fisheries; Observer Program; final rule. Code of Federal Regulations. U.S. Government Printing Office, Washington, D.C, Title 15, Part 902 and Title 50, Part 679.
Wigley, S.E., Rago, P.J., Sosebee, K.A., Palka, D.L., 2007. The Analytic Component to the Standardized Bycatch Reporting Methodology Omnibus Amendment: Sampling Design, and Estimation of Precision and Accuracy, 2nd Edition. U.S. Dept. of Comm., Woods Hole, Massachusetts, Northeast Fish. Sci. Cent. Ref. 07–09.
Wigley, S.E., Palmer, M.C., Legault, C., 2011. A comparison of discard rates derived from at-sea monitoring and observer trips. Working Paper # 11 in the Appendix of: Northeast Fisheries Science Center (NEFSC) 2011. In: 52nd Northeast Regional Stock Assessment Workshop (52nd SAW), U.S. Dept. of Comm., Northeast Fish. Sci. Cent. Ref. 11–17. Woods Hole, Massachusetts, p. 962.