Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: American Lobster Management Board

FROM: American Lobster Technical Committee

DATE: October 8, 2017

SUBJECT: Harvester Reporting and Biological Sampling in the Lobster Fishery

The Technical Committee (TC) was tasked with evaluating the current 10% minimum harvester reporting requirement as well as identifying biological sampling gaps in the lobster fishery. The purpose of these tasks is to help inform Draft Addendum XXVI, which the Board initiated in January 2017. The report is split into three sections: 1) Executive Summary; 2) Lobster Harvester Reporting Analysis; and 3) Biological Sampling Gaps.

1. Executive Summary

Harvester Reporting

The TC was tasked with identifying a statistically valid sample of harvester reporting in the lobster fishery. This task was prompted by the fact that, while Addendum X implemented a minimum of 10% harvester reporting with the expectation that states will eventually implement 100% harvester reporting in the lobster fishery, Maine continues to require 10% of harvesters to fill out logbooks. Given that Maine accounts for the vast majority of lobster landings (>80%), this has prompted questions about the efficacy of 10% harvester reporting.

Overall, the TC provides the following conclusions and recommendations to the Board.

- To best characterize the US lobster fishery, the TC supports 100% harvester reporting to accurately account for all trap hauls and the spatial extent of the effort. In conjunction, the TC recommends states, in particular Maine, move towards electronic reporting given that the scale of the Maine lobster fishery (~6,000 licenses and more than 265,000 trips annually) may make the current paper logbooks inefficient and cost prohibitive for 100% reporting. Reporting programs that sample less than 100% of harvesters should be reviewed every three to five years to verify the adequacy of the program.
- In the interim, the TC finds the current 10% harvester reporting to be sufficiently precise to track trends in the lobster fishery. The TC finds the 10% reporting achieves CVs below 5% for all metrics considered and is accurate relative to dealer landings. The TC does note that the statistical precision of the current reporting sub-sample is, in large part, due to the immense size of the lobster fishery. As a result, changes in the number of license holders, particularly decreases, may lower the precision of the current reporting scheme and require sampling a larger portion of the fishing fleet.

- Although the TC finds that the current level of 10% harvester reporting is acceptable, the analyses indicate that latent licenses are being oversampled creating inefficiencies and lower precision in the current system of sub-sampling. Using past data, patterns in variability, and current Maine Harvester Logbook Program effort, the TC proposes an optimized sampling approach, rather than a proportional one, to ensure the program is spending the greatest effort on active permits in the fishery. More specifically, under this optimal allocation, greater sampling effort is placed on active LC1, LC2, and LC3 permits and less effort is allocated to some latent efforts or recreational permits. Additional sampling is also allocated to latent LC3 permits as there is currently a trend for these licenses to become active. This improves the statistical precision of the harvester reporting program by focusing effort on permits who actively participate in the fishery.

Biological Sampling
Recent biological data (2015-2016) were reviewed to identify gaps in the current lobster sampling program and provide recommendations on increased biosampling in the fishery. Data reviewed included sea sampling and port sampling by state agencies and NOAA Fisheries (i.e. the Standardized Bycatch Reporting Methodology (SBRM) observer program), as well as additional sea samples from the Commercial Fisheries Research Foundation (CFRF). Samples for each season/stat area/year (i.e., stratum) were compared to the landings from the respective stratum for the last year of available data in the 2015 benchmark stock assessment (2013).

Overall, the TC provides the following conclusions and recommendations to the Board.

- The greatest gaps in biological sampling occur in LCMA 3, including offshore Gulf of Maine and Georges Bank. 13 stat area and quarter combinations did not meet the threshold (3 samples per stratum) for combined sea and port sampling during both 2015 and 2016 while an additional 17 stat area and quarter combinations did not meet the threshold in one of the two years.
- The TC recommends that NOAA Fisheries implement a lobster biosampling program independent of the Standardized Bycatch Reporting Methodology (SBRM) sampling to ensure adequate sampling of federally-permitted vessels. The sampling frame should include all federally-permitted vessels, not just vessels with VTR requirements.
- The TC recommends collecting a minimum of 3 samples from all stratum with landings to meet the assessment threshold and avoid gap-filling. When less than 3 samples are available for a stratum in the assessment, data are borrowed from similar strata as a proxy.
- Sea samples are preferred over port samples because they provide information on discarded lobsters in addition to landed lobsters.

2. Lobster Harvester Reporting Analysis

Problem Statement

In February 2007, Addendum X under Amendment 3 to the ASMFC Lobster Fishery Management Plan was approved to increase and improve the data collection in the US lobster fishery. In response to the Addendum, all states except Maine developed 100% harvester data programs to collect catch and effort data. Contained within Addendum X, was the minimum requirement for 10% of harvesters to report trip level catch and effort data (logbooks). The Lobster Technical Committee (TC) reviewed the efficacy of this 10% harvester reporting in a March 2007 report, but the analysis was primarily completed using available Connecticut harvester data as a proxy for the larger fishery in Maine, where data were not available. Ten years later, the Board has asked the TC to revisit the 10% requirement because it is still being used by the State of Maine. Specifically, the Board tasked the TC with identifying a statistically valid sample of harvester reporting. This document revisits the TC's 2007 review regarding the representative nature of sub-sampling catch and effort data in the Maine lobster fishery using available Maine Dealer data and Harvester Logbooks.

Background

Maine's fishery has nearly 6,000 commercial lobster license holders selling to approximately 300 dealers completing more than 265,000 dealer transactions or trips. Historically, Maine's landings were collected on a voluntary basis with dealers reporting monthly, while a sub-sample of effort data was collected through port and sea sampling programs. In 2004, Maine instituted mandatory monthly reporting at the dealer level. Prior to 2004, it was estimated that landings were underestimated by 25-35% (Wilson et al. 2004). In 2007, when the Addendum X was approved, the State of Maine did not have a mandatory trip level data collection program for catch or effort. In 2008, Maine implemented a 100% Dealer Reporting Program at the trip level for landings, but, with nearly 6,000 licenses, the cost to implement a 100% Harvester Logbook Program using traditional paper logbooks was too high. Addendum X allowed for at least 10% of harvesters reporting through logbooks with the expectation of 100% reporting in time. Since 2008, Maine's Harvester Logbook Program has been collecting catch and effort data from 10% of each Maine license type in each of Maine's seven fishing zones (see below).

The original 2007 TC analysis was based on the Connecticut lobster fishery, which was (and still is) much smaller than Maine's with several hundred commercial license holders as compared to several thousand in Maine. Connecticut implemented mandatory trip level reporting by harvesters and dealers in the 1980s. This two-ticket system was deemed ACCSP compliant and provided a check and balance for catch and effort information. Connecticut was the model on which the TC recommended all states adopt similar reporting standards. The 2007 TC report used 1997 and 2003 Connecticut harvester data for annual landings and trap hauls as a proxy for the Maine fishery. The choice of those two years reflected when resource conditions were favorable (1997) and poor (2003). Using the Connecticut data, the TC determined that 30% was the optimal target for a statistically valid sample for landings and trap hauls, but due to financial constraints, 10% was adequate.

The original intent of Addendum X was for all harvester reporting to be at 100% coverage of the active harvesters when financially and logistically possible. With Maine Dealer Reporting Program data available for 2008-2016 and Harvester logbook data available for 2008-2015, the TC was asked to revisit the efficacy analysis using Maine data to determine if 10% harvester reporting in Maine is sufficiently precise for characterizing and tracking harvester behavior.

Description of existing sampling programs

Since 2008, the Maine Harvester Logbook Program has been using a stratified random 10% sample of harvesters to produce a representative dataset of Maine harvesters. More specifically, fishermen are categorized by their license type and fishing zone, and 10% of harvesters from each combination of license type and zone are selected to report for the upcoming calendar year (more information below). All Maine lobster license holders, except those chosen the previous year, are included in the annual random draw, including licenses that had no landings the previous year and permits that require Federal Vessel Trip Reports (VTRs). Vessel selection for the coming year is based on their license type from the previous year. Thus, the final proportion of vessels across license types is not exactly 10% because vessels may change license types and enter or leave the fishery over this two-year period. Those permit holders that are required to submit VTRs do not submit duplicate reports to the Harvester Logbook Program but continue to report only through NMFS's VTRs. To complete the data set of all licenses selected, the VTR permits selected as part of the annual 10% process were added to the Maine harvester logbook dataset.

Between 650 and 700 harvesters are chosen annually. All reports are submitted on paper, fax or email. The Harvester Logbook Program enters about 30,000 records annually. A record is a line of data for each trip or monthly "did not fish" entry. If a harvester is selected and does not submit the required logbooks, his license cannot be renewed the next year.

Current Stratification: licenses and zones

The license types are based on age (<18 years old, 18-70 years old, and > 70 years old) and number of unlicensed crew allowed to work on the boat in addition to the captain (none, 1, or 2) (Table 1). There are a few license types that were excluded from below analyses including tribal licenses and non-residential licenses. Apprentice licenses are not required to report and were also excluded. Maine has seven lobster management zones, A-G (Figure 1).

Table 1. Maine lobster license types and descriptions.

License Type	Description
LC1	Lobster/Crab Type 1, no crew
LCO	Lobster/Crab Type 1, >70
LC2	Lobster/Crab Type 2, one crew
LC2O	Lobster/Crab Type 2, >70
LC3	Lobster/Crab Type 3, two crew
LC3O	Lobster/Crab Type 3, >70
LCS	Lobster/Crab Student
LCU	Lobster/Crab Under Age 18
LNC	Lob/Crab Non-Commercial
NLC1	Non-resident Lobster/Crab, Type 1
NLC2	Non-resident Lobster/Crab, Type 2
NLC3	Non-resident Lobster/Crab, Type 3
NLCU	Non-resident Lobster/Crab, <18
various	Tribal Lobster/Crab

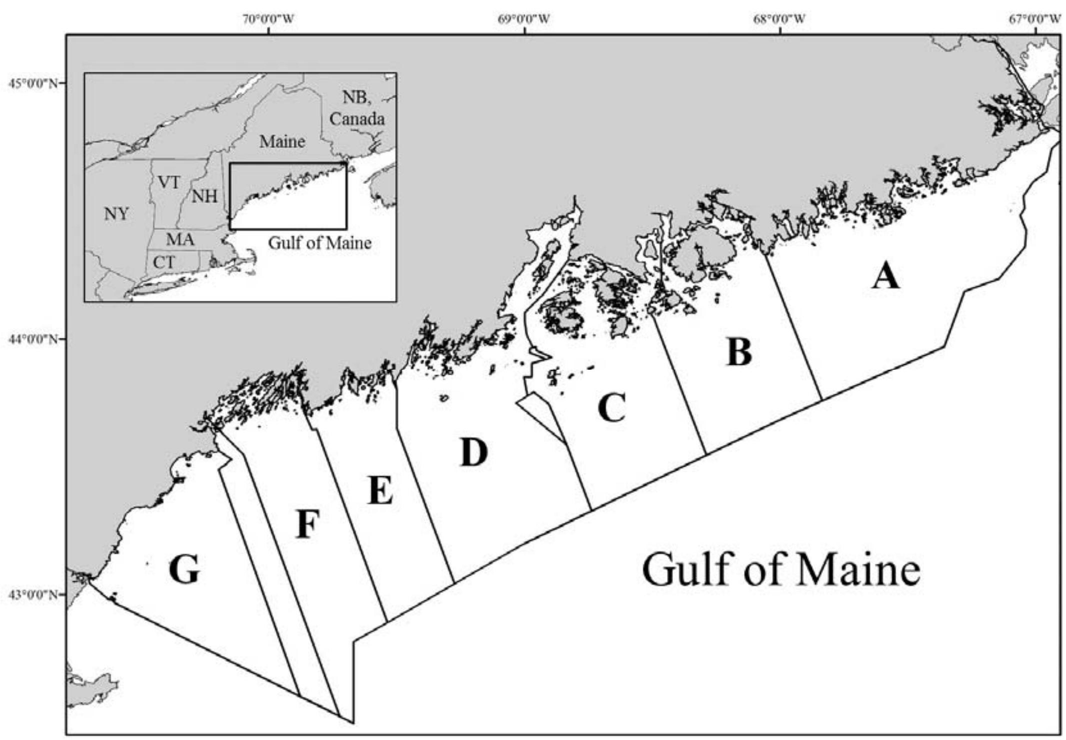

Figure 1. Map of Maine Lobster Management Zones in Area 1.

Objectives

1. Evaluate the precision of the current 10% reporting in Maine and assess the metrics provided by the Harvester Logbook Program.

2. Evaluate the benefits of a higher percentage of harvester reporting in Maine.
3. Evaluate methods and benefits of optimizing the current Harvester Logbook Program to improve precision and efficiency, particularly looking at the stratification and allocation of harvester reporting among license holders.

Statistical Validity of 10% Harvester Reporting

Using only the harvester data from 2008 – 2015, the coefficient of variation (CV) was calculated for six different metrics from the harvester reports: number of trips per year, number of trap hauls per year, total landings, total soak nights, average number of traps in the water, and maximum number of traps in the water for the year. A CV is a measure of variability from the mean and can be used to determine the precision of results; a lower CV means less variation and greater statistical confidence. Data were first aggregated to vessel levels and then merged with the license data to assign license types to each vessel. Stratified CVs were then calculated, treating license type as strata.

CVs tended to be low and stable across all six variables (Figure 2). The CV for landings was highest, being just below 0.05 with trap hauls and soak nights both averaging around 0.04 and number of trips averaging around 0.03. CVs for average number of traps and max number of traps were both below 0.03 and declined across the time series.

We also examined the CVs for these six variables by license type (Figure 3). CVs for all metrics averaged below 0.1 and were stable for LC2 and LC3 licenses, with LC1 vessels averaging around 0.1. CVs for LCS, LCO, LCU, and LNC licenses were typically higher and much more variable across years, probably due to both variability of fishing activities and smaller sample sizes.

Finally, we examined the accuracy and precision of the current harvester reporting by comparing estimates of total landings to dealer landings. Using the harvester data, we calculated the total landings and 95% confidence intervals for each year and plotted them against the total landings by year as reported in the dealer data (Figure 4). The two data sets compare admirably well with most mean harvester-based landings estimates being at or slightly below total dealer landings. Harvester confidence intervals (CIs) were about 10% of the mean estimate, varying from +/- 6 to 12 million pounds across years. Only in 2009 did the estimated CI for harvester landings (70.8 +/- 6.9 million pounds) not encompass the actual value of dealer-reported landings (81.2 million pounds).

Conclusions for 10% validity

We evaluated the current system and found that the 10% harvester reporting with the current stratification is producing data with low and stable CVs over time for the metrics of total annual trap hauls, total soak nights, trips, average traps hauled per day, and maximum traps in the water. When the metrics are calculated for each license type, the CVs are higher but the three license classes that encompass most of the fishery (LC1, LC2, and LC3) had CVs 10% or lower. The licenses types with higher CVs have fewer permit holders (e.g. LCU) or high variability in fishing status (e.g. LCO). Overall, the 10% harvester reporting seems to be producing a sufficiently precise representation of the Maine fishery.

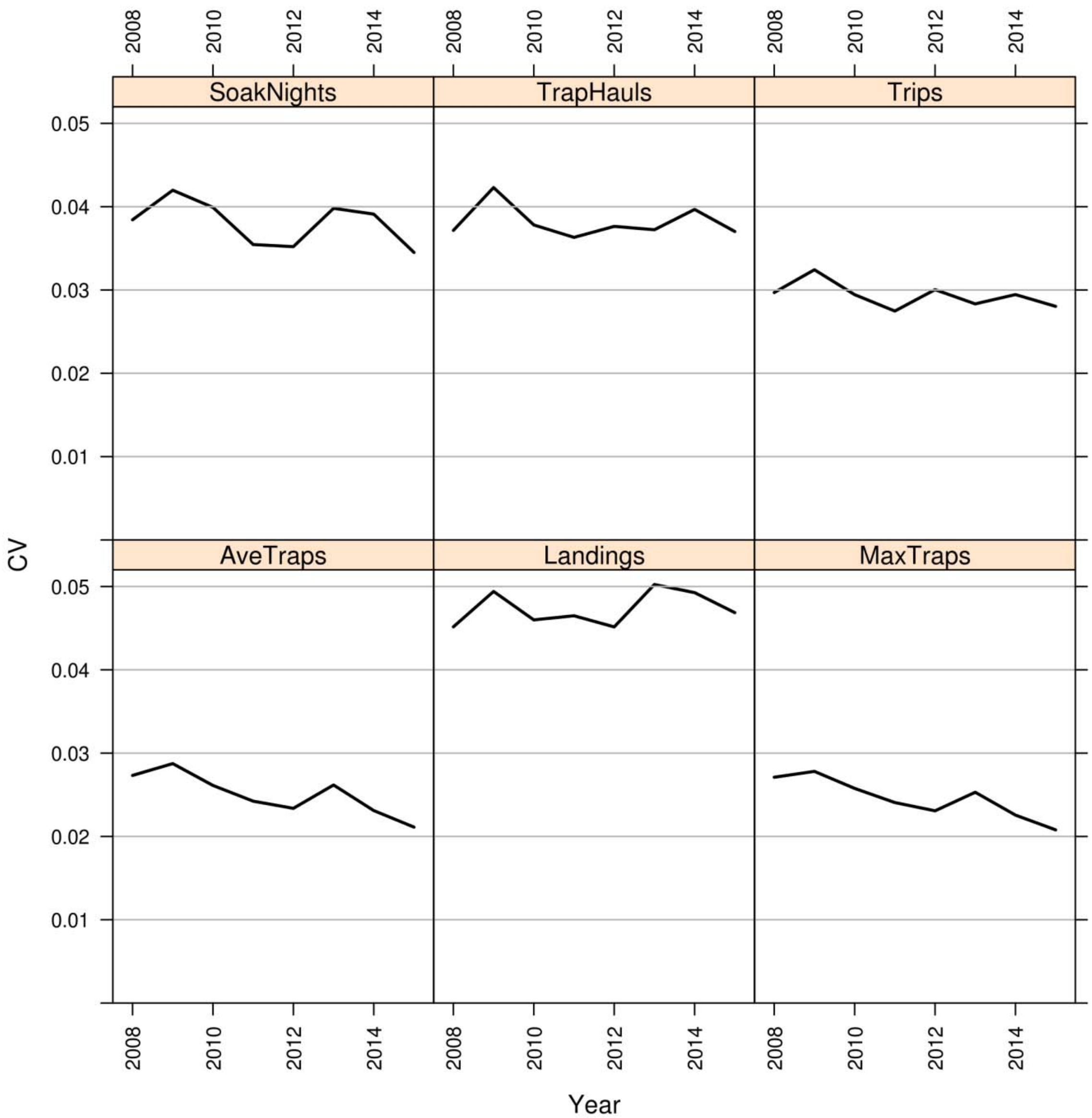

Figure 2. Calculated CVs from harvester data (pooled across license types), by year, for various reporting fields.

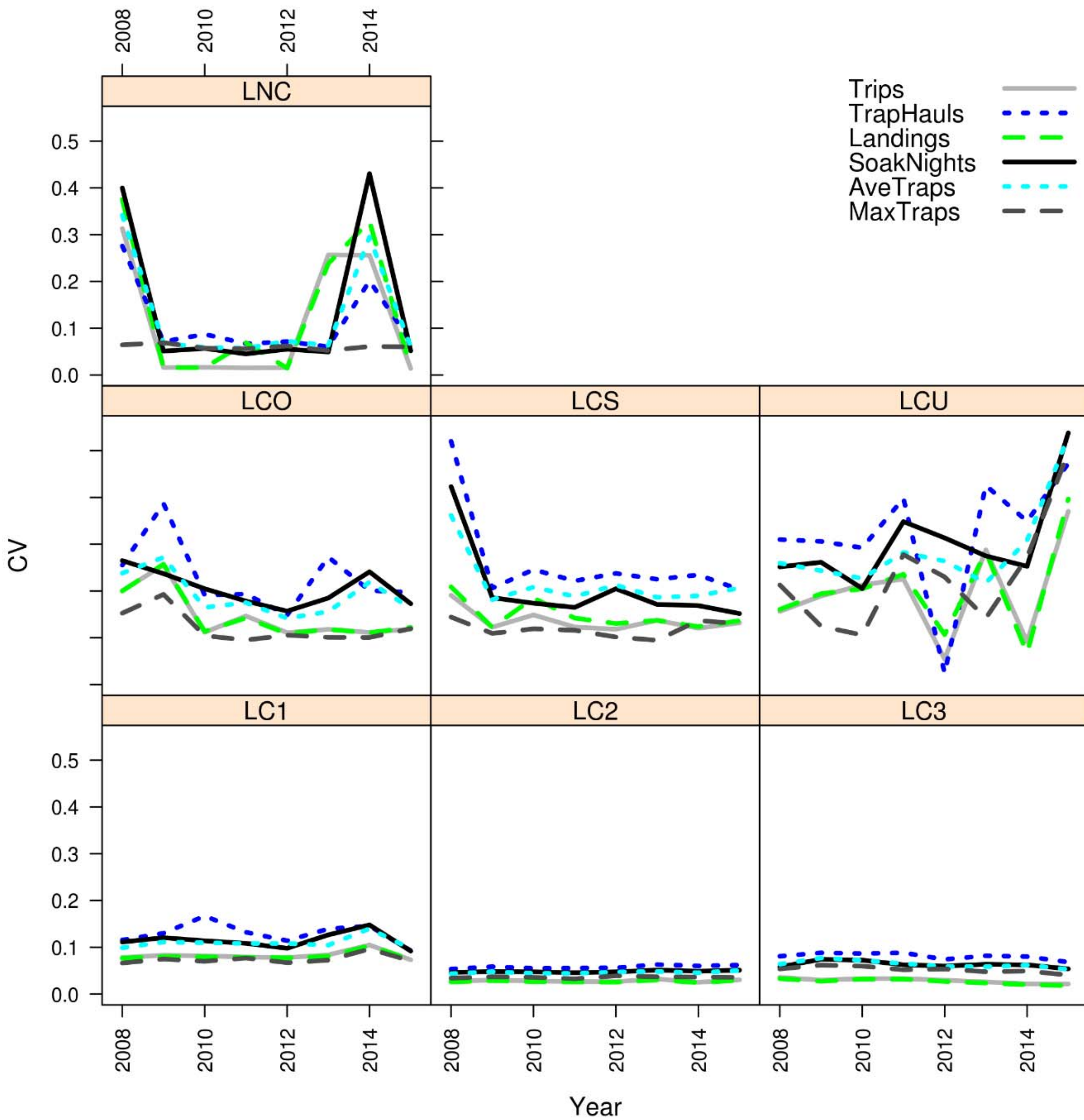

Figure 3. Time series of calculated CVs by license type across reporting fields.

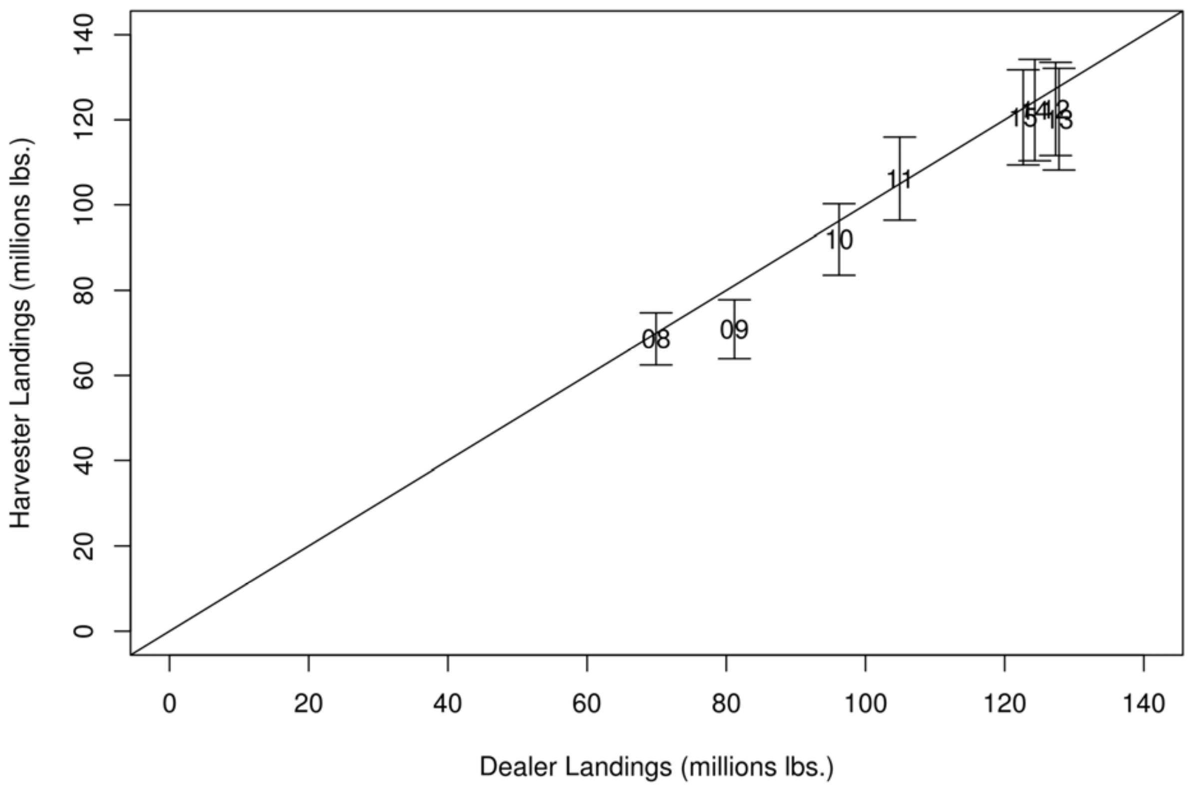

Figure 4. Harvester-estimated total landings (+ / - 95% CI) compared to dealer-reported landings. 2008 – 2015. Digits represent landings year. The diagonal line is the 1:1 proportional line.

Analyzing Potential Benefits of Increasing the Minimum Percentage of Harvester Reporting
Next, the TC evaluated potential benefits of increasing the percentage of harvester reporting in the Maine lobster fishery, particularly looking at the resulting CVs. The TC examined the effect of increasing the percentage of harvester reporting from 10% through 50%, in 10% intervals through bootstrapping CVs for trap hauls from the Maine harvester logbook data. Increasing sampling effort decreased trap haul CVs from around 0.035 at 10% proportional reporting to 0.012 at 50% proportional reporting (Figure 5). Reported CVs from bootstrapping are probably biased slightly high, particularly for higher reporting levels, as the bootstrapping procedure is necessarily resampling with replacement where actual harvester reporting would be selecting vessels without replacement. Overall, the TC notes that all of the CVs for 10% through 50% harvester reporting are quite low and small improvements in the CVs may come at large expenses to the state.

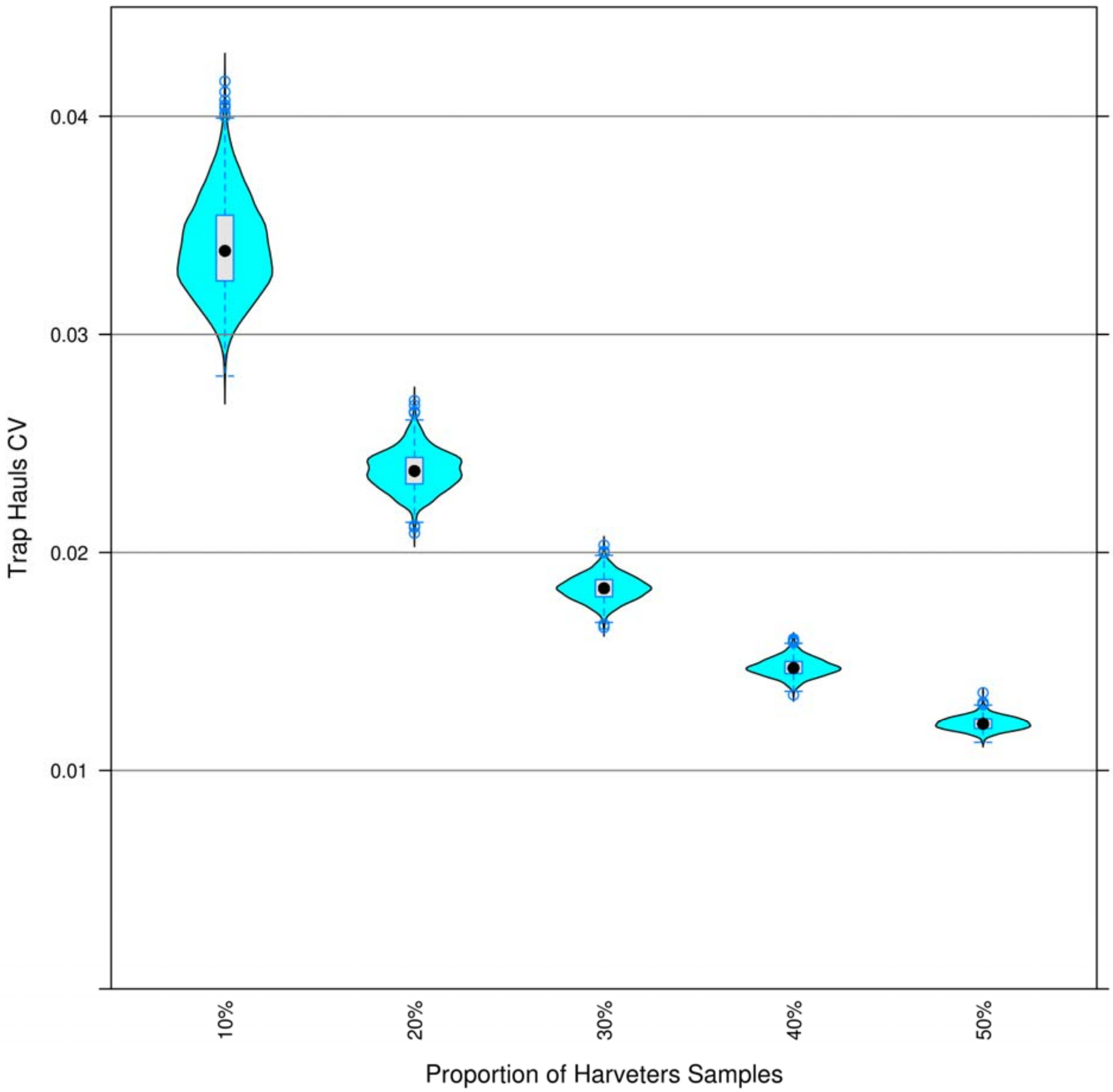

Figure 5. Comparison of trap haul CVs with proportional sampling under 10 – 50% harvester reporting.

Methods to Improve Harvester Reporting Under Current 10% Minimum Requirement

While the CVs that result from 10% harvester reporting are low, there may be ways to improve the precision of the estimates from harvester data or increase the efficiency of the system. To this end, the TC investigated what factors are important in explaining the variation in trap hauls and landings in the Maine lobster fishery and what method of allocating harvester reporting across permit holders results in a lower CV.

Evaluation of License Stratification

Generalized linear models (GLMs) were used to evaluate characteristics (factors) that might explain variation in metrics of interest from Maine's lobster fishery, and thus be beneficial to incorporate into a stratification scheme. The characteristics used in the current stratification, license type and zone, were included in the models in addition to license status (i.e., active vs latent) and year. License status was included in models as it is expected to have an effect on metrics and is an indication of future status. Proportionally, license status tends to be relatively stable over time (Figure 6), but some harvesters did change status between selection and reporting years (Figure 7). Due to these observed changes, latent licenses cannot be perfectly predicted and, therefore, cannot be excluded from selection as they contribute to the distribution of metrics.

License types were divided between license statuses during selection year (e.g., LC1 active and LC1 latent). Year was included in models to determine if variation in metrics is due to a year effect and if allocation should be based on data from a subset of years or all data combined. An interaction between license type and status and zone was included in GLMs to evaluate if licenses should be stratified by license type and status and zone combinations. Metrics evaluated included trap hauls from the harvester logbook data and landings from dealer data. Since dealer data includes 100% of landings, we used this dataset when examining factor effects on landings. However, since dealer data does not include effort information, we had to use the harvester dataset to examine factor effects on trap hauls.

License types for harvesters 70 and older (LCO, LCO2, LCO3) were combined into one license type. Non-resident and tribal licenses were dropped from the analysis due to small numbers of these licenses. Recreational licenses were also dropped from the analysis due to much smaller trap limits (5) than most commercial licenses (800) and because recreational harvesters do not sell their catch to dealers. Latent licenses were determined by assuming that any license that did not sell landings to dealers did not fish during the year.

A negative binomial GLM was used for total annual trap hauls by license. The delta-lognormal method (Lo et al. 1992) was used to evaluate characteristics' effects on two different processes, a binomial GLM to evaluate effects on license status during the reporting year and a normal GLM to evaluate effects on the distribution of annual landings on the log scale by active licenses. Comparison of GLMs was made based on Akaike information criterion (AIC) and relative percent deviance explained by the model. Lower relative values of AIC and higher relative percent deviance explained indicate better model fit. These criteria are used to measure the quality of one model against another when predicting a data set.

The negative binomial GLM estimating trap hauls with an interaction between license type and status and zone resulted in the lowest AIC (Table 2). Percent deviance explained and AIC were very similar among models with license type and status, but deteriorated for all models without license type and status. These results indicate that license type and status are the best predictors of trap hauls among the factors evaluated and additional factors provide little information in estimating trap hauls.

Model-generated estimates of annual trap hauls varied by license type and status, with nearly all (85%) direct comparisons being significantly different (for example, LC1 active compared to LC1 latent) (Table 3).

The normal GLM estimating landings from active licenses with a year effect and an interaction between license type and status and zone resulted in the lowest AIC and highest percentage of deviance explained (Tables 4, 5). Similarly, the binomial GLM estimating reporting status with an interaction between license type and status and zone produced the best results. Adding year and zone to the models only resulted in marginal improvements, at best, suggesting that these characteristics add relatively little information when compared to the models with only license type and status as a factor.

Conclusions for evaluation of stratification

Given the similar results from models estimating trap hauls from harvester logbook data and landings from dealer data, stratifying harvesters for selection based on license type and status is a reasonable balance between statistical power (i.e., marginal increase in AIC) and logistics (i.e., stratification by one characteristic as opposed to a combination of two or more). Including year provided little, if any, improvement to models and supports the use of the full data set for allocating reporting requirements. Including zone also results in relatively little improvement compared to license type and status. However, the potential need to develop estimates by lobster management zone for spatial characterization justifies some allocation to ensure data are available from across zones. Samples within license type and status could be allocated post-stratification proportional to the licenses in each zone.

Table 2. AIC and percent deviance explained for negative binomial GLMs using harvester logbook data.

Model	AIC	Percent Deviance Explained
Trap Hauls~Year+License Type and Status*Zone	70,307	20.83
Trap Hauls~License Type and Status*Zone	70,304	20.81
Trap Hauls~License Type and Status+Zone	70,314	19.76
Trap Hauls~License Type and Status	70,343	19.18
Trap Hauls~Zone	71,353	1.51
Trap Hauls~Year	71,368	0.10
Trap Hauls~1	71,359	NA

Table 3. Differences in annual trap hauls between commercial license type and status. An asterisk indicates a significant difference (p<0.05) and a blank indicates no significant difference.

	LC1 Active	LC1 Latent	LC2 Active	LC2 Latent	LC3 Active	LC3 Latent	LCS Active	LCS Latent	LCU Active	LCU Latent	Over 70 Active	Over 70 Latent
LC1 Active												
LC1 Latent	*											
LC2 Active	*	*										
LC2 Latent	*	*	*									
LC3 Active	*	*	*	*								
LC3 Latent		*	*	*	*							
LCS Active	*	*	*	*	*	*						
LCS Latent	*	*	*	*	*	*	*					
LCU Active		*	*	*	*		*	*				
LCU Latent	*		*	*	*	*			*			
Over 70 Active		*	*	*	*		*	*		*		
Over 70 Latent	*	*	*	*	*	*		*	*		*	

Table 4. AIC and percent deviance explained for normal GLMs using dealer data.

Model	AIC	Percent Deviance Explained
log(landings)~Year+License Type and Status*Zone	51,555	48.56
log(landings)~License Type and Status*Zone	52,450	46.61
log(landings)~License Type and Status+Zone	52,545	46.25
log(landings)~License Type and Status	54,034	42.82
log(landings)~Zone	65,948	6.35
log(landings)~Year	66,753	3.18
log(landings)~1	67,529	NA

Table 5. AIC and percent deviance explained for binomial GLMs using dealer data. Reporting status is active or latent two years after the initial license type and status used as a factor in the model.

Model	AIC	Percent Deviance Explained
Reporting Status~Year+License Type and Status*Zone	21,322	40.92
Reporting Status~License Type and Status*Zone	21,317	40.92
Reporting Status~License Type and Status+Zone	21,356	40.56
Reporting Status~License Type and Status	21,410	40.39
Reporting Status~Zone	35,499	1.11
Reporting Status~Year	35,849	0.13
Reporting Status~1	35,891	NA

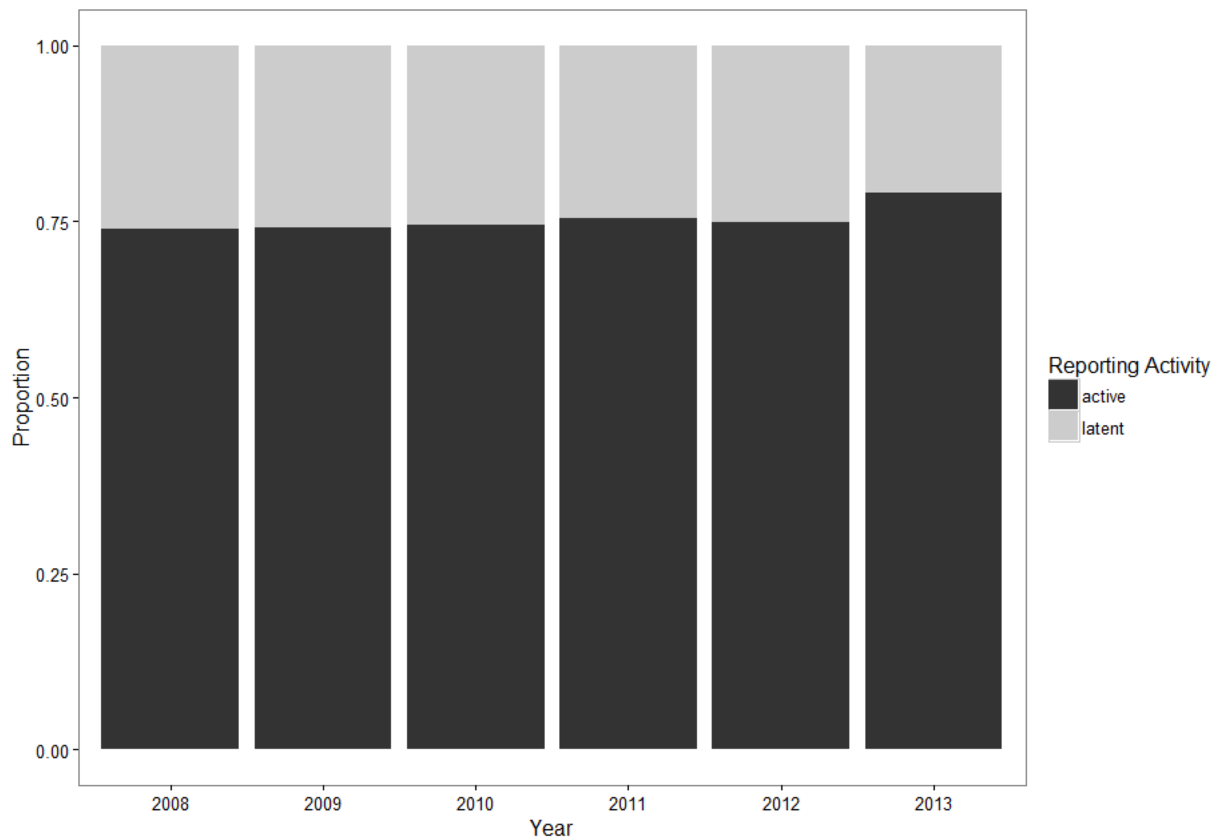

Figure 6. License reporting status (i.e. two years later) by year from the Maine dealer data.

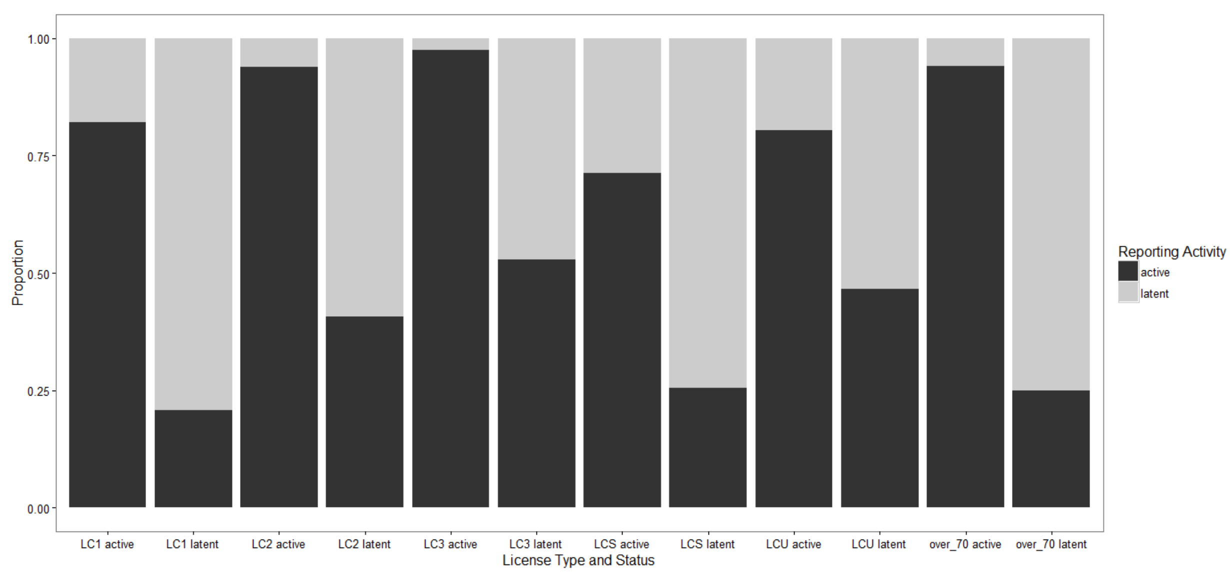

Figure 7. License reporting status (i.e. two years later) by license type and status during potential selection year as determined from the Maine dealer data.

Optimal Allocation for Current Harvester Logbook Program

The final part of this analysis looks to optimize the current harvester reporting program in Maine. One problem with harvester reporting is that many licenses are not actively fishing in a given year, and, thus, a portion of the harvester reporting resources are being assigned to such latent licenses. The sampling of latent licenses occurs because vessels are selected for reporting in the coming year based on the license type they purchased in the previous year, thus incurring a 2-year lag between the basis for selection and actual reporting.

Table 6 shows the sampling history of Maine's Harvester Reporting from 2008 – 2015 by license type and status in the same year. Vessels selected for reporting but with no reported landings are considered latent. Total number of vessels selected for reporting ranged from 744 in 2008 to 650 in 2015. Across all years, most vessels selected to report were active LC2 (30.5%), followed by recreational permits (LNC, 18.6%), active LC3 permits (14.0%) and latent LC1 permits (11.0%). Notably, most selected LC1 permits were latent but most selected LC2 and LC3 permits were active. The total number of LC1 and LC2 permits declined over these years while the number of LC3 permits increased. The large number of latent permits being sampled, particularly for LC1, suggests that efficiency in harvester reporting could be gained by taking a vessel's history of status (active or latent) into account when selecting vessels for coming years.

Table 6. Number of vessels selected to submit harvester reports by license type and status (active vs latent status was determined based on dealer data).

License Class	Status	2008	2009	2010	2011	2012	2013	2014	2015	Ave % of all reporting vessels
LC1	Active	63	62	63	53	50	47	47	48	7.80%
	Latent	90	91	79	88	61	75	62	65	11.00%
LC2	Active	256	200	241	233	216	193	184	167	30.50%
	Latent	15	17	26	10	22	16	15	13	2.40%
LC3	Active	86	77	70	94	92	108	119	128	14.00%
	Latent	1	4	2	2	6	4	7	6	0.60%
LCO	Active	30	33	40	37	35	40	39	41	5.30%
	Latent	20	15	8	10	24	19	19	18	2.40%
LCS	Active	28	26	28	31	26	37	34	33	4.40%
	Latent	19	11	9	13	18	15	18	14	2.10%
LCU	Active	6	7	8	1	5	6	3	2	0.70%
	Latent	0	1	2	1	1	0	0	1	0.10%
LNC	NA	130	123	141	141	140	127	111	114	18.60%
Total		744	667	717	714	696	687	658	650	100.00%

It is possible to optimize the allocation of sampling resources in a stratified survey, if certain characteristics of the strata are known (Cochran 1977). The optimal allocation of effort across strata can be calculated as:

$$p_L = \frac{(NumVessels_L * \ sdPar_L * \ \sqrt{Cost_L})}{\sum(NumVessels_L * \ sdPar_L * \ \sqrt{Cost_L})}$$

Where L is a given license type and status, p_L is the proportion of all sampled vessels to be drawn from a license type, $NumVessels_L$ is the number of vessels in a license type, $sdPar_L$ is the standard deviation of the parameter to be optimized for a license type, and $Cost_L$ is the cost (effort) associated with sampling a vessel from a license type. Thus, a license type and status will be sampled more heavily if it contains a larger number of vessels, has a higher standard deviation, and a lower sampling cost.

For this analysis, we treat the combination of license type and status (active vs latent) as our sampling strata, based on the prior evaluation of stratification, and calculated an optimal allocation of sampling resources across license type and status, based on each of our six variables. Management zone was excluded from the analysis for simplicity and because it was found to be of minor importance in describing the variability in trap hauls and landings in the above GLM analysis. The number of vessels in each license type and status was taken from license and dealer data in 2015, as there were clear shifts in the numbers of licenses and license status across years. Standard deviations for each of the six variables were derived from harvester data and calculated across all years as sampling of some combinations of license types and status were not sufficient in some years to get stable estimates, and there were no trends for these values to change across time. The time lag in the system was modeled by calculating the standard deviations from the harvester data, matched to a vessel's license and status from two years earlier. The cost of harvester reporting for each license type and status was based on the number of records for each from harvester data, again averaged across all years, assuming this is a suitable proxy for the amount of time that Maine DMR staff spend entering data and providing support for a reporting vessel. The same two-year lag was applied to costs by matching the number or records from a license with its license type and status two years prior. Also, for the calculation of vessel costs, vessels with less than 12 reports in a year were assumed to have filed 12 reports that year (monthly) and corrected accordingly.

The resulting number of vessels of each license type can then be calculated as:

$$n_L = \frac{\sum(p_L * Cost_L)}{Cost_{total}}$$

Where n_L is the number of vessels selected from license type L and $Cost_{total}$ is the total amount of resources available for sampling. Under this scenario, we assumed that the total number of reports that Maine DMR staff would be able to process remained constant, so $Cost_{total}$ was fixed at the number of reports the harvester reporting program handled in 2015. Using these estimates of number of vessels in each license type and status, standard deviations of variables, and costs of monitoring vessels, we calculate the appropriate number of vessels in each license type and status that should be reporting.

Figure 8 shows the optimal allocation proportions as calculated specifically based on each of our six harvester variables (trips, trap hauls, soak nights, max traps, landings, and average traps hauled per day). Proportional allocations were distributed similarly across the various license types for each of the six variables examined, with active LC2 and LC3 usually getting the highest proportions of the allocations, the exception being the number of trips, which would allocate additional effort to the recreational vessels. Latent vessels were consistently allocated less sampling effort than active vessels across license types. The similarity in allocation distributions for the different metrics suggests that optimally allocating sampling based on one variable is likely to perform reasonably well for many of the other metrics of potential interest.

Because it is not simple to optimize allocation simultaneously for multiple variables, we used the optimal allocation proportions for trap hauls in this analysis, as this is a variable that is particularly important to track from harvester reporting. Table 7 shows a comparison between the current proportional sampling design and potential optimal sampling design, based on the 2015 harvester data. LC2_Active and LC3_Active both have a large number of vessels, and high standard deviations but high numbers of records submitted each year (cost) and so make up >60% of vessels sampled under optimized sampling. LC3_Latent vessels have a small number of licenses and low number of records but comparably high variances and, thus, are also prioritized under optimized sampling. Conversely, recreational permits represent the largest type of licenses but have a low standard deviation so are sampled less under optimal sampling (114 vessels under proportional sampling vs 6 vessels under optimal sampling). Similarly, latent permits tend to be sampled less (LC1_Latent: 70 vessels under proportional sampling vs 21 vessels under optimal sampling). Because the optimization tends to shift sampling effort to license types with higher costs for monitoring and we are using a fixed cost, the total number of vessels selected for reporting would go down from 650 for proportional sampling to 522 for optimal sampling. It is noteworthy that, of the factors determining the proportions in optimal allocation, the number of vessels and standard deviation of the data are well defined. However, the cost associated with sampling a vessel, based on # records submitted/year, could be better refined, which would change the allocation of sampling.

Using this optimal allocation across licenses and status, we bootstrapped CVs for our six variables of interest from harvester reporting data and compared the results to bootstrapped CVs from proportionally allocated harvester reporting (Figure 9). Optimizing allocation for trap hauls only marginally decreased estimated CVs, from 0.035 to 0.032, compared to proportional allocation. Similarly, CVs decreased marginally from proportional sampling for landings (from 0.047 to 0.041). CVs for soak nights were similar but more variable for optimal sampling. Conversely, CVs for number of trips, average traps, and max traps were also more variable but increased marginally with the mean CV for number of trips increasing from 0.026 to 0.037. Based on the optimal allocation for other variables (Figure 8), these observed increases in CVs and increased variance of the CVs are probably the result of decreasing sampling and small sample sizes for student (LCS) and recreational (LNC) licenses. Although the optimized allocation had mixed results for different metrics, the trap haul variable is the highest priority variable and can only be characterized by harvester reports and this approach improves the precision.

Since the goal of Addendum X was to achieve 100% harvester reporting, incrementally if necessary, we examined the interaction between increasing overall sampling effort and optimal allocation of vessel selection. For this analysis, we bootstrapped the CV of annual trap hauls, allowing the total cost of sampling to vary and thus the total percentage of vessels sampled to increase from 20 - 50%. Similar to increasing the percentage of vessels sampled, increasing sampling effort resulted in decreased CVs with optimally-allocated vessel selection modestly outperforming proportional sampling (Figure 10). However, bootstrapped CV were also ~20% less variable under optimal allocation than proportional allocation, suggesting that future estimates could be more both more precise and consistent.

It is important to recognize that the above analysis on optimal allocation is preliminary and that additional work would be appropriate before implementing this methodology for the State of Maine. In particular, averaging across allocations that were optimized for different variables may be able to further improve the performance across all variables with minimal loss in precision to individual variables. Addition collaboration with the State of Maine could also better quantify the effort costs of monitoring different license classes, making for better cost estimates and further improving the cost estimates used in the allocation.

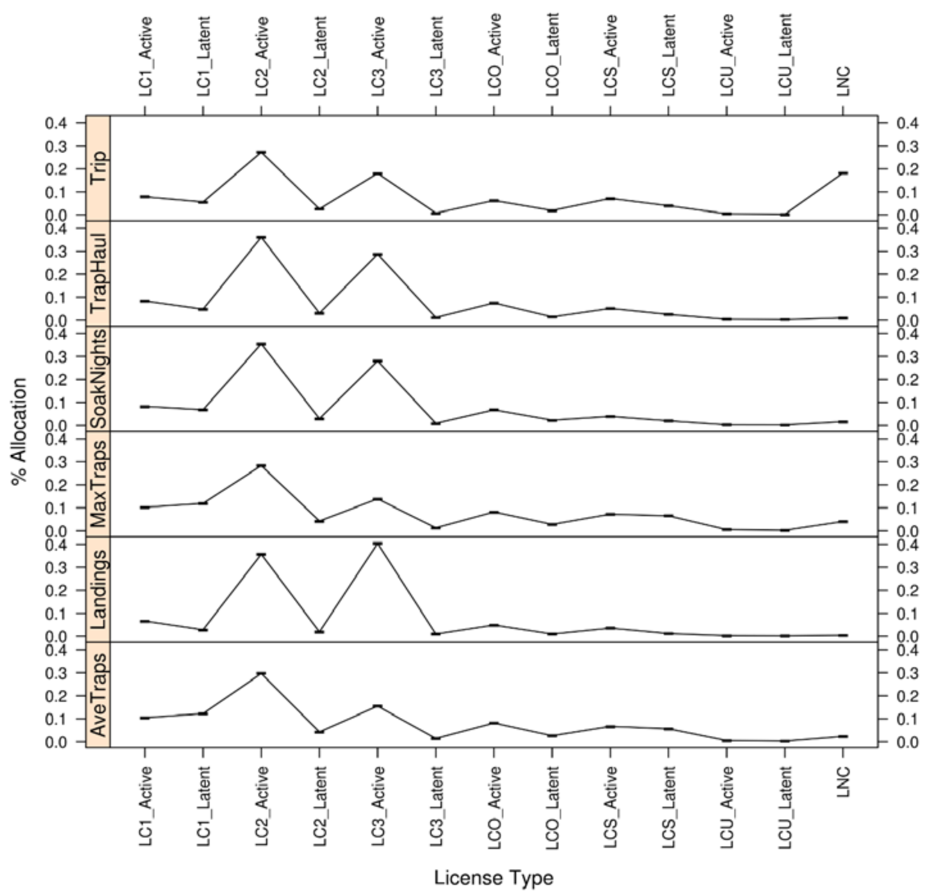

Figure 8. Optimal allocation of vessels for 2015 across license type and status, based on different harvester parameters.

Table 7. For each license type and status, the total number of licenses in 2015, mean annual cost to sample each vessel (i.e., average number of harvester reports by vessel by year), the standard deviation of annual trap hauls, the number of vessels and % of licenses sampled under current 10% system, and, under the proposed optimal allocation scheme, the % of the total sampling effort, # of vessels selected, and % of all licenses in that type selected. Data here are based on a two-year lag, where vessel selections were made in 2013 for the 2015 reporting year.

				Current 10% Reporting		Optimal Allocation		
License Status	**Total # Licenses**	**# Records / Year**	**SD TrapHauls**	**# Vessels**	**% of licenses**	**Allocation**	**# Vessels**	**% of licenses**
LC1_Active	**446**	**52.9**	**8,034**	**41**	**9.2%**	**8.4%**	**44**	**9.87%**
LC1_Latent	**459**	**37.8**	**3,157**	**70**	**15.3%**	**4.0%**	**21**	**4.58%**
LC2_Active	**1669**	**78.6**	**11,344**	**190**	**11.4%**	**36.4%**	**188**	**11.26%**
LC2_Latent	**154**	**41.5**	**6,684**	**20**	**13.0%**	**2.7%**	**14**	**9.09%**
LC3_Active	**1220**	**95.1**	**13,242**	**100**	**8.2%**	**28.2%**	**146**	**11.97%**
LC3_Latent	**39**	**13.0**	**9,941**	**4**	**10.3%**	**1.8%**	**10**	**25.64%**
LCO_Active	**372**	**50.6**	**8,523**	**30**	**8.1%**	**7.6%**	**40**	**10.75%**
LCO_Latent	**168**	**16.7**	**2,427**	**14**	**8.3%**	**1.7%**	**9**	**5.36%**
LCS_Active	**494**	**27.1**	**3,085**	**36**	**7.3%**	**5.0%**	**26**	**5.26%**
LCS_Latent	**333**	**17.5**	**1,826**	**27**	**8.1%**	**2.5%**	**13**	**3.90%**
LCU_Active	**31**	**38.5**	**5,067**	**3**	**9.7%**	**0.4%**	**3**	**9.68%**
LCU_Latent	**13**	**21.0**	**6,396**	**1**	**7.7%**	**0.3%**	**2**	**15.38%**
LNC	**1790**	**18.0**	**141**	**114**	**6.4%**	**1.0%**	**6**	**0.34%**
Total Vessels				**650**			**522**	

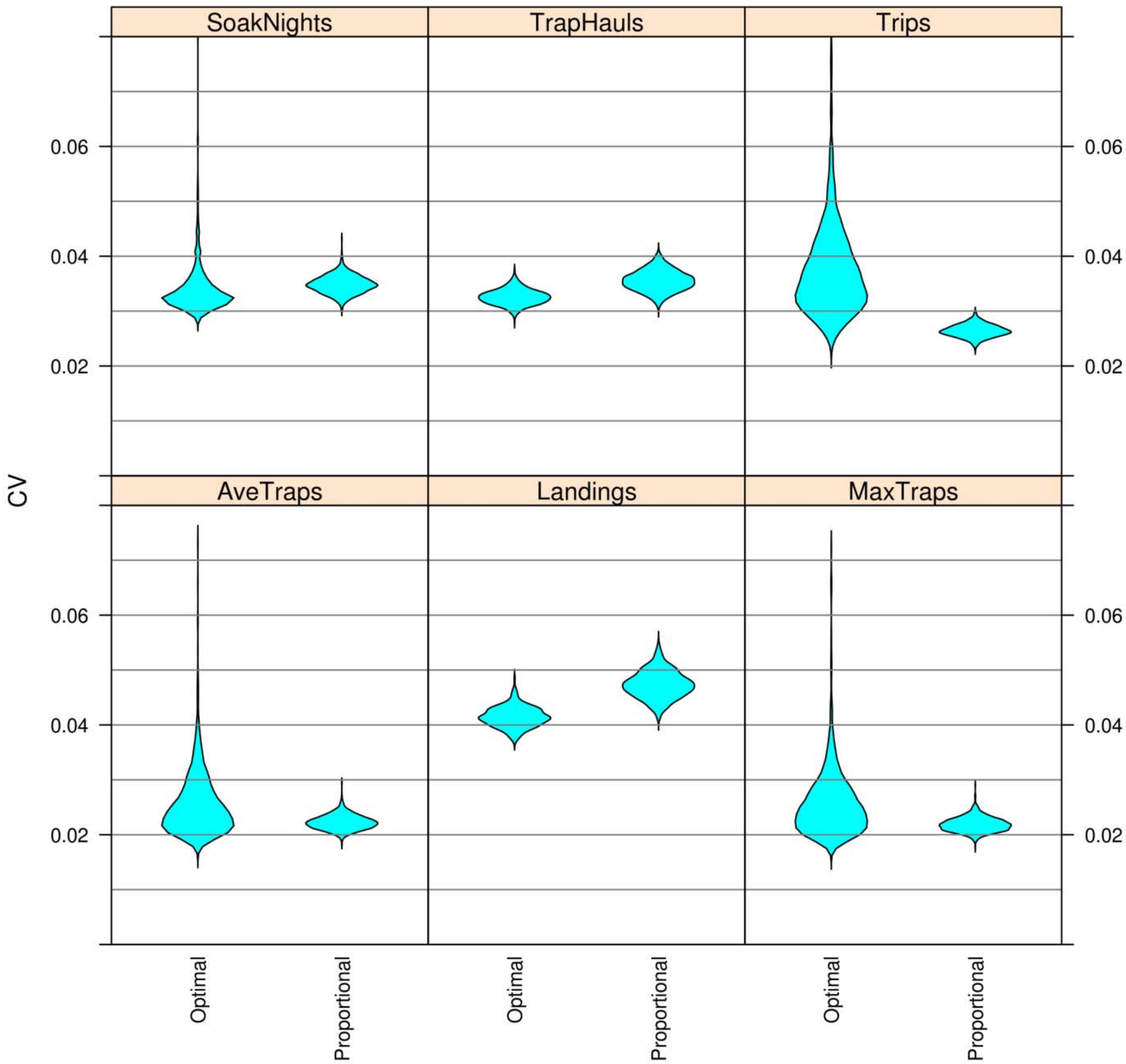

Figure 9. Bootstrapped distributions of CVs under current proportional allocation and optimal allocation based on trap hauls, assuming current sampling effort.

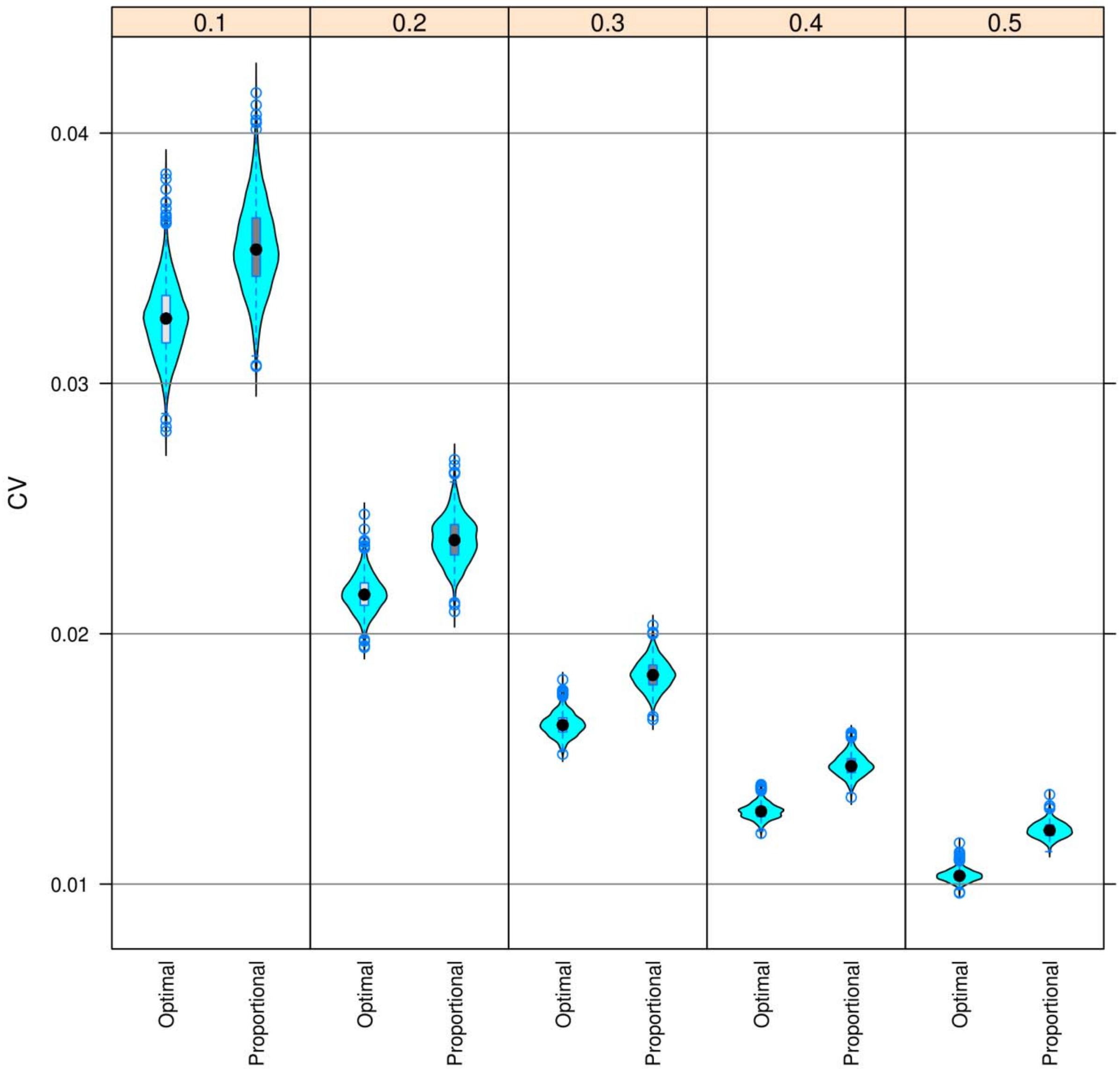

Figure 10. Comparison of Trap Haul CVs with optimal vs proportional sampling under 10 – 50% harvester reporting

Overall summary and Recommendations

To best characterize the US lobster fishery, the TC believes 100% harvester reporting is preferable to accurately account for all trap hauls and the spatial extent of the effort. Given the scale of the Maine lobster fishery with nearly 6,000 licenses and more than 265,000 trips annually, collecting this large amount of data with paper reports is challenging and inefficient. As a result, the TC recommends the state move towards electronic reporting.

The 2007 TC analysis on reporting levels using Connecticut's 100% coverage of harvester reports of their smaller fleet as a proxy for Maine's larger fishery indicated that 30% reporting was necessary to minimize the CV's of trap hauls in the Maine fishery. Addendum X found compromise with 10% minimum reporting level and required stratification by license class and Maine lobster zone. Tasked to revisit the 2007 conclusions and recommendations, the current TC analyses support a change of recommendations. The TC determined, due to the large scale of the Maine lobster fishery and subsequent large sample sizes, that 10% reporting is statistically significant and achieves CVs below 5% for all metrics considered. The expanded harvester data for total landings is statistically accurate when compared to the total dealer landings. Increasing the percentage of reporting between 10% and 100% provides marginal benefit to precision of the estimates.

Although the TC finds that the current level of 10% is statistically sufficient, the analyses identify that latent licenses are being oversampled creating inefficiencies and lower precision in the system of subsampling. The TC confirms the use of Maine license class as an appropriate stratification using zones for spatial coverage, but determined that active or latent status should be incorporated into the stratification. Using past harvester and dealer data, patterns in variability, and current Maine Harvester Logbook Program costs, the TC proposes an optimized sampling approach, rather than a proportional one, to assure the program is spending the greatest effort on active permits in the fishery but does not disregard the unpredictable latent permits in the system that also contribute to landings and effort.

3. Biological Sampling Gaps

Recent biological data (2015-2016) were reviewed to identify gaps in the current lobster sampling program and provide recommendations on increased biosampling in the fishery. Data reviewed included sea sampling and port sampling by state agencies and NOAA Fisheries (i.e. the Standardized Bycatch Reporting Methodology (SBRM) observer program), as well as additional sea samples from the Commercial Fisheries Research Foundation (CFRF). Both sex and length data are of primary importance during sampling as this data is used to characterize the catch sex ratio and size composition. Port samples can only be used to characterize size composition and sex ratio of landed lobsters, while sea samples with disposition codes (i.e., discarded or retained) can be used to characterize size composition and sex ratio of all lobsters caught (discards and landings). However, sea sampling is generally more expensive.

All biological samples were assigned to stat area, quarter, and year (i.e., stratum) of collection, the current level of detail used to characterize catch in the stock assessment. For port sampling, a sample is one vessel or one walk down the dock, depending on the sampling program. For sea sampling, a sample is all data collected by a sampler for a day within a stat area. Sample sizes were compared to the landings from the respective stratum for the last year of available data in the 2015 benchmark stock assessment (2013). Strata were filtered to those that accounted for at least 100,000 pounds of landings to determine the most important strata. Strata with sample sizes less than three were identified as strata that need increased biological sampling. A threshold of three samples was used as, during the previous stock assessment, stat areas which did not meet this number required gap-filling. Moreover, when the threshold number of samples was not available for a stratum in the assessment, data were borrowed from similar strata as a proxy. Collecting at least three samples from strata should reduce or eliminate the need to gap-fill biological data in future assessments, in turn, reducing data uncertainty in the assessments.

Results of the analysis indicate that the majority (>90%) of the fishery is sufficiently sampled, particularly inshore GOM which is well covered by the states except in the winter (Tables 8-9, Figures 11-12). Nineteen stat area and quarter combinations did not meet the sampling threshold for sea sampling (i.e, biological data on total catch) during both years, while an additional twenty five stat area and quarter combinations did not meet the threshold in one of the two years (Table 8). Figure 12 shows sea sampling coverage. Thirteen stat area and quarter combinations did not meet the threshold for combined sea and port sampling (i.e., landing biological data) during both years, while an additional seventeen stat area and quarter combinations did not meet the threshold in one of the two years (Table 9). Figure 12 shows combined sea and port sampling coverage. Much of the gaps in sampling are in LMA3 (offshore Gulf of Maine and George's Bank). Many stat area and quarter combinations met the threshold in 2015, but did not meet the threshold in 2016 due to a change in sampling effort in the SBRM observer program. This highlights the dependence of many stat area and quarter combinations (particularly those in the George's Bank region) on SBRM observer sampling. The fishery is also dependent on CFRF sampling, particularly in years when there are fewer SBRM sea days allocated to the lobster fishery. CFRF sampling is contingent on grant funding and, therefore, could be discontinued if that funding is not available. Without CFRF sea sampling, an additional eight stat area and quarter combinations would not have met the sample size threshold during both years (Table 10). Notably, in the absence of CFRF sampling, much of offshore SNE falls below our sampling threshold (Figure 13), which would make it more difficult to track this stock which is rapidly changing.

Recommendations

- The TC recommends that NOAA Fisheries implement a lobster biosampling program independent of the Standardized Bycatch Reporting Methodology (SBRM) sampling to ensure adequate sampling of federally-permitted vessels. The sampling frame should include all federally-permitted vessels, not just vessels with VTR requirements (this change in the SBRM sampling frame is currently being considered at the Council level) and should, at a minimum, try to randomize vessel selection. The program should be stratified by statistical area. In statistical areas in overlapping waters, state and federal programs should coordinate to ensure complementary sampling programs and increased efficiency to meet the needs of the assessment.
- The TC recommends collecting the minimum number of samples to meet the assessment threshold (3) and avoid gap-filling from all stat area/quarter/years with landings. Stat areas with landings should be identified based on data from the most recent stock assessment. Importantly, the number of samples should be appropriate to characterize landings in the stat area/quarter/year; sample sizes should increase for

areas with a high volume of landings. See Figures 11-13 for guidance on stat area and quarter combinations that have not met this threshold over the last two years.

- Sea samples are preferred over port samples because they provide information on discarded lobsters in addition to landed lobsters. However, port samples should be collected if sea sampling is not feasible (e.g., not enough funding, poor sampling conditions – winter, reluctant cooperation).
- As fishing effort continues to shift, this evaluation will need to be updated on a regular basis to identify priority sampling areas in the fishery. Stock assessments provide an optimal time for this evaluation as landings by stat area are updated and sampling data is compiled. Annual compliance reports also provide an opportunity to evaluate the success and implementation of current sampling recommendations.

Table 8. Sea sample size by stat area, quarter, and year for strata that accounted for at least 100,000 pounds of landings in 2013.

		N Sea Samples	
Stat Area	Quarter	2015	2016
525	4	8	1
464	3	41	2
525	3	7	1
526	3	18	2
561	3	56	1
562	1	1	1
526	4	20	0
522	4	7	0
464	1	14	2
522	2	1	0
465	4	9	2
522	3	20	0
464	2	2	1
522	1	0	0
525	2	10	1
616	3	5	0
561	4	10	0
525	1	2	0
561	2	1	3
515	2	11	2
515	1	7	2
515	4	1	0
623	3	0	0
515	3	1	1
616	2	4	0
521	1	0	0
561	1	3	2
612	1	4	0
465	2	3	0
537	1	0	1
526	2	2	0
464	4	5	2
616	4	8	0
611	2	1	6
623	4	0	0
465	1	4	0
623	2	0	0
465	3	0	0
616	1	2	0
526	1	4	0
538	4	0	0
611	1	0	0
538	1	0	0
611	4	0	1

Table 9. Combined port and sea sample size by stat area, quarter, and year for strata that accounted for at least 100,000 pounds of landings in 2013.

		N Port and Sea Samples	
Stat Area	Quarter	2015	2016
525	4	9	2
525	3	7	2
562	1	1	3
526	4	21	2
522	2	1	0
522	3	20	0
522	1	1	0
616	3	5	1
561	4	14	1
525	1	3	1
561	2	2	5
515	4	5	2
623	3	0	0
515	3	2	3
521	1	0	0
612	1	4	2
465	2	4	0
537	1	0	1
526	2	5	2
616	4	8	1
611	2	1	6
623	4	0	0
623	2	0	0
465	3	0	0
616	1	2	0
526	1	7	1
538	4	0	0
611	1	0	0
538	1	0	0
611	4	0	1

Table 10. Sea sample size by stat area, quarter, and year without CFRF sea samples included for strata that accounted for at least 100,000 pounds of landings in 2013.

		N Sea Samples	
Stat Area	Quarter	2015	2016
562	3	50	0
537	3	15	2
537	4	4	1
525	4	5	0
562	4	18	0
464	3	37	0
525	3	7	0
526	3	18	0
539	3	6	0
561	3	55	0
562	1	0	0
526	4	20	0
522	4	7	0
464	1	12	0
522	2	1	0
465	4	6	0
522	3	20	0
464	2	1	0
562	2	10	0
522	1	0	0
525	2	8	0
616	3	0	0
561	4	8	0
525	1	0	0
561	2	0	0
515	2	10	0
515	1	7	0
539	2	2	0
515	4	1	0
623	3	0	0
515	3	1	0
616	2	2	0
521	1	0	0
561	1	3	0
612	1	4	0
465	2	3	0
537	1	0	1
526	2	2	0
539	4	1	0
464	4	2	0
616	4	4	0
611	2	1	6
623	4	0	0
465	1	4	0
623	2	0	0
465	3	0	0
616	1	0	0
539	1	0	0
526	1	0	0
538	4	0	0
611	1	0	0
538	1	0	0
611	4	0	1

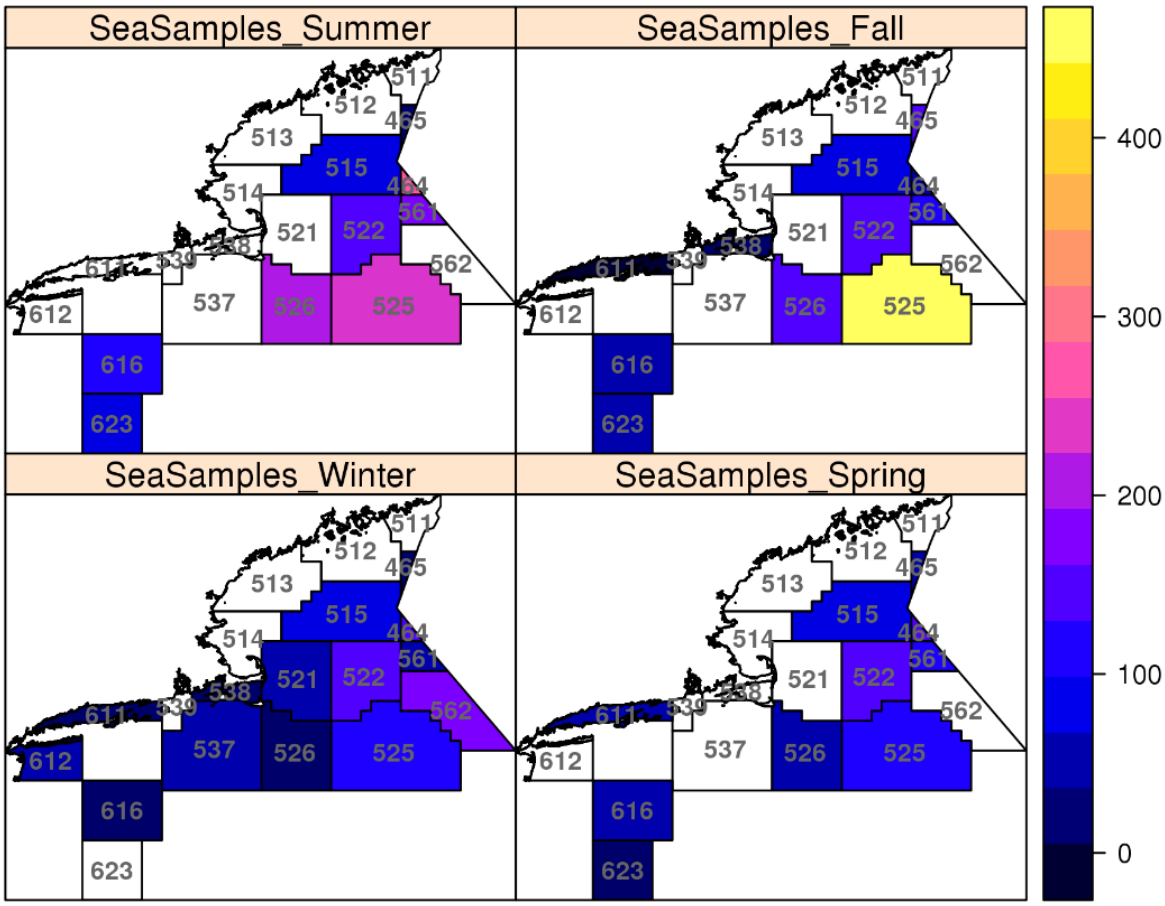

Figure 11. Coverage of sea sampling from 2015-2016 by stat area and quarters that accounted for at least 100,000 pounds of landings in 2013. The color scale indicates pounds landed in 2013 for stat area and quarters with inadequate sea sampling (n<3) during at least one year over that span. Any stat area and quarter combinations in white had at least three samples collected for both 2015 and 2016.

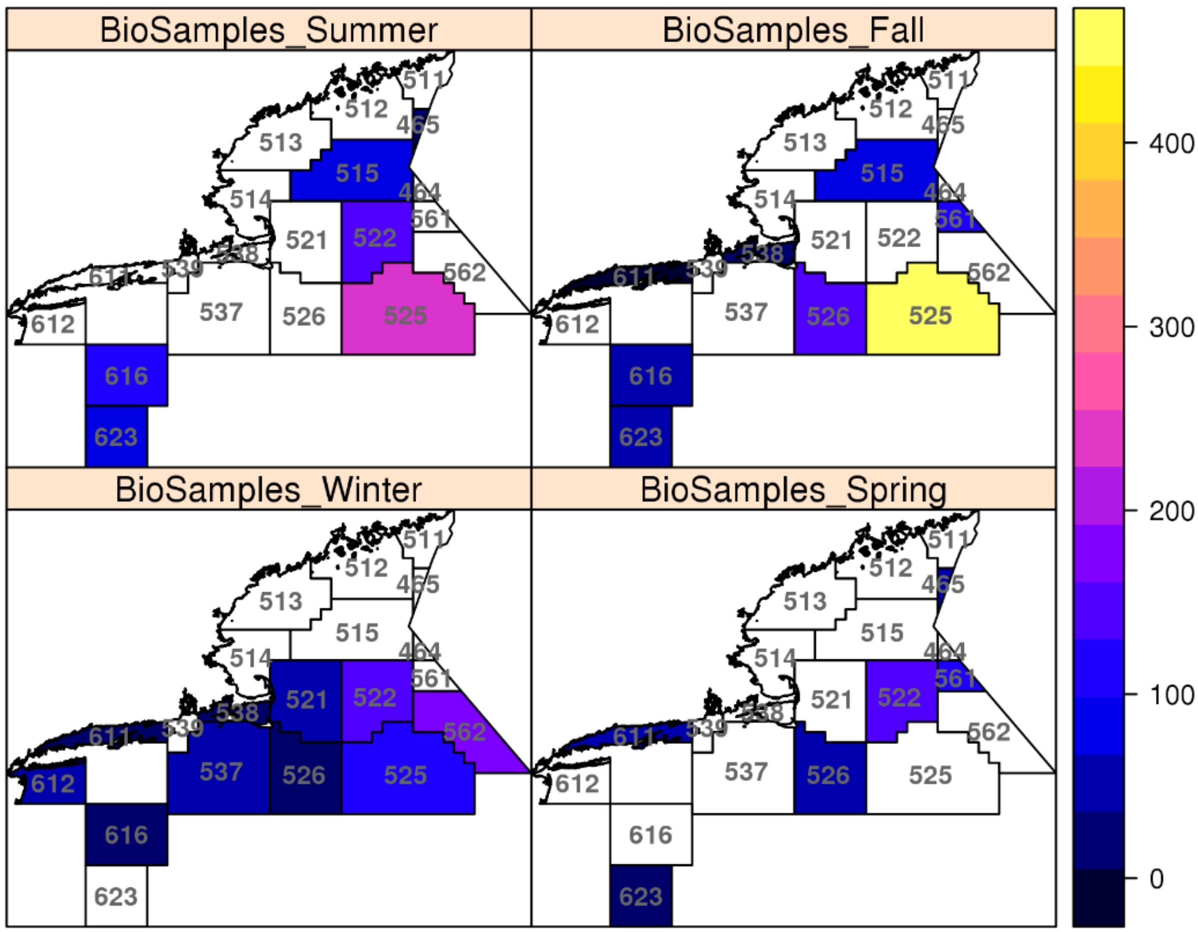

Figure 12. Coverage of biosampling (port and sea samples combined) from 2015-2016 by stat area and quarters that accounted for at least 100,000 pounds of landings in 2013. The color scale indicates pounds landed in 2013 for stat area and quarters with inadequate sea sampling (n<3) during at least one year over that span. Any stat area and quarter combinations in white had at least three samples collected for both 2015 and 2016.

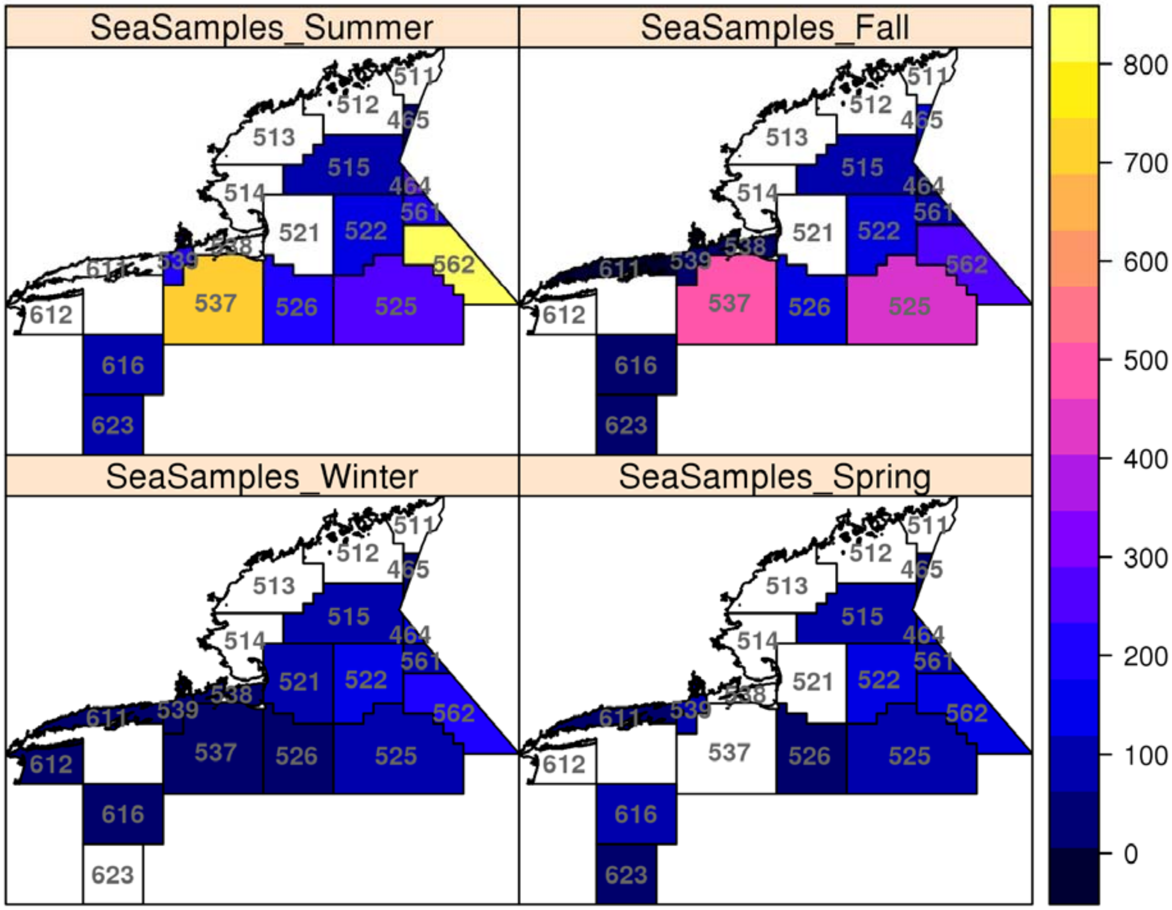

Figure 13. Coverage of sea sampling without CFRF sea samples from 2015-2016 by stat area and quarters that accounted for at least 100,000 pounds of landings in 2013. The color scale indicates pounds landed in 2013 for stat area and quarters with inadequate sea sampling (n<3) during at least one year over that span. Any stat area and quarter combinations in white had at least three samples collected for both 2015 and 2016.

References

Cochran, W.G., 1977, Sampling Techniques (Wiley, New York).

Lo, N.C., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Canadian Journal of Fisheries and Aquatic Sciences 49: 2515-2526.

Wilson C.W. M.Gosselin, D.A. Libby, H. Bray and G. Robinson. 2004. Maine Landings Issues, Issue paper for consideration by the ASMFC Lobster Technical Committee. August 2004, 9 pp.