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Alternative Sampling Designs for the 2018 Annual Deployment Plan of the North Pacific Observer Program

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ABSTRACT

Changes in regulation enacted in 2013 have enabled the Alaska Fisheries Science Center's Fishery Monitoring and Analysis Division (FMA) and the Alaska Regional Office's Sustainable Fisheries Division to work collaboratively on an Annual Deployment Plan (ADP). Each ADP documents how the National Marine Fisheries Service (NMFS) plans to deploy observers into fishing activities for the coming year under the limits of available funding. Draft ADPs are presented to the North Pacific Fishery Management Council (Council) during September - October and are finalized in December.

The sampling design for observer deployment has two elements: how the population is subdivided (i.e., stratification schemes) and how available samples are allocated (i.e., allocation strategies). Here the relative performance of 10 alternative sampling designs (at the primary sampling unit- the trip) are compared in support of the draft 2018 ADP. These alternative sampling designs consisted of the combination of two stratification schemes (gear-type only or gear-type × tendering activity), two metrics upon which to base optimizations [one consisting of discard of groundfish with Prohibited Species Catch (PSC) of Pacific halibut and the other consisting of the prior and PSC of Chinook salmon], and three allocation strategies (no optimization, a "hurdle" approach to optimization, and a optimization only). All optimization allocations incorporate three variables measured over the past 3 years: variance in the metric, the average cost of observing a trip, and the number of trips. Total afforded sample size is determined by the available budget and the average cost of observing each trip. Resulting selection rates derive from sample size, allocation weightings and the anticipated fishing effort which was defined as the most recent complete year of data.

The total number of observer days that can be afforded is 4,062 which represents a 33% increase from 2017. Gap analyses that examine the chance of at least one or three observed trips in a NMFS Area × gear type combination (cell) were used as a performance metric. Gap analyses illustrated that stratifications based on gear type (3 strata) were outperformed by stratifications based on gear type × tendering activity (6 strata). Potential gaps in observer coverage appear to be mostly concentrated in areas with low fishing effort with fewer than 12 trips in a cell. Simulations were performed to measure the potential impact of unknown vessel participation in electronic monitoring (EM). The variability in gap analyses from randomized differences in EM participant vessels was relatively minor (less than 10% probability of observation shifts across deployment designs).

The NMFS recommended an observer deployment design for the draft 2018 ADP that has gear type × tendering stratification and uses a "hurdle" approach to sample allocation wherein 15% base coverage is obtained first across all strata and the remainder is optimized according to the variance in the metric of discarded groundfish catch combined with PSC Pacific halibut and Chinook salmon. At their October 2017 meeting the Council did not support the NMFS recommendation and instead proposed a five strata design with optimal sample allocations based on discarded groundfish catch and PSC of Pacific halibut only. Comparisons between the NMFS and Council recommended designs were included in the final 2018 ADP.

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INTRODUCTION

The North Pacific Observer Program uses a hierarchical sampling design with randomization at all levels to achieve unbiased data from fishing operations in the region. The Annual Deployment Plan (ADP) documents how NMFS plans to deploy observers in the partial coverage category onto fishing trips in the upcoming year under the limits of available funding.

The ADP provides an annual process for NMFS and the Council to evaluate the sampling design used to deploy observers and EM. In the Draft 2017 ADP, NMFS presented six alternative stratification designs for deployment of observers (NMFS 2016a). The adopted design in the Final 2017 ADP allocates observed trips among six strata defined by gear and tendering activity according to an optimized allocation resulting from the interactions of stratum size and variance in total discarded catch with Pacific halibut Prohibited Species Catch (PSC, NMFS 2016b). Following the most recent Annual Report (NMFS 2017a) and subsequent Council motion this analysis builds upon the 2017 ADP design by evaluating whether to continue the tender strata definition and compares the following alternative allocation designs: 1) equal coverage rates that can be afforded across all strata with available funding; 2) 15% coverage rates across all strata with optimization on anything above 15%; and 3) optimization of all partial-coverage trips. All allocation strategies evaluated include those based on discarded groundfish and halibut, Chinook salmon PSC and a blended combination of the two. In addition, this ADP accounts for the uncertainty introduced by Electronic Monitoring (EM) pool by simulating the full range of potential partial coverage populations in the hook-and-line and pot gear strata.

This analysis provides a comparison of the relative performance of alternative strata definitions, stratification schemes, and allocation designs for the deployment of observers into the partial coverage fleet for consideration in 2018.

METHODS

Data Preparation: Defining the Partial Coverage Fleet

The partial coverage fleet in general consists of the catcher vessel fleet when not participating in a catch sharing or cooperative style management program. Changes to this general design have resulted from NMFS policy, Council Action, and regulations. Activities expected to occur in 2018 that have been excluded from observer coverage in the past include 1) catcher vessels while fishing in state-managed fisheries, 2) catcher vessels fishing with jig gear, 3) catcher vessels fishing that are sized < 40 feet in length overall (LOA), and 4) vessels that volunteer for EM. It was assumed that AFA-endorsed trawl catcher vessels that volunteered to carry full observer coverage when fishing in the Bering Sea and Aleutian Islands in 2017 will continue to do so in 2018.

A database containing 2014, 2015, and 2016 species-specific catch amounts, dates, locations, and disposition, and observation status was first enhanced with additional information from the Alaska Regional Office and FMA, and then parsed to reflect the partial coverage fleet subject to observer coverage in 2017, and finally re-labelled according to the alternative deployment designs for 2018.

Budget Forecasting

The available budget for observer days in 2018 was estimated from carryover funds from the previous fiscal year, stable fee revenues between 2018 and 2019, and a $1M increase in Federal funding in fiscal year 2018. Sea-day expenditures were set so that the total number of observer days would remain stable between 2018 and 2019 and there would be no carryover funds after December of 2019. Budget forecasting is necessary to determine not only the number of sea-days expected for the upcoming calendar year, but also to determine how much money should be allocated for each contract year, which runs from 17 June of one year to 16 June of the next. For this reason, calendar years were divided into two seasons(s): a first half (FH) period from 1 January 2017 to 16 June 2017 and a second half (SH) from 17 June 2017 to 31 December 2018.

The exercise of budget forecasting starts in the SH of the calendar year (y) prior to the ADP (y - 1; here y is = 2018 and y - 1 = the SH of 2017). The forecasting process requires an estimation of available funds (F). The available sea day budget for the current fiscal year (B_o, comprised of SH 2017 and FH 2018) was determined by subtracting the expected travel for the current fiscal year from F. Expected travel (T_{exp}) was estimated from the division of the total observer day funds expended for each season of the previous fiscal year (E_o) into the total travel funds (T) expended in the previous fiscal year and multiplying this ratio (R) by the available funds for the current fiscal year, or

$$T_{exp} = \frac{\sum_{s=1}^{S} E_{o,\,y-1}}{\sum_{s=1}^{S} T_{y-1}} F = RF\,. \qquad \text{Eq. (1)}$$

In order to calculate the funds remaining at the end of the current fiscal year, the total number of sea days and their cost is needed. While the number of observer days (d_o) in FH 2017 are known, those of SH 2017 were assumed using the number of expected days from the 2017 ADP (NMFS 2016b). The expected expenditures of funds for observer days (E_o) for each season is the product of d_o and the cost of a sea-day from the contract between NMFS and its observer provider. Subtraction of E_o from B_o in SH 2017 yielded the value for F in the FH of 2018. Since FH 2018 is in the SH of the fiscal year, travel funds were already accounted for, so the only expenditure to account for in this time period is the expenditure of observer days. By setting (1) T_{exp} to equal a constant R with an updated F each fiscal year, (2) d_o FH $y + 1..n$ equal to d_o in FH 2018, and (3) d_o SH $y + 1..n$ equal to the ratio of d_o SH : d_o FH, the value for d_O FH 2018 could be used as the main input into initial cost forecasts. The value for d_o FH 2018 was adjusted until the E_o 2019 = B_o 2019, and d_o 2018 = d_o 2019.

The values for F_{2018} and the average cost of an observer day (from F_{2018} divided by d_o 2018) from above were then passed as inputs into the analyses described in the *Deployment Design* section below. From 1,000 iterations of simulated sampling, the value for the ratio of d_o SH 2018 : d_o FH 2018 was determined and passed back into the budget forecasts. The values for d_o FH 2018 was then adjusted in an iterative process until E_o 2019 = B_o 2019, and d_o 2018 = d_o 2019. At this point the budgetary forecast was considered complete, and the values for F_{2018} and the average cost of an observer day in 2018 were passed a final time into the analyses described in the sections.

Deployment Design

The sampling design for observer deployment (hereafter 'deployment design') involves two elements; how the population of partial coverage trips is subdivided (*stratification*), and what proportion of the total observer deployments are to occur within these subdivisions (*allocation*).

Stratification Schemes

Stratification is the partitioning of units in the population into independent groups (or sub-populations). These groupings are individually called stratum (strata if plural). Stratified random sampling is the act of obtaining independently random samples from within each stratum. For this reason, strata need to be defined based on criteria known prior to the draw of the sample. This means that elements of fishing trips known prior to departure are valuable in defining deployment strata, whereas catch is not.

There are numerous reasons for creating strata. These include the following: when a separate estimate for a sub-population is desired, when administrative convenience (field logistics) requires it, and to increase the precision of sample-based estimates of the total. Increased precision is accomplished through the division of a heterogeneous population into homogeneous sub-populations, and the resulting variance of the population total being calculated from the variance of the individual stratum (Cochran 1977). The collection of strata that together subdivide the population of trips in partial coverage constitutes a stratification scheme. In this study two stratification schemes were considered. These stratification schemes (with the number of the individual strata in parentheses) are as follows:

1. Gear × Tender (6 strata)

This *status quo* stratification divides the partial coverage trips into six strata based on gear and tendering status.

- Hook and Line ≥ 40' LOA (HAL).
- Tender Hook and Line ≥ 40' LOA (Tender HAL).

- Pot ≥ 40' LOA (POT).
- Tender Pot ≥ 40' LOA (Tender POT).
- Trawl (TRW).
- Tender Trawl (Tender TRW).

2. Gear (3 strata)

This stratification was used in 2016 and is comprised of HAL, POT, and TRW vessels.

Sample Allocation

Sample allocation refers to the allotment of trips in a stratum. Three allocation strategies were compared for 2018 observer deployment (the full workflow for the methods used in these designs is found in Fig. 1):

1. Equal Allocation

This allocation design estimates the equal coverage rate (trips sampled/total trips) across strata that can be afforded with available funding. Unlike previous years when optimal allocation was used, this design allocates samples proportional to fishing effort in a stratum. Similar to past years, the number of fishing trips (N) that occur within H strata was assumed to be equal to the most recent years' fishing activity. The cost of an observed trip in each stratum (c_h) is estimated as the product of the mean trip duration in a stratum and the cost of an observer day. The equal coverage rate afforded (r) across all strata was then calculated as

$$r_h = \frac{F_{2018}}{\sum_{h=1}^{H} c_h \, N_h}, \qquad \text{Eq. (2)}$$

where F_{2018} is the estimated funds from the budget forecasting.

2. 15% + Optimized

Unlike equal rates afforded, this sample allocation adopts a "hurdle" approach to optimization. Optimization aims to maximize precision for the chosen metrics for the least cost. In this allocation strategy, observer sea days are first allocated equally up to a 15% coverage rate. Once 15% has been met, an optimal allocation algorithm (described below) is used to allocate remaining monitored trips among strata. If available funding does not permit equal allocation up to 15%, the total amount of additional funds needed to meet 15% is estimated. The minimum 15% coverage rate was recommended by the Observer Science Committee because it has been shown to eliminate or minimize severe gaps in observer data (Faunce et al. 2017, NMFS 2017, NMFS 2015c, NMFS 2015d, p. 98). This allocation first estimates the number of trips left over in each stratum after 15% coverage has been met

$$N_{h+} = N_h - (0.15 \times N_h) \qquad \text{Eq. (3)}$$

and then calculates the new budget (F_+) available for optimized allocation among strata

$$F_{2018+} = \sum_{h=1}^{H} c_h \, N_{h+} \, . \qquad \text{Eq. (4)}$$

The F_{2018+} and N_{h+} are then used in the optimization algorithm, where F_{2018+} and N_{h+} are substituted for F_{2018} and N_h, respectively, in the following equations.

3. Optimized

This design was used in the 2016 and 2017 ADP and has no minimum sample size requirement. If n is the number of observed trips afforded for the year among all partial coverage fishing trips in each strata (N_h), and the estimate of the chosen metric of interest has S^2 variance, the number of samples that is considered optimum for each stratum (n_h) is denoted by the product of the total sample size and the optimal weighting (W_{hopt}),

$$n_h * W_{hopt}, \quad \text{where } W_{hopt} = \frac{\frac{N_h S_h}{\sqrt{c_h}}}{\sum_{h=1}^{H}\left(\frac{N_h S_h}{\sqrt{c_h}}\right)} \quad \text{Cochran (1977).} \qquad \text{Eq. (5)}$$

While equation 1 gives the allocation of observed trips among strata, it does not give the total sample size. To obtain this we can rearrange the previous equation as

$$n = \frac{F_{2018} \sum_{h=1}^{H}\left(\frac{N_h S_h}{\sqrt{c_h}}\right)}{\sum_{h=1}^{H}\left(N_h S_h \sqrt{c_h}\right)} \quad \text{Cochran (1977).} \qquad \text{Eq. (6)}$$

The value for n is used to solve for the sample size in each stratum using the stratum weightings described previously. The resulting coverage rate in each stratum is obtained from the division of n_h by N_h.

Blended allocations

Optimized sample allocations were generated using the variance of discarded catch with Pacific halibut PSC included. However, optimizations may be conducted on more than one target metric. Following the 9 June 2017 Council Motion that emphasized PSC-limited fisheries, we included an additional variable of Chinook PSC counts into the optimization. Cochran (1977) shows that the *blended optimal allocation* (m_h) is derived from the average number of optimal sample sizes measured across L metrics,

$$m_h = n \times \overline{n}_h, \quad where \ \overline{n}_h = \frac{\sum_{l=1}^{L} n_{l,h}}{L}. \qquad \text{Eq. (7)}$$

It is worth noting that unless n_h among all metrics are positively correlated, the resulting compromise allocations may be substantially different from n_h for any individual target metric.

Evaluation of Alternative Designs

Data from 2014, 2015, and 2016 were combined and treated as a single meta-year for the calculation of optimal allocation weightings (W_{hopt}) in each strata. Distributions of the trip duration, discarded catch with halibut PSC, and Chinook PSC counts for each stratification scheme were plotted since these form the raw ingredients for the sample size allocation formulae (Fig. 2).

Gap Analyses

Observers provide an invaluable service to the generation of total catch estimates; if there are no observer data in a given domain of interest, then data must be borrowed from similar or adjacent sampling units, resulting in poor inference about the total catch. An insufficient level of observer coverage can have implications for in-season quota management, catch estimation, stock assessment, and management of protected resources. The evaluation of alternative designs was determined using gap analysis following previous evaluations of observer program deployments (NMFS 2015a, NMFS 2016a). Gap analysis estimates the probability of observing a trip in a given domain of interest; the fewer the gaps, the better the design.

The gap analyses and all subsequent analyses were performed using 2016 data under the assumption that immediate past fishing activity is a good predictor of future fishing activity (Fig. 1). Similar to the 2017 ADP, the number of partial coverage trips corresponding to each stratification scheme was summed into domains defined by gear and NMFS reporting area (NMFS 2016a, NMFS 2016b).

The hypergeometric distribution was used to calculate the probability of observing at least one and three trips within a domain for each stratification and allocation design. These probabilities were made binary (0 and 1) based on whether or not they exceeded 50%. This value was chosen as the minimum acceptable value since it represents equal chance of meeting the needs of variance calculation within a domain. The proportion of domains that passed the three or more criteria was calculated for comparison and represented as a G score (G) for each allocation strategy. This G score was divided by the maximum G score within a given stratification scheme to provide a relative metric. This relative G score ranges from 0.00 to 1.00, where 1.00 is best.

Uncertainty Due to Electronic Monitoring

The EM pool will remain a voluntary stratum in the partial coverage category in 2018. Methods used to estimate costs and allocate funds for maintenance and growth of the EM program in 2018 are described in Appendix B of NMFS 2017b. This analysis estimates that there will be sufficient funding available to wire 35 new vessels for monitoring in 2018 for a total of 110 EM vessels. Enrollment into the EM stratum is open until 1 November 2017, after the publication date and presentation of the Draft ADP to the NPFMC. The Final Rule for EM states that hook-and-line and pot gear vessels in the partial coverage category are eligible to volunteer for the EM stratum. Because the open enrollment period extends beyond the date of completion of the ADP, the 2018 population of vessels in the HAL and POT strata were unknown. To account for this uncertainty, 10,000 simulations of random draws of 35 new vessels from the HAL and POT strata were performed and coverage rate and gap analyses on the vessels remaining in the partial coverage category were evaluated from each simulation. The differences in the outcomes from each simulation were depicted as error bars around the resulting coverage rates and a subset of random draws from the outcomes of the gap analyses. All resulting tables show the mean estimates of coverage rates and probabilities from the gap analyses from the simulation outcomes.

RESULTS AND DISCUSSION

The total number of observer days available for deployment in the Observer Program is 4,062. Depending on the deployment design chosen, the ratio between the SH and FH days is 0.876 - 0.879 to 1.

The optimization algorithm puts more samples where 1) strata are larger, 2) variance of a chosen metric is larger, and 3) costs are lower (Cochran 1977). This accommodates differential trip duration and differential costs between observation types (e.g., human vs. cameras) that may be needed in future ADPs. Moreover, the comparison of coverage rates using equal allocation, 15% plus optimization, and full optimization elucidates the tradeoff between minimizing gaps in coverage and emphasizing the importance of certain metrics such as groundfish discards and PSC.

Whether resulting rates of observer coverage differ between deployment designs depends upon how the rates are compared (Fig. 3, Tables 1, 2). Coverage rates differ substantially between allocation designs, in particular between designs that use equal or 15% + optimized allocation and designs that rely solely on optimization based on chosen metrics. Within a given allocation design, coverage rates vary minimally within a stratum between stratification schemes. For example, within the 15% + optimized on discarded groundfish catch including Pacific halibut PSC allocation, the rates for TRW, HAL, and POT vary minimally between stratification schemes (TRW = 18.08%, 18.16%; HAL = 17.33%, 17.32%; POT = 15.59%, 15.56% for Gear and Gear × Tender, respectively; Tables 1, 2). The lack of difference in coverage rates within a stratum and allocation design is due to the fact that tendering strata are relatively small in terms of total trips compared to gear-based strata (N_{h2018} in Tables 1, 2). The Optimized allocation based on blended discarded groundfish catch with halibut and Chinook PSC results in the lowest rates for HAL and POT and the highest rates in TRW (HAL = 10.76%, 10.86%; POT = 2.20%, 2.04%; TRW = 31.15%, 34.42% for Gear and Gear × Tender, respectively).

Results from gap analyses indicate that allocation based solely on optimization results in the most gaps in observer coverage (Fig. 4, where the curves that reach the top the fastest, or the farthest to the left, represent designs that result in the fewest gaps in coverage). The optimized allocation based on blended discarded groundfish catch with halibut and Chinook PSC has the most gaps, whereas designs that use equal or 15% + optimized allocations result in far fewer gaps in coverage (indicated by high relative G scores in Table 3). The best performing designs result in a predicted 76% and 62% of cells with at least a 50% probability of having three or more observed trips in the Gear and Gear × Tender stratification, respectively. A closer examination of resulting gaps by NMFS Reporting Area and stratum combination in the Bering Sea and Aleutian Islands (Tables 4, 5) and the Gulf of Alaska (Tables 6, 7) suggests that potential gaps (shown in bold) in designs that use equal or 15% + optimized allocations only occur when there is low fishing effort (fewer than 12 fishing trips) in that cell.

Results from the simulation analysis, which was conducted to account for uncertainty introduced by open-enrollment of HAL and POT boats into EM, suggests that its impact on ADP results is relatively minor. The “error” bars shown in Figure 3 are undetectable except in the HAL Tender stratum. The variability in HAL Tender can be accounted for by the small number of predicted trips in this stratum (7 trips, Table 2). The variability seen in the gap analyses is also relatively minor, with the probability of observing at least three trips shifting less than 10% across deployment designs (Fig. 4).

The 15% + optimized allocation is a balance between the prioritization of PSC-limited fisheries in optimization weighting schemes and the need to reduce gaps in observer coverage in the partial coverage category. Within this allocation design, the gear-based stratification scheme that optimizes on discarded groundfish catch and halibut PSC performs the best in the gap analysis 4). However, there are numerous reasons to select the Gear × Tender stratification. First, the Gear × Tender stratification scheme, which was first implemented in 2017, has not been fully evaluated in the Annual Report process. Maintaining this stratification scheme for another year, while improving the allocation design, would allow the Observer Program to fully analyze the effects and performance of these designs. Further, as discussed in the 2016 Observer Program Annual Report, tendering activity in pollock trawl fisheries continues to represent a sampling challenge for the Observer Program (NMFS 2017). Although it has yet to be evaluated whether the addition of a Tender TRW stratum fully alleviates this problem, it does ensure an expectation for a certain level of coverage for that operation type.

This analysis relies on several key assumptions and has limitations. For example, it is assumed that discarded catch on each sampled trip is known without variance, and a simple single-stage estimator of trip variances are used in optimization algorithms. The variances used in this analysis are not the same that will arise from the five-stage sampling design of the observer program (Cahalan et al. 2014). Previous studies have demonstrated that although the vessel was a significant factor in estimating total discards, the first stage of nested sampling designs (vessel or trip) is often the stage with the least amount of variance (Allen et al. 2002, Borges et al. 2004). Multi-stage based estimates of variance for each stratum and metric will be used in subsequent analyses when they become available.

The resulting coverage rates for observer deployment depend upon the amount of fishing effort and the available number of observer days. Since this analysis is focused on the relative performance of alternative stratification schemes, it uses a simplified assumption of future fishing effort-- namely that fishing in 2016 will be identical to that in 2018. This assumption is made in anticipation that for the Final 2018 ADP, when a stratification scheme is selected, a more careful estimate of anticipated fishing effort would be made at that time, and resulting rates adjusted to reflect this new prediction. This approach was adopted for the Final 2017 ADP (NMFS 2016b).

Finally, the resulting coverage rates presented in this study should only be considered preliminary estimates and may differ from rates determined in the Final ADP or realized in 2018. Once a stratification design for the Final ADP is established and EM participants known, more focused simulated sampling procedures will be used to estimate expected coverage rates following the methods described in the Final 2016 and 2017 ADPs (NMFS 2015b, NMFS 2016b).

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Table 1. -- Comparison of the number of trips in a stratum (N_{h2018}), the optimal sample weighting (W_{hopt}), preliminary predicted observed trips (n_h), days (d_h), and coverage rates (r_h) resulting from the Gear-based stratification scheme under three allocation designs: 1) Equal allocation, 2) 15% + Optimized, and 3) Optimized. Metrics used for optimization included: 1) discarded groundfish catch with Pacific halibut prohibited species catch (PSC) and 2) a blended optimization of 1) and Chinook PSC (in numbers of fish).

Stratum (*h*)	**Metric**	N_{h2018}	W_{hopt}	n_h	d_h	r_h **(%)**
Equal Allocation						
HAL	None	2,237		388	1,896	17.36
POT	None	963		167	599	17.36
TRW	None	2,686		466	1,567	17.36
15% + Optimized						
HAL	Discards w/ halibut PSC (*Status quo*)	2,237	0.37	388	1,892	17.33
POT	Discards w/ halibut PSC (*Status quo*)	963	0.04	150	538	15.59
TRW	Discards w/ halibut PSC (*Status quo*)	2,686	0.59	486	1,632	18.08
HAL	Blended: Discards w/ halibut PSC + Chinook PSC	2,237	0.21	365	1,784	16.33
POT	Blended: Discards w/ halibut PSC + Chinook PSC	963	0.02	147	528	15.29
TRW	Blended: Discards w/ halibut PSC + Chinook PSC	2,686	0.77	521	1,751	19.40
Optimized						
HAL	Discards w/ halibut PSC (*Status quo*)	2,237	0.41	417	2,035	18.63
POT	Discards w/ halibut PSC (*Status quo*)	963	0.04	42	151	4.38
TRW	Discards w/ halibut PSC (*Status quo*)	2,686	0.55	558	1,877	20.79
HAL	Blended: Discards w/ halibut PSC + Chinook PSC	2,237	0.23	241	1,175	10.76
POT	Blended: Discards w/ halibut PSC + Chinook PSC	963	0.02	21	76	2.20
TRW	Blended: Discards w/ halibut PSC + Chinook PSC	2,686	0.75	836	2,811	31.15

Table 2.-- Comparison of the number of trips in a stratum (N_{h2018}), the optimal sample weighting (W_{hopt}), preliminary predicted observed trips (n_h), days (d_h), and coverage rates (r_h) resulting from the Gear × Tender stratification scheme under the allocation designs described in Table 1. Bold values denote NMFS recommendations for the 2018 ADP. Bold values denote NMFS recommendations for the 2018 ADP.

Stratum (*h*)	**Metric**	N_{h2018}	W_{hopt}	n_h	d_h	r_h **(%)**
Equal Allocation						
TRW	None	2,427		421	1,377	17.34
HAL	None	2,231		387	1,890	17.34
POT	None	858		149	517	17.34
Tender TRW	None	259		45	196	17.34
Tender HAL	None	7		1	4	15.46
Tender POT	None	105		18	78	17.31
15% + Optimized						
TRW	Discards w/ halibut PSC (*Status quo*)	2,427	0.55	441	1,442	18.16
HAL	Discards w/ halibut PSC (*Status quo*)	2,231	0.37	386	1,888	17.32
POT	Discards w/ halibut PSC (*Status quo*)	858	0.03	133	464	15.56
Tender TRW	Discards w/ halibut PSC (*Status quo*)	259	0.04	44	194	17.13
Tender HAL	Discards w/ halibut PSC (*Status quo*)	7	0.00	1	4	15.42
Tender POT	Discards w/ halibut PSC (*Status quo*)	105	0.01	17	72	16.02
TRW	**Blended: Discards w/ halibut PSC + Chinook PSC**	**2,427**	**0.75**	**480**	**1,571**	**19.78**
HAL	**Blended: Discards w/ halibut PSC + Chinook PSC**	**2,231**	**0.21**	**364**	**1,781**	**16.34**
POT	**Blended: Discards w/ halibut PSC + Chinook PSC**	**858**	**0.02**	**131**	**456**	**15.28**
Tender TRW	**Blended: Discards w/ halibut PSC + Chinook PSC**	**259**	**0.02**	**42**	**182**	**16.06**
Tender HAL	**Blended: Discards w/ halibut PSC + Chinook PSC**	**7**	**0.00**	**1**	**4**	**15.42**
Tender POT	**Blended: Discards w/ halibut PSC + Chinook PSC**	**105**	**0.00**	**16**	**70**	**15.46**

Table 2. -- Continued.

Stratum (*h*)	**Metric**	N_{h2018}	W_{hopt}	n_h	d_h	r_h **(%)**
Optimized						
TRW	Discards w/ halibut PSC (*Status quo*)	2,427	0.52	530	1,736	21.86
HAL	Discards w/ halibut PSC (*Status quo*)	2,231	0.41	416	2,035	18.67
POT	Discards w/ halibut PSC (*Status quo*)	858	0.03	35	121	4.07
Tender TRW	Discards w/ halibut PSC (*Status quo*)	259	0.03	31	136	11.99
Tender HAL	Discards w/ halibut PSC (*Status quo*)	7	0.00	1	4	15.47
Tender POT	Discards w/ halibut PSC (*Status quo*)	105	0.01	7	29	6.50
TRW	Blended: Discards w/ halibut PSC + Chinook PSC	2,427	0.73	835	2,733	34.42
HAL	Blended: Discards w/ halibut PSC + Chinook PSC	2,231	0.23	242	1,184	10.86
POT	Blended: Discards w/ halibut PSC + Chinook PSC	858	0.02	18	61	2.04
Tender TRW	Blended: Discards w/ halibut PSC + Chinook PSC	259	0.02	16	68	6.02
Tender HAL	Blended: Discards w/ halibut PSC + Chinook PSC	7	0.00	0	0	0.01
Tender POT	Blended: Discards w/ halibut PSC + Chinook PSC	105	0.00	4	16	3.62

Table 3. -- Results of gap analyses by deployment design. G scores are the proportion of cells with at least a 50% chance of observing three (G3) or one (G1) trips during the year. G Relative is the G score for each allocation design divided by the maximum, where G relative equal to 1.00 represent the designs with the fewest predicted gaps in coverage. Allocations are listed in descending order by G3.

Allocation design	**G3**	**G3 Relative**	**G1**	**G1 Relative**
Gear Stratification				
Equal Allocation	0.76	1.00	0.91	1.00
15% + Optimized on Discards + Halibut + Chinook PSC	0.76	1.00	0.91	1.00
15% + Optimized on Discards + Halibut PSC	0.76	1.00	0.91	1.00
Optimized on Discards + Halibut PSC	0.73	0.96	0.91	1.00
Optimized on Discards + Halibut + Chinook PSC	0.64	0.84	0.79	0.87
Gear × Tender Stratification				
Equal Allocation	0.62	1.00	0.84	1.00
15% + Optimized on Discards + Halibut + Chinook PSC	0.62	1.00	0.84	1.00
15% + Optimized on Discards + Halibut PSC	0.62	1.00	0.84	1.00
Optimized on Discards + Halibut PSC	0.58	0.93	0.80	0.95
Optimized on Discards + Halibut + Chinook PSC	0.47	0.75	0.64	0.76

Table 4. -- The number of trips and associated likelihood of observing at least three trips within each NMFS Reporting Area and stratum combination in the Bering Sea and Aleutian Islands for each allocation design under the Gear-based stratification scheme. If the likelihood of observing at least three trips is less than 0.50, the cell is bolded in order to identify potential gaps more easily. The number of trips in an Area Stratum combination are not whole numbers since fishing trips can span more than one NMFS Reporting Area.

BSAI Gear Stratification

NMFS Area_Stratum	Trips	Equal Allocation	15% + Optimized on Discards + Halibut PSC	15% + Optimized on Discards + Halibut + Chinook PSC	Optimized on Discards + Halibut PSC	Optimized on Discards + Halibut + Chinook PSC
509_POT	129.0	1.00	1.00	1.00	0.94	0.56
509_TRW	133.7	1.00	1.00	1.00	1.00	1.00
513_HAL	5.4	**0.06**	**0.06**	**0.05**	**0.07**	**0.02**
514_HAL	11.2	**0.31**	**0.31**	**0.28**	**0.35**	**0.12**
517_HAL	5.4	**0.06**	**0.06**	**0.05**	**0.07**	**0.02**
517_POT	96.4	1.00	1.00	1.00	0.81	**0.36**
517_TRW	104.7	1.00	1.00	1.00	1.00	1.00
518_HAL	32.7	0.94	0.94	0.92	0.96	0.70
518_POT	18.6	0.65	0.58	0.57	**0.05**	**0.01**
519_HAL	21.3	0.74	0.74	0.70	0.78	**0.41**
519_POT	195.5	1.00	1.00	1.00	0.99	0.83
519_TRW	39.7	0.98	0.98	0.99	0.99	1.00
521_HAL	30.8	0.92	0.92	0.89	0.94	0.66
521_POT	0.5	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
523_HAL	4.2	**0.03**	**0.03**	**0.03**	**0.04**	**0.01**
524_HAL	12.0	**0.35**	**0.35**	**0.32**	**0.40**	**0.13**
541_HAL	76.3	1.00	1.00	1.00	1.00	0.99
541_POT	1.0	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
542_HAL	25.2	0.83	0.83	0.80	0.87	0.52
543_HAL	2.2	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Table 5. -- The number of trips and associated likelihood of observing at least three trips within each NMFS Reporting Area and stratum combination in the Gulf of Alaska for each allocation design under the Gear-based stratification scheme. If the likelihood of observing at least three trips is less than 0.50, the cell is bolded in order to identify potential gaps more easily. The number of trips in an Area Stratum combination are not whole numbers since fishing trips can span more than one NMFS Reporting Area.

GOA Gear Stratification

NMFS Area_Stratum	Trips	Equal Allocation	15% + Optimized on Discards + Halibut PSC	15% + Optimized on Discards + Halibut + Chinook PSC	Optimized on Discards + Halibut PSC	Optimized on Discards + Halibut + Chinook PSC
610_HAL	192.3	1.00	1.00	1.00	1.00	1.00
610_POT	256.8	1.00	1.00	1.00	1.00	0.95
610_TRW	940.1	1.00	1.00	1.00	1.00	1.00
620_HAL	148.9	1.00	1.00	1.00	1.00	1.00
620_POT	90.0	1.00	1.00	1.00	0.77	**0.32**
620_TRW	503.2	1.00	1.00	1.00	1.00	1.00
630_HAL	764.6	1.00	1.00	1.00	1.00	1.00
630_POT	175.1	1.00	1.00	1.00	0.99	0.77
630_TRW	964.3	1.00	1.00	1.00	1.00	1.00
640_HAL	176.2	1.00	1.00	1.00	1.00	1.00
649_HAL	74.9	1.00	1.00	1.00	1.00	0.99
650_HAL	419.7	1.00	1.00	1.00	1.00	1.00
659_HAL	234.0	1.00	1.00	1.00	1.00	1.00

Table 6. -- The number of trips and associated likelihood of observing at least three trips within each NMFS Reporting Area and stratum combination in the Bering Sea and Aleutian Islands for each allocation design under the Gear ×Tender stratification scheme. If the likelihood of observing at least three trips is less than 0.50, the cell is bolded in order to identify potential gaps more easily. The number of trips in an Area Stratum combination are not whole numbers since fishing trips can span more than one NMFS Reporting Area.

BSAI Gear × Tender Stratification

NMFS Area_Stratum	**Trips**	**Equal Allocation**	**15% + Optimized on Discards + Halibut PSC**	**15% + Optimized on Discards + Halibut + Chinook PSC**	**Optimized on Discards + Halibut PSC**	**Optimized on Discards + Halibut + Chinook PSC**
509_POT	124.8	1.00	1.00	1.00	0.90	**0.48**
509_Tender_POT	4.2	**0.03**	**0.02**	**0.02**	**0.00**	**0.00**
509_Tender_TRW	1.5	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
509_TRW	132.2	1.00	1.00	1.00	1.00	1.00
513_HAL	5.4	**0.06**	**0.06**	**0.05**	**0.07**	**0.02**
514_HAL	11.2	**0.31**	**0.31**	**0.28**	**0.35**	**0.12**
517_HAL	5.4	**0.06**	**0.06**	**0.05**	**0.07**	**0.02**
517_POT	92.2	1.00	1.00	1.00	0.74	**0.29**
517_Tender_POT	4.2	**0.03**	**0.02**	**0.02**	**0.00**	**0.00**
517_Tender_TRW	0.5	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
517_TRW	104.2	1.00	1.00	1.00	1.00	1.00
518_HAL	32.7	0.94	0.94	0.92	0.96	0.70
518_POT	18.6	0.65	0.58	0.57	**0.04**	**0.01**
519_HAL	21.3	0.74	0.74	0.70	0.78	**0.42**
519_POT	194.6	1.00	1.00	1.00	0.99	0.79
519_Tender_POT	0.9	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
519_TRW	39.7	0.98	0.98	0.99	1.00	1.00
521_HAL	30.8	0.92	0.92	0.89	0.94	0.66
521_POT	0.5	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
523_HAL	4.2	**0.03**	**0.03**	**0.03**	**0.04**	**0.01**

Table 6. -- Continued.

BSAI Gear × Tender Stratification

NMFS Area_Stratum	Trips	Equal Allocation	15% + Optimized on Discards + Halibut PSC	15% + Optimized on Discards + Halibut + Chinook PSC	Optimized on Discards + Halibut PSC	Optimized on Discards + Halibut + Chinook PSC
524_HAL	12.0	**0.35**	**0.35**	**0.32**	**0.40**	**0.14**
541_HAL	76.3	1.00	1.00	1.00	1.00	0.99
541_POT	1.0	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
542_HAL	25.2	0.83	0.83	0.80	0.87	0.52
543_HAL	2.2	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Table 7. -- The number of trips and associated likelihood of observing at least three trips within each NMFS Reporting Area and stratum combination in the Gulf of Alaska for each allocation design under the Gear ×Tender stratification scheme. If the likelihood of observing at least three trips is less than 0.50, the cell is bolded in order to identify potential gaps more easily. The number of trips in an Area Stratum combination are not whole numbers since fishing trips can span more than one NMFS Reporting Area.

GOA Gear × Tender Stratification

NMFS Area_Stratum	**Trips**	**Equal Allocation**	**15% + Optimized on Discards + Halibut PSC**	**15% + Optimized on Discards + Halibut + Chinook PSC**	**Optimized on Discards + Halibut PSC**	**Optimized on Discards + Halibut + Chinook PSC**
610_HAL	192.3	1.00	1.00	1.00	1.00	1.00
610_POT	191.1	1.00	1.00	1.00	0.99	0.78
610_Tender_POT	65.6	1.00	1.00	1.00	0.91	**0.47**
610_Tender_TRW	250.5	1.00	1.00	1.00	1.00	1.00
610_TRW	689.6	1.00	1.00	1.00	1.00	1.00
620_HAL	148.9	1.00	1.00	1.00	1.00	1.00
620_POT	70.8	1.00	1.00	1.00	0.56	**0.17**
620_Tender_POT	19.2	0.70	0.64	0.61	**0.11**	**0.02**
620_Tender_TRW	5.3	**0.06**	**0.06**	**0.05**	**0.02**	**0.00**
620_TRW	497.9	1.00	1.00	1.00	1.00	1.00
630_HAL	764.6	1.00	1.00	1.00	1.00	1.00
630_POT	164.3	1.00	1.00	1.00	0.97	0.68
630_Tender_POT	10.8	**0.30**	**0.25**	**0.24**	**0.02**	**0.00**
630_Tender_TRW	1.0	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
630_TRW	963.3	1.00	1.00	1.00	1.00	1.00
640_HAL	176.2	1.00	1.00	1.00	1.00	1.00
649_HAL	74.9	1.00	1.00	1.00	1.00	0.99
650_HAL	419.7	1.00	1.00	1.00	1.00	1.00
659_HAL	227.5	1.00	1.00	1.00	1.00	1.00
659_Tender_HAL	6.6	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

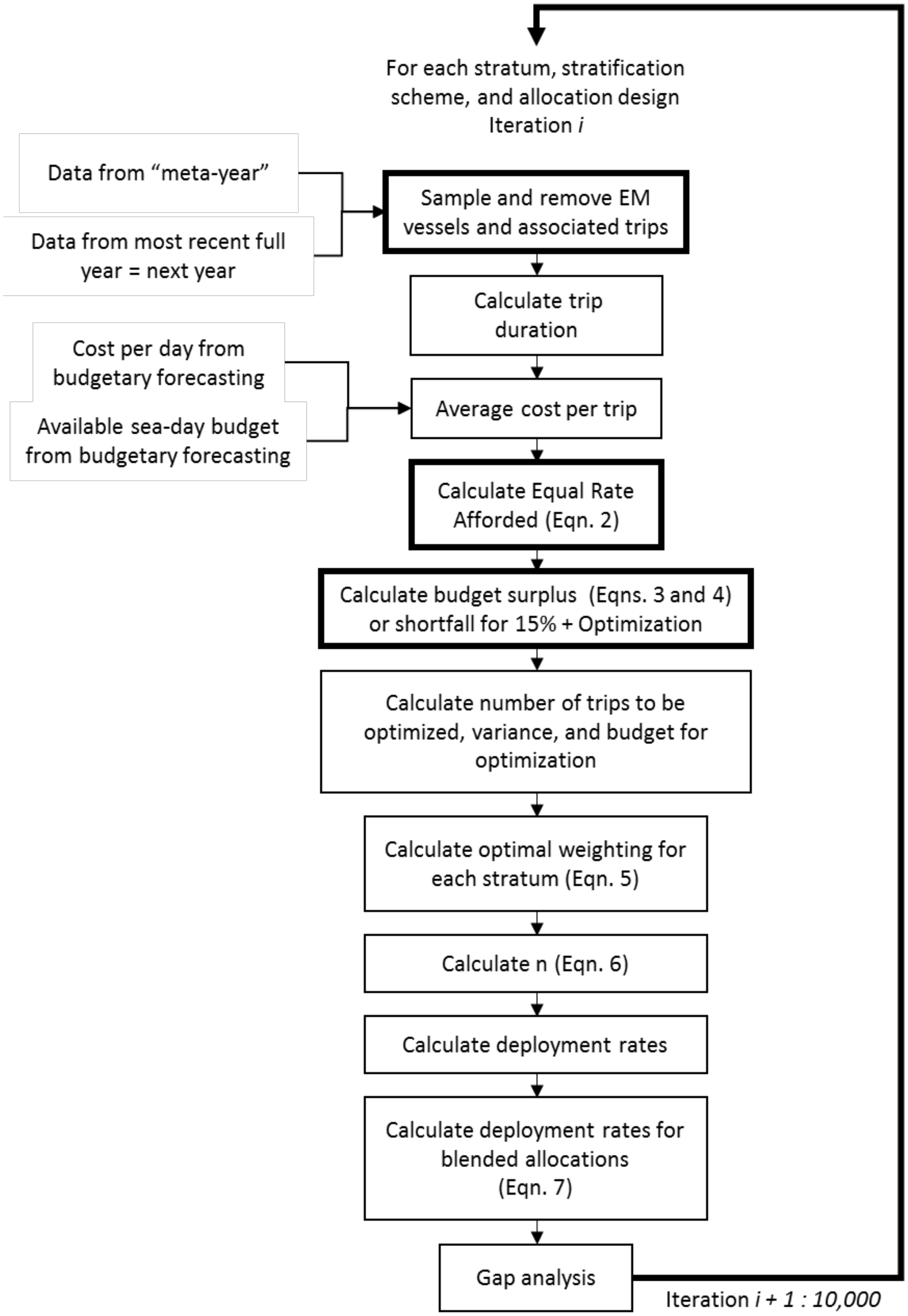

Figure 1. -- Flow chart depicting methods used in this analysis for each allocation and stratification design under consideration for the 2018 ADP. Blocks highlighted in bold are new methods this year.

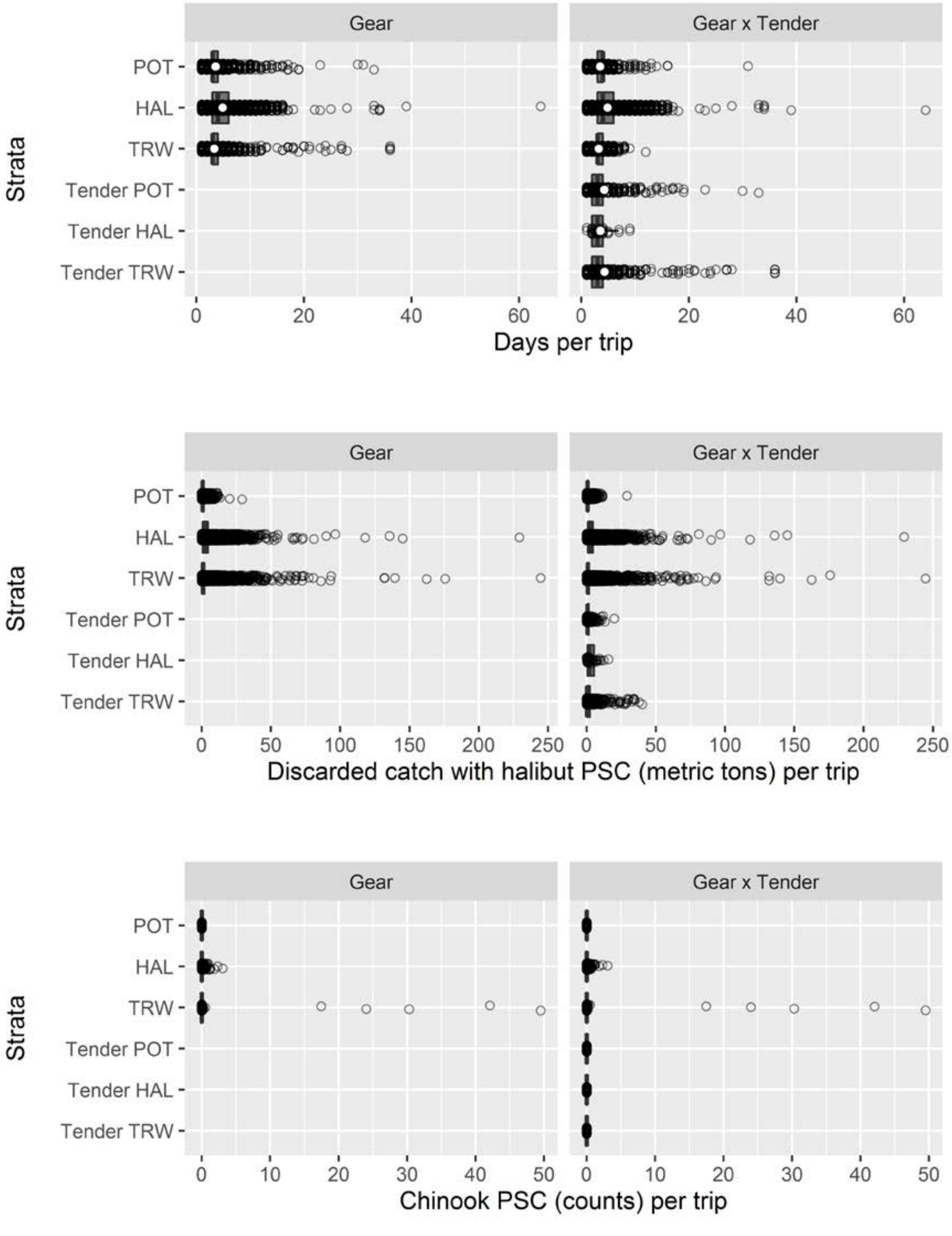

Figure 2. -- The distribution of trip duration in days (top panels), discarded groundfish catch including Pacific halibut PSC in metric tons (middle panels), and Chinook PSC in counts (bottom panels) for each stratum in the Gear and Gear × Tender stratification schemes. Shaded boxes denote the 25th, 50th, and 75th percentiles, and individual trips are shown as open circles.

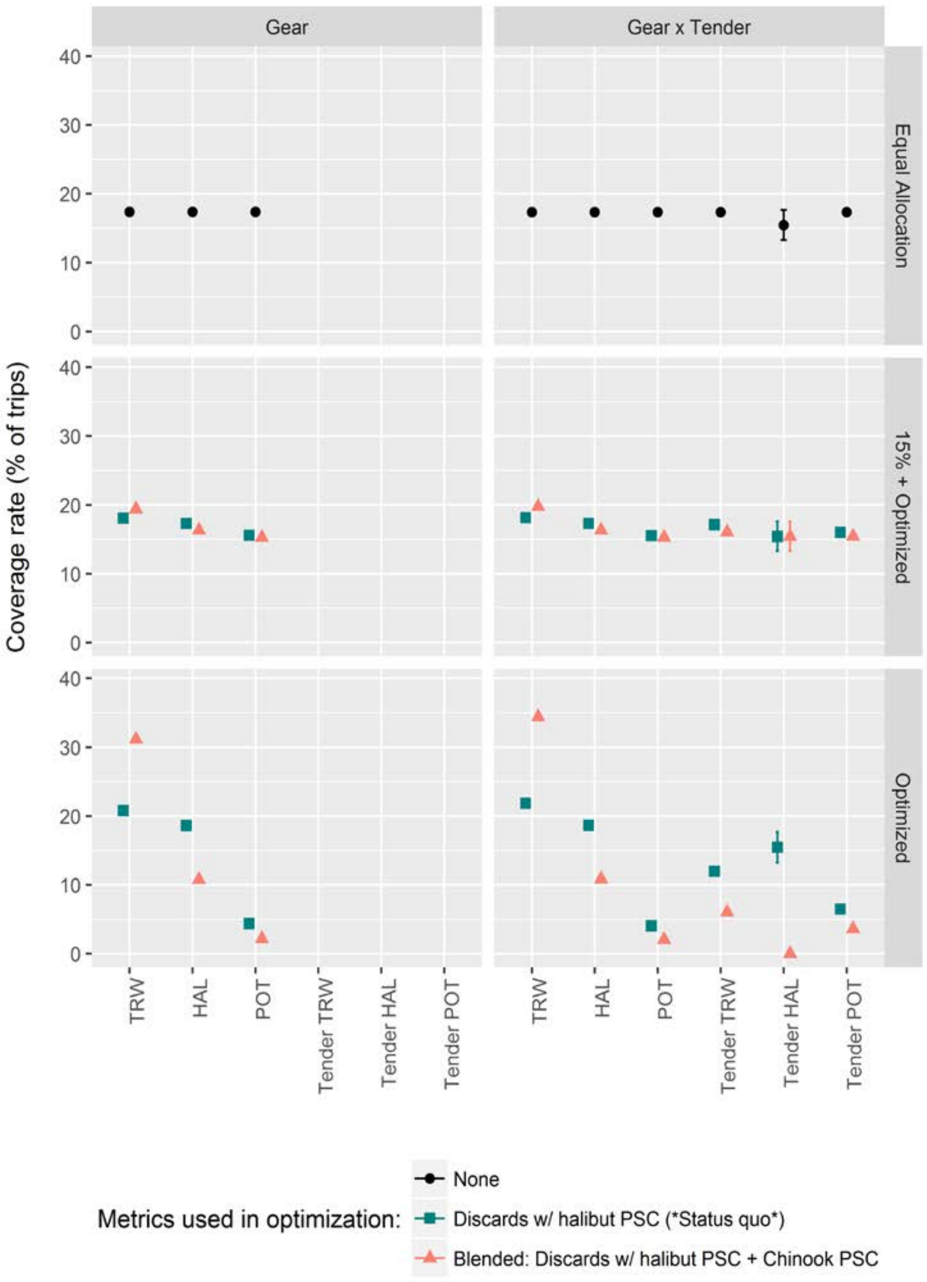

Figure 3. -- Comparison of preliminary draft coverage rates resulting from two stratification schemes (Gear and Gear × Tender) and three allocation designs (Equal Allocation, 15% + Optimized, and Optimized). Metrics used for optimization included discards with Pacific halibut prohibited species catch (PSC) (teal) and a blended optimization of discards with Pacific halibut and Chinook PSC (blue). Rates in the top panels are shown in black because no optimization occurred. Error bars depict uncertainty (+/- 1 standard deviation) in predicted coverage rates caused by the fact that the population of hook-and-line (HAL) and pot gear (POT) vessels in the partial coverage category is not defined in the Draft 2018 ADP due to open enrollment into Electronic Monitoring.

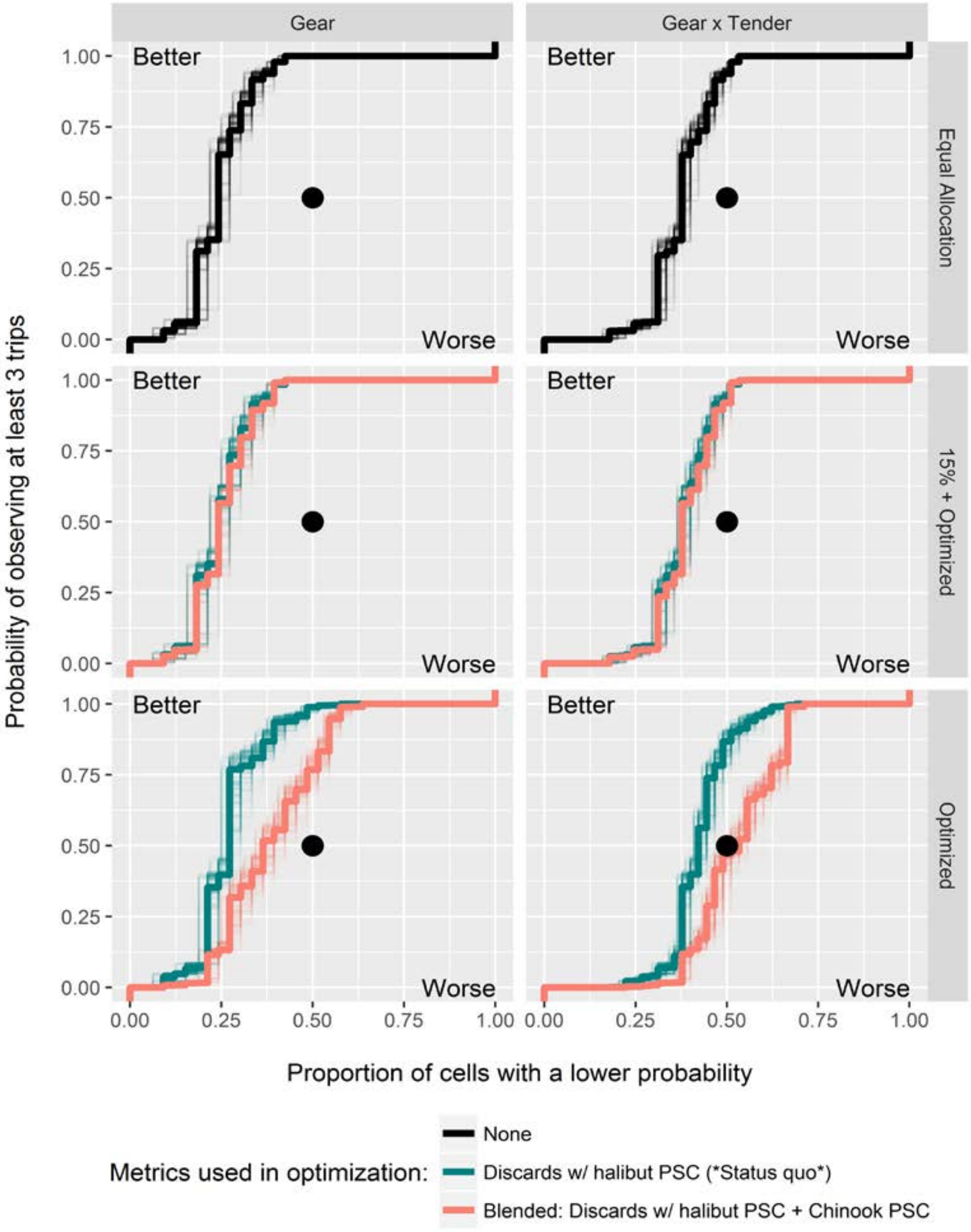

Figure 4. -- Empirical cumulative distribution curves for the probability of observing at least three trips in a domain defined by NMFS Area and stratum for two stratification schemes (Gear and Gear × Tender) and three allocation designs (Equal Allocation, 15% + Optimized, and Optimized). Metrics used for optimization included discards with Pacific halibut prohibited species catch (PSC) (teal) and a blended optimization of discards with Pacific halibut and Chinook PSC (blue). Curves in the top panels are shown in black because no optimization occurred. Better performing designs are those that reach a value of 1 furthest to the left of the plot. The shaded regions around the curves reflect uncertainty in the gap analyses caused by the fact that the population of hook-and-line and pot gear vessels in the partial coverage category is not defined due to open enrollment into Electronic Monitoring.

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