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U.S. DEPARTMENT OF COMMERCE
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Alternative Sampling Designs for the 2019 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 fishery monitoring tools 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 and electronic monitoring deployment has two elements: how the population is subdivided (i.e., stratification schemes) and how available samples are allocated (i.e., allocation strategies). The electronic monitoring stratum was defined by NMFS and Council policy and was not considered for evaluation of alternative sampling designs. Only one stratification scheme based on the gear and tender status of the vessel was considered for observers within the draft 2019 ADP. A total of three alternative sample allocations were considered within the gear- and tender-based stratification: 1) no optimization (i.e., sample size proportional to fishing effort), 2) 15% minimum coverage plus optimized trips, where optimization is based on discarded groundfish, halibut Prohibited Species Catch (PSC), and Chinook PSC, and 3) 15% minimum coverage plus optimized trips where optimization is based on discarded groundfish, halibut PSC, Chinook PSC, and crab PSC.

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 3,110 which represents a 23% decrease from 2018. This number of observer days was sufficient only to cover the minimum coverage "hurdle" of 15% of trips within each stratum when using 2017 fishing effort as a proxy for 2019 fishing effort, as was done in the draft 2019 ADP. Therefore, all sampling designs presented in the draft 2019 ADP performed the same according the different metrics used to evaluate design performance. However, when days are fully optimized without a minimum coverage hurdle, the design which includes crab PSC outperforms the design that does not include crab PSC. The results of this fully optimized design were not included in the draft 2019 ADP because this design was not under consideration for implementation by NMFS or the Council. However, the results of the fully optimized design are included here to illustrate the differences in performance that result when crab PSC is included in the optimization metric.

In September 2018, the NMFS recommended an observer deployment design for the draft 2019 ADP that uses a hurdle approach to sample allocation and optimizes trips according to the variance in the metric of discarded groundfish catch, halibut PSC, Chinook PSC, and crab PSC. At their October 2018 meeting the Council did not support the NMFS recommendation and instead supported the use of the design that excludes crab PSC from the optimization metric. The design supported by the Council was ultimately implemented by NMFS for the 2019 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 and electronic fisheries monitoring tools (EM) 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 deployment of fishery monitoring tools and improve the sampling design of the monitoring program. In the Draft 2018 ADP, NMFS presented six alternative deployment designs for observers (NMFS 2017a). The exclusive focus on observers and not EM is due to the fact that participation in EM is set up such that only vessels and vessel operators that volunteer for the upcoming year can be considered for EM, and NMFS only has the power to refuse volunteer vessels rather than select vessels to carry EM. The Council has established EM as a valid catch estimation tool in the North Pacific through its workgroup process, and that process has resulted in a policy decision to set selection rates at 30% of trips.

The adopted design in the Final 2018 ADP allocated observed trips among five strata defined by gear and tendering activity according to an optimized allocation resulting from the interactions of stratum size and variance from a combination of discarded groundfish, Pacific halibut Prohibited Species Catch (PSC), and Chinook salmon PSC (NMFS 2017b). The most recent Annual Report (NMFS 2018c) and subsequent Council motion (7 June 2018) recommended that the Draft 2019 ADP continue the 2018 ADP design, and include an evaluation of 1) minimum rates that can be afforded; 2) 15% minimum in all strata (i.e., a coverage 'hurdle' as was implemented in 2018); and 3) a gear-specific hurdle approach. Within budget constraints, observer deployment beyond the minimum hurdle was directed to be that which resulted from optimization based on discarded groundfish, Pacific halibut PSC, and Chinook salmon PSC. However, NMFS was also directed to consider the addition of other PSC species (crab) by the Council's Science and Statistical Committee. While specifics according to a gear-specific "hurdle" is addressed in Appendix B of the Draft 2019 ADP (NMFS 2018b), this analysis provides a comparison of the relative performance of alternative deployment designs for observers in the partial coverage fleet in 2019.

METHODS

Data Preparation: Defining the Partial Coverage Fleet

The partial coverage fleet in general consists of the catcher vessel fleet and some catcher processors 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 2019 that will continue to be excluded from observer coverage 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 2018 will continue to do so in 2019.

A database containing 2016, 2017, and 2018 species-specific catch amounts, dates, locations, and disposition, and observation status was first enhanced with additional information from the Alaska Regional Office and FMA, then parsed to reflect the partial coverage fleet subject to observer coverage in 2019, and finally re-labelled according to the alternative deployment designs (if any) described below.

Budget Forecasting

The available budget for observer days in 2019 was set such that total number of observer days would remain stable between 2019 and 2020 under the condition that expenditures in 2020 equaled available revenue in that year. Budget forecasting is necessary to determine not only the number of sea-days expected for each upcoming year, but also how much money should be expected to be allocated for each fiscal year, which are offset by 6 months. For this reason, calendar years were divided into a first half (FH) period from 1 January to 17 June and a second half (SH) from 18 June to 31 December.

The exercise of determining the available budget requires that several assumptions are made given what is known. We have known expenditures through the first half of the current calendar year, and estimates for the cost of an observer day for future years. The value for sea day and travel expenditures for the second half of the current calendar year first need to be determined. This was estimated by using a ratio estimator. The ratio of the number of days used in the first half and second half of the prior calendar year was multiplied by the number of days used in the first half of the current calendar year to determine the expected number of days in the second half of the current calendar year. The expected travel expenditures for the second half of the current calendar year derived from the ratio between the number of observer days used and the travel expended during the second half of the prior year and multiplying this value by the estimated number of observer days for the second half of the current year. From these calculations, the expected cost of the current calendar year could be estimated from 1) the sum of observer days in each half of the year multiplied by the cost of an observer day and 2) the actual and estimated travel for both halves of the year.

The expected available budget for the current ADP calendar year was determined by deducting the expected cost of observing the prior year by the available budget. Expected fee revenues were added to this figure and expected to arrive in the second half of the year.

Under the assumption that the program size in terms of total observer days is to remain equal, two values are required to move forward. The first of these is for how long would the FMA and NMFS like to retain this size program, and the second of these is the ratio between the number of observer days expected in the first half and the second half of the year. The first question is a matter of policy and here was set at the period 2019 and 2020. The second question is derived from a three-step iterative process. The first step is to assume that the ratio of observer days in the first and second half of the current year will be the same as that in future years, and that the ratio of travel expenditures to observer days will also follow the same pattern and relationship. Using the same calculations as for the second half of the current year, the number of observer days can be increased until the budget expenditures in following years is met. Summing the expected cost and total number of observer days for the ADP year and dividing one by the other gets the total expected cost of an observer day. These values are then passed into ADP algorithms that determine the expected trip duration, number of trips and coverage rates per ADP stratum. Depending on the design chosen for the ADP, an updated ratio of the expected number of days used in the first half and second half of the ADP year is produced. This ratio is then used to update the budget scenarios for the ADP and future years, and the number of days afforded is increased or decreased in the first half of the ADP year as appropriate. This yields another set of cost of an observer day, total observer days, and cost of the program that act as the final inputs to the ADP.

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

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: 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 strata (Cochran 1977). The collection of strata that together subdivide the population of trips in partial coverage constitutes a stratification. In this study only one stratification was considered: one that divides the partial coverage trips into strata based on gear and tendering status, excepting the Hook and Line + Tender combination. This stratification (referred to as the Gear × Tender stratification) contains the following strata:

- Hook and Line ≥ 40' LOA (HAL).
- Pot ≥ 40' LOA (POT).
- Tender Pot ≥ 40' LOA (Tender POT).
- Trawl (TRW).
- Tender Trawl (Tender TRW).

Sample Allocation

Sample allocation refers to the allotment of trips afforded to a stratum. A total of five sample allocations belonging to three 'types' are compared here (the full workflow for the methods used in these designs is found in Fig. 1). These types are as follows:

1. Equal Allocation

This allocation design estimates the equal coverage rate (trips sampled/total trips) across strata that can be afforded with available funding. 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) was 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

$$r_h = \frac{F_{2019}}{\sum_{h=1}^{H} c_h N_h}, \quad (1)$$

where F_{2019} is the estimated funds from the budget forecasting.

2. 15% + Optimized

Unlike equal rates afforded, this sample allocation adopts a "hurdle" approach to optimization. First, observer sea days are allocated equally among strata up to a 15% coverage rate (the base-rate or hurdle). Once 15% has been met, an optimal allocation algorithm (described below) is used to allocate remaining resources 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 (NMFS 2015c p. 98, Faunce et al. 2017, NMFS 2017a), and was adopted by NMFS in the 2018 ADP (NMFS 2017b). This allocation first estimates the number of trips left over in each stratum after 15% coverage has been met using

$$N_{h+} = N_h - (0.15 \times N_h), \tag{2}$$

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

$$F_{2019+} = \sum_{h=1}^{H} c_h \, N_{h+}. \tag{3}$$

The F_{2019+} and N_{h+} is then allocated following the optimized design, where F_{2019+} and N_{h+} are substituted for F_{2019} and N_h, respectively, in the following equations.

3. Optimized

This design was used in the 2016 and 2017 ADP and uses "optimal" allocation, an algorithm design to maximize precision for the chosen metrics for the least cost regardless of a "base-rate" of coverage. If n is the number of observed trips afforded for the year among all partial coverage fishing trips in each stratum (N_h), and the estimate of total discarded catch including halibut PSC from these trips (the chosen metric) 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}),

$$n * W_{hopt}, \text{ where } W_{hopt} = \frac{\frac{N_h S_h}{\sqrt{c_h}}}{\sum_{h=1}^{H}\left(\frac{N_h S_h}{\sqrt{c_h}}\right)} \quad \text{Cochran (1977).} \tag{4}$$

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 equation 1 as

$$n = \frac{F_{2019}\sum_{h=1}^{H}\left(\frac{N_h S_h}{\sqrt{c_h}}\right)}{\sum_{h=1}^{H}(N_h S_h \sqrt{c_h})} \quad \text{Cochran (1977).} \tag{5}$$

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. Cochran (1977) shows that the *blended optimal allocation* (m_h) is derived from the average number of optimal sample sizes measured across L metrics,

$$m_h = \overline{n}_h, \quad where \ \overline{n}_h = \frac{\sum_{l=1}^{L} n_{l,h}}{L}. \tag{6}$$

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. Optimized sample allocations for types 2 and 3 above were generated using the variance of a) discarded groundfish catch, halibut Prohibited Species Catch (PSC), and Chinook salmon PSC, and b) discarded groundfish catch, halibut PSC, Chinook salmon PSC, and crab PSC.

The five types of allocations that are presented include the following:

1. Equal rates afforded (allocations are distributed by fishing effort - all strata get the same coverage rate).
2. 15% + Optimized based on groundfish discards, halibut PSC, and Chinook salmon PSC.

3. 15% + Optimized based on groundfish discards, halibut PSC, Chinook salmon PSC, and crab PSC.
4. Optimized based on groundfish discards, halibut PSC, and Chinook salmon PSC.
5. Optimized based on groundfish discards, halibut PSC, Chinook salmon PSC, and crab PSC.

Data from 2015, 2016, and 2017 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, halibut PSC, Chinook PSC, and crab PSC for each stratification scheme were plotted since these form the raw ingredients for the sample size allocation formulae (Fig. 2).

Evaluation of Alternative Designs

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, potentially 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 for observer deployment was determined using gap analysis following previous evaluations of observer program deployments (NMFS 2015a, NMFS 2015b, NMFS 2016a, NMFS 2016b) with a slight change in the calculations described in Appendix D of the draft 2019 ADP (NMFS 2018b). 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 2017 data under the assumption that immediate past fishing activity is a good predictor of future fishing activity.

Similar to the past ADPs, 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 2017a).

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 design scheme. 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

In 2018 there were 141 vessels included in the EM stratum. Although the Council recommended that the EM pool be expanded to 165 vessels if funding is sufficient (7 June 2018 Motion; NMFS 2018b, Appendix A), this analysis does not evaluate the addition of any new EM vessels beyond the 2018 vessels.

RESULTS AND DISCUSSION

The total number of observer days available for deployment in the Observer Program is dependent upon the available budget, the anticipated fishing effort and the average cost of an observed day. This analysis uses a total amount of observer days that should remain constant for

2019 and 2020. However, the expected program expenditures will result in a negative balance during deployment between 1 January and 16 June 2021. The number of total observer days that results from this projection is 3,110. Depending on the deployment design chosen, approximately 50.9% of available sea days will be used between 1 January and 16 June of the 2019 calendar year.

The optimization algorithm employed here puts more samples where 1) strata are larger, 2) variance of a chosen metric is larger, and 3) costs are lower (Cochran 1977). The methods used herein cannot only be used to accommodate differential trip duration but also differential costs between observation types (e.g., human vs. cameras) in future ADPs. Moreover, the comparison of coverage rates using equal allocation, 15% plus optimization, and optimization elucidates the trade-off between minimizing gaps in coverage and emphasizing the importance of certain metrics such as groundfish discards and PSC.

A focus on resulting coverage rates in the Draft ADP is not as productive as focusing on how those observer days are allocated and the potential for gaps in coverage. This is because estimates of fishing effort and budgets are preliminary during the Draft ADP. Instead of focusing on deployment rates, focusing on observer day allocations and potential gaps ensures that the correct design is chosen for the Final ADP based on the merits of the design and not the expected deployment rates. An exception to this is the equal rates afforded, which provides context as to the relative impact that optimization dollars will have on final deployment rates. Based on current budget and fishing effort used in this document, the equal rates afforded deployment rate (%) is 15. Coverage rates do not differ substantially between equal allocation and the 15% + optimization designs because the budget does not afford any optimized days above the base coverage (Fig. 3, Table 1).

Optimized observer day allocations differ in their weightings depending on whether or not crab PSC is included as a metric or not. One way to think about optimized allocations is that of every optimized dollar, in allocations that do not include crab PSC, 72 cents goes to TRW, 23 cents goes to HAL, and 2 cents goes to POT strata. In comparison, the identical summary for allocations including crab PSC put 64 cents to TRW, 18 cents to HAL, and 15 cents to POT gear (see column W_{opt} in Table 1).

Results from gap analyses indicate that allocation based solely on optimization results in the most gaps in observer coverage. This is shown in Figure 4, where the curves that reach the top the fastest, or the furthest to the left, represent designs that result in the fewest gaps in coverage (details in Tables 3 and 4). The design that uses an optimized allocation based on blended discarded groundfish catch with halibut and Chinook PSC has the most gaps, whereas designs that use either equal or 15% + optimized allocations have the least gaps. The optimized allocation based on blended discarded groundfish catch with halibut, Chinook, and crab PSC had only slightly more gaps than the best performing designs (indicated by high relative G scores in Table 2). The best performing designs result in a predicted 59% of cells with at least a 50% probability of having three or more observed trips in the Gear and Gear × Tender stratification, respectively.

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. Allocation that includes crab PSC vastly outperformed that where it was not included. For these reasons FMA recommended the 15% + Optimization design with allocation of optimized observer days based on blended discarded groundfish catch with halibut, Chinook, and crab PSC. However, at their October 2018 meeting, the Council supported the 15%

+ Optimization design that excludes crab PSC, citing the fact that no fisheries hit their limit of crab PSC.

This analysis relies on several key assumptions. First, we assume 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.

Again, it is important that the reader understand that the resulting coverage rates for observer deployment depend upon the amount of fishing effort and the available number of observer days which is dependent upon budget and trip duration. Since this analysis is focused on the *relative* performance of alternative deployment designs, it uses a simplified assumption of future fishing effort- namely that fishing in 2017 will be identical to that in 2019. This assumption is made in anticipation that for the Final 2019 ADP, when a deployment design is selected, a more careful estimate of anticipated fishing effort will be made for 2019, and resulting rates will be adjusted to reflect this new prediction (see Ganz and Faunce 2019). Consequently, the resulting coverage rates presented in this study differ from rates determined in the Final ADP (NMFS 2018a, Appendix B).

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TABLES

Table 1. -- Comparison of the number of trips in a stratum (N_{h2019}), 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 three allocation designs: 1) Equal allocation, 2) 15% + Optimized, and 3) Optimized. Metrics used for optimization included 1) discarded groundfish catch with Pacific halibut and Chinook prohibited species catch (PSC) and 2) discarded groundfish catch with Pacific halibut, Chinook, and crab PSC.

Stratum (h)	Metric	N_{h2018}	W_{hopt}	n_h	d_h	r_h (%)
Equal Allocation						
TRW	None	2,085		313	1,014	15.00
HAL	None	2,013		302	1,530	15.00
POT	None	811		122	450	15.00
Tender TRW	None	69		10	52	15.00
Tender POT	None	71		11	63	15.00
15% + Optimized						
TRW	Discards w/ halibut PSC + Chinook PSC	2,085	0.72	313	1,014	15.00
HAL	Discards w/ halibut PSC + Chinook PSC	2,013	0.23	302	1,530	15.00
POT	Discards w/ halibut PSC + Chinook PSC	811	0.02	122	450	15.00
Tender TRW	Discards w/ halibut PSC + Chinook PSC	69	0.03	10	52	15.00
Tender POT	Discards w/ halibut PSC + Chinook PSC	71	0.00	11	63	15.00
TRW	Discards w/ halibut PSC + Chinook PSC + crab PSC	2,085	0.64	313	1,014	15.00
HAL	Discards w/ halibut PSC + Chinook PSC + crab PSC	2,013	0.18	302	1,530	15.00
POT	Discards w/ halibut PSC + Chinook PSC + crab PSC	811	0.15	122	450	15.00

Stratum (*h*)	Metric	N_{h2018}	W_{hopt}	n_h	d_h	r_h (%)
Tender TRW	Discards w/ halibut PSC + Chinook PSC + crab PSC	69	0.02	10	52	15.00
Tender POT	Discards w/ halibut PSC + Chinook PSC + crab PSC	71	0.01	11	63	15.00
Optimized						
TRW	Discards w/ halibut PSC + Chinook PSC	2,085	0.70	581	1,885	27.88
HAL	Discards w/ halibut PSC + Chinook PSC	2,013	0.23	180	910	8.93
POT	Discards w/ halibut PSC + Chinook PSC	811	0.01	12	43	1.44
Tender TRW	Discards w/ halibut PSC + Chinook PSC	69	0.06	52	263	75.85
Tender POT	Discards w/ halibut PSC + Chinook PSC	71	0.00	2	12	2.82
TRW	Discards w/ halibut PSC + Chinook PSC + crab PSC	2,085	0.63	528	1,713	25.34
HAL	Discards w/ halibut PSC + Chinook PSC + crab PSC	2,013	0.17	136	687	6.73
POT	Discards w/ halibut PSC + Chinook PSC + crab PSC	811	0.14	119	440	14.67
Tender TRW	Discards w/ halibut PSC + Chinook PSC + crab PSC	69	0.05	40	198	57.25
Tender POT	Discards w/ halibut PSC + Chinook PSC + crab PSC	71	0.01	12	73	17.25

Table 2. -- 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 × Tender Stratification				
Equal Allocation	0.59	1.00	0.84	1.00
15% + Optimized on Discards + Halibut + Chinook PSC	0.59	1.00	0.84	1.00
15% + Optimized on Discards + Halibut + Chinook + Crab PSC	0.59	1.00	0.84	1.00
Optimized on Discards + Halibut + Chinook + Crab PSC	0.57	0.97	0.82	0.98
Optimized on Discards + Halibut + Chinook PSC	0.39	0.66	0.65	0.78

Table 3. -- 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 sum of area-specific trips may be greater than the overall number of trips, since some trips span more than one area and therefore count as multiple area-specific trips.

BSAI Gear × Tender Stratification

NMFS Area_Stratum	Trips	Equal Allocation	15% + Optimized on Discards + Halibut + Chinook PSC	15% + Optimized on Discards + Halibut + Chinook + Crab PSC	Optimized on Discards + Halibut + Chinook PSC	Optimized on Discards + Halibut + Chinook + Crab PSC
509_POT	146.0	1.00	1.00	1.00	**0.37**	1.00
509_POT_TENDER	16.0	**0.47**	**0.47**	**0.47**	**0.00**	0.54
509_TRW	122.0	1.00	1.00	1.00	1.00	1.00
509_TRW_TENDER	1.0	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
512_POT	1.0	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
513_HAL	9.0	**0.14**	**0.14**	**0.14**	**0.04**	**0.02**
513_POT	5.0	**0.03**	**0.03**	**0.03**	**0.00**	**0.02**
514_HAL	28.0	0.81	0.81	0.81	**0.46**	**0.29**
516_POT	1.0	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
516_POT_TENDER	1.0	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
517_HAL	8.0	**0.10**	**0.10**	**0.10**	**0.03**	**0.01**
517_POT	82.0	1.00	1.00	1.00	**0.11**	1.00
517_POT_TENDER	3.0	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
517_TRW	113.0	1.00	1.00	1.00	1.00	1.00
517_TRW_TENDER	1.0	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
518_HAL	51.0	0.99	0.99	0.99	0.85	0.68
518_POT	22.0	0.67	0.67	0.67	**0.00**	0.65
519_HAL	28.0	0.81	0.81	0.81	**0.46**	**0.29**
519_POT	194.0	1.00	1.00	1.00	0.58	1.00

BSAI Gear × Tender Stratification

NMFS Area_Stratum	Trips	Equal Allocation	15% + Optimized on Discards + Halibut + Chinook PSC	15% + Optimized on Discards + Halibut + Chinook + Crab PSC	Optimized on Discards + Halibut + Chinook PSC	Optimized on Discards + Halibut + Chinook + Crab PSC
519_POT_TENDER	5.0	**0.02**	**0.02**	**0.02**	**0.00**	**0.03**
519_TRW	11.0	**0.22**	**0.22**	**0.22**	0.63	0.56
521_HAL	28.0	0.81	0.81	0.81	**0.46**	**0.29**
523_HAL	5.0	**0.03**	**0.03**	**0.03**	**0.01**	**0.00**
524_HAL	16.0	**0.44**	**0.44**	**0.44**	**0.17**	**0.09**
541_HAL	80.0	1.00	1.00	1.00	0.98	0.92
541_POT	6.0	**0.05**	**0.05**	**0.05**	**0.00**	**0.04**
542_HAL	34.0	0.90	0.90	0.90	0.60	**0.41**
543_HAL	4.0	**0.01**	**0.01**	**0.01**	**0.00**	**0.00**

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 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 sum of area-specific trips may be greater than the overall number of trips, since some trips span more than one area and therefore count as multiple area-specific trips.

GOA Gear × Tender Stratification

NMFS Area_Stratum	Trips	Equal Allocation	15% + Optimized on Discards + Halibut + Chinook PSC	15% + Optimized on Discards + Halibut + Chinook + Crab PSC	Optimized on Discards + Halibut + Chinook PSC	Optimized on Discards + Halibut + Chinook + Crab PSC
610_HAL	186.0	1.00	1.00	1.00	1.00	1.00
610_POT	160.0	1.00	1.00	1.00	**0.43**	1.00
610_POT_TENDER	32.0	0.95	0.95	0.95	**0.00**	0.97
610_TRW	543.0	1.00	1.00	1.00	1.00	1.00
610_TRW_TENDER	65.0	1.00	1.00	1.00	1.00	1.00
620_HAL	161.0	1.00	1.00	1.00	1.00	1.00
620_POT	32.0	0.88	0.88	0.88	**0.01**	0.87
620_POT_TENDER	17.0	0.52	0.52	0.52	**0.00**	0.59
620_TRW	762.0	1.00	1.00	1.00	1.00	1.00
620_TRW_TENDER	6.0	**0.04**	**0.04**	**0.04**	0.97	0.80
630_HAL	695.0	1.00	1.00	1.00	1.00	1.00
630_POT	166.0	1.00	1.00	1.00	**0.46**	1.00
630_POT_TENDER	7.0	**0.07**	**0.07**	**0.07**	**0.00**	**0.09**
630_TRW	698.0	1.00	1.00	1.00	1.00	1.00
640_HAL	203.0	1.00	1.00	1.00	1.00	1.00
640_POT	12.0	**0.26**	**0.26**	**0.26**	**0.00**	**0.25**
649_HAL	78.0	1.00	1.00	1.00	0.98	0.91
649_POT	1.0	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
650_HAL	464.0	1.00	1.00	1.00	1.00	1.00

GOA Gear × Tender Stratification

NMFS Area_Stratum	Trips	Equal Allocation	15% + Optimized on Discards + Halibut + Chinook PSC	15% + Optimized on Discards + Halibut + Chinook + Crab PSC	Optimized on Discards + Halibut + Chinook PSC	Optimized on Discards + Halibut + Chinook + Crab PSC
650_POT	18.0	0.52	0.52	0.52	**0.00**	0.51
659_HAL	212.0	1.00	1.00	1.00	1.00	1.00

FIGURES

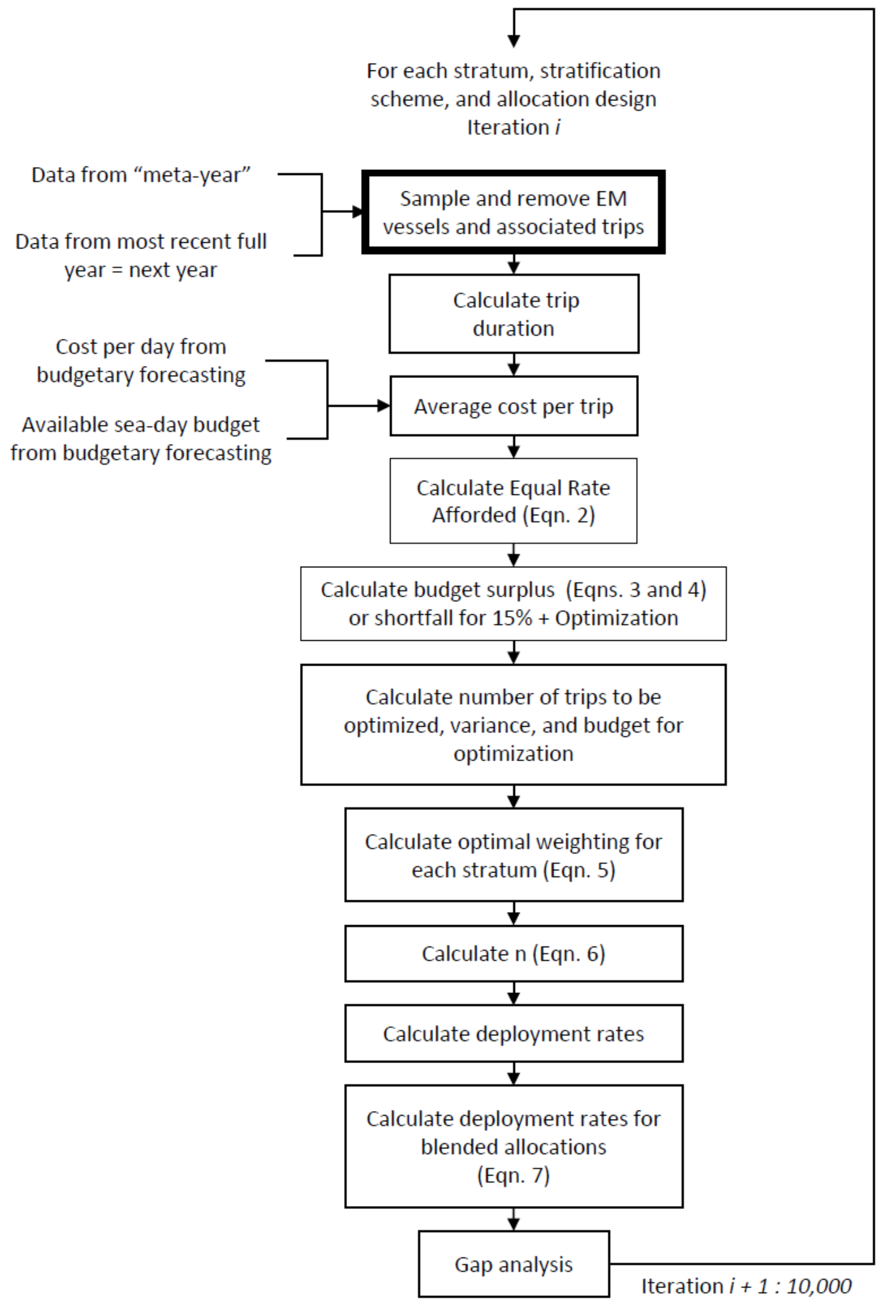

Figure 1. -- Flow chart depicting methods used in this analysis for each allocation and stratification design under consideration for the 2019 ADP. Sampling EM vessels was not conducted in this year, which is a departure from past years (bold box).

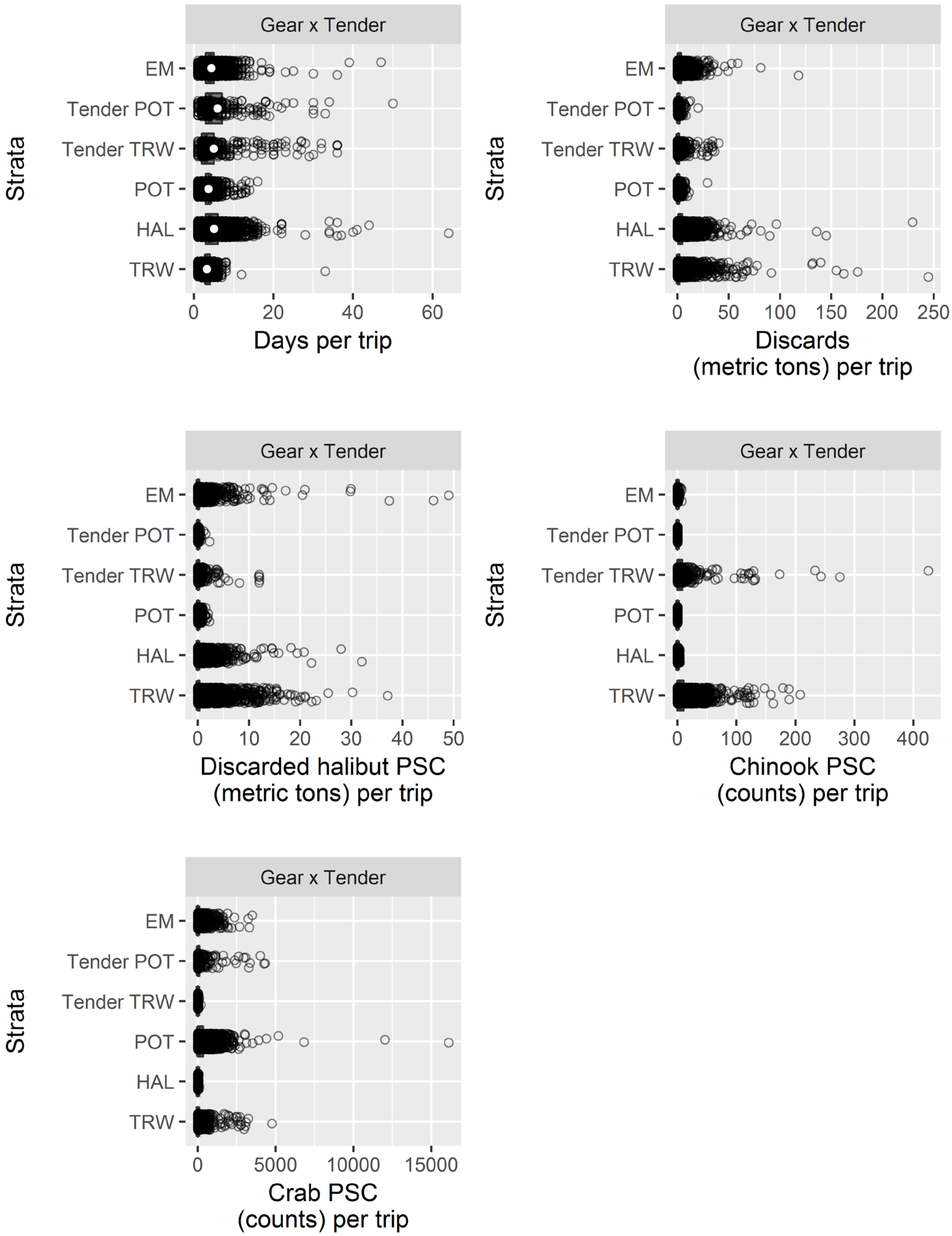

Figure 2. -- The distributions of trip duration in days, discarded groundfish catch, Pacific halibut prohibited species catch (PSC), Chinook PSC, and crab PSC for each stratum in the Gear × Tender stratification scheme. Shaded boxes denote the 25th, 50th, and 75th percentiles, and individual trips are shown as open circles.

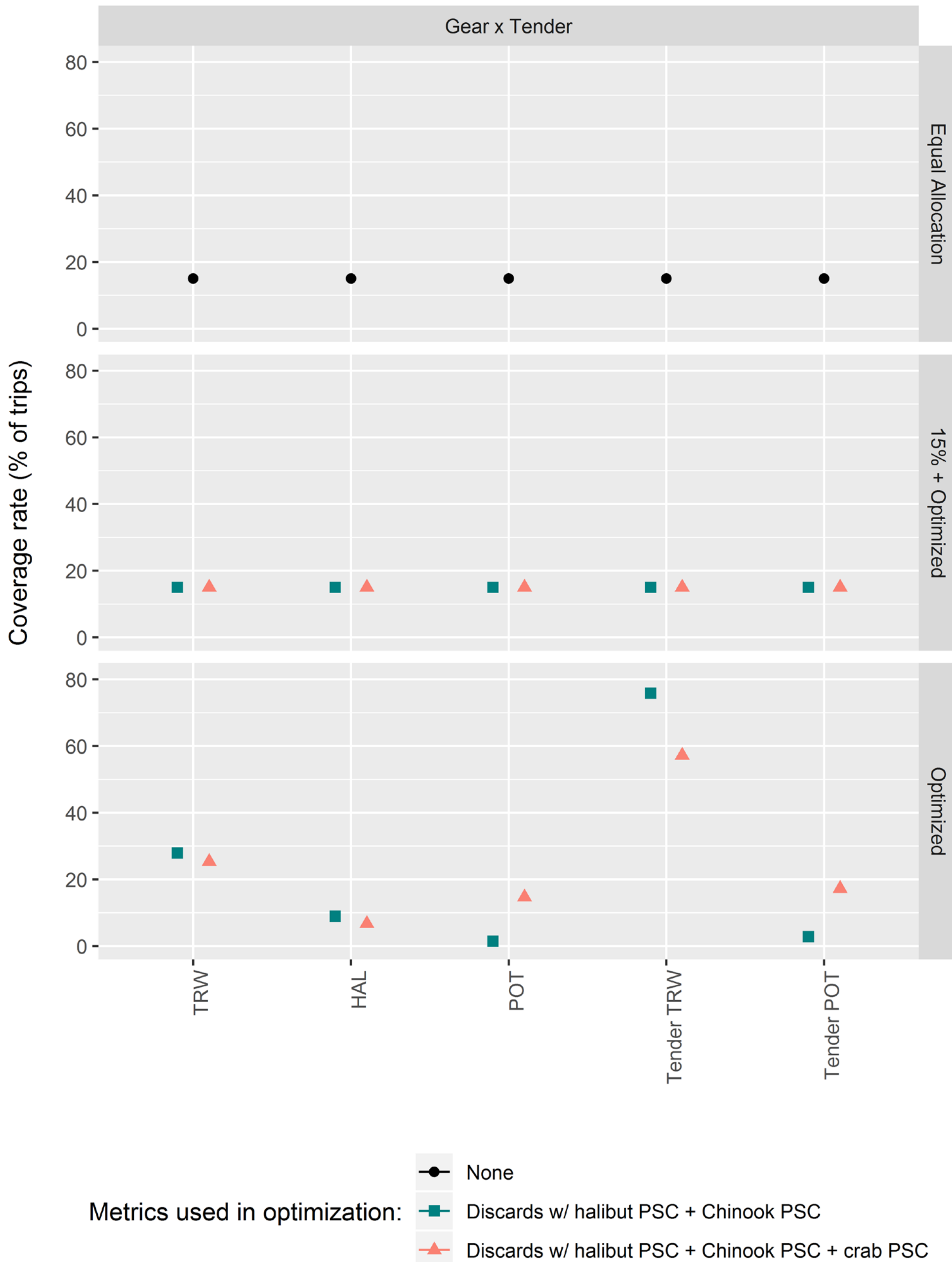

Figure 3. -- Comparison of preliminary draft coverage rates resulting from the Gear × Tender stratification scheme and three allocation designs (Equal Allocation, 15% + Optimized, and Optimized). Metrics used for optimization included discarded groundfish catch with Pacific halibut and Chinook prohibited species catch (PSC) (teal) and discarded groundfish catch with Pacific halibut, Chinook, and crab PSC (pink). Rates in the top panels are shown in black because no optimization occurred.

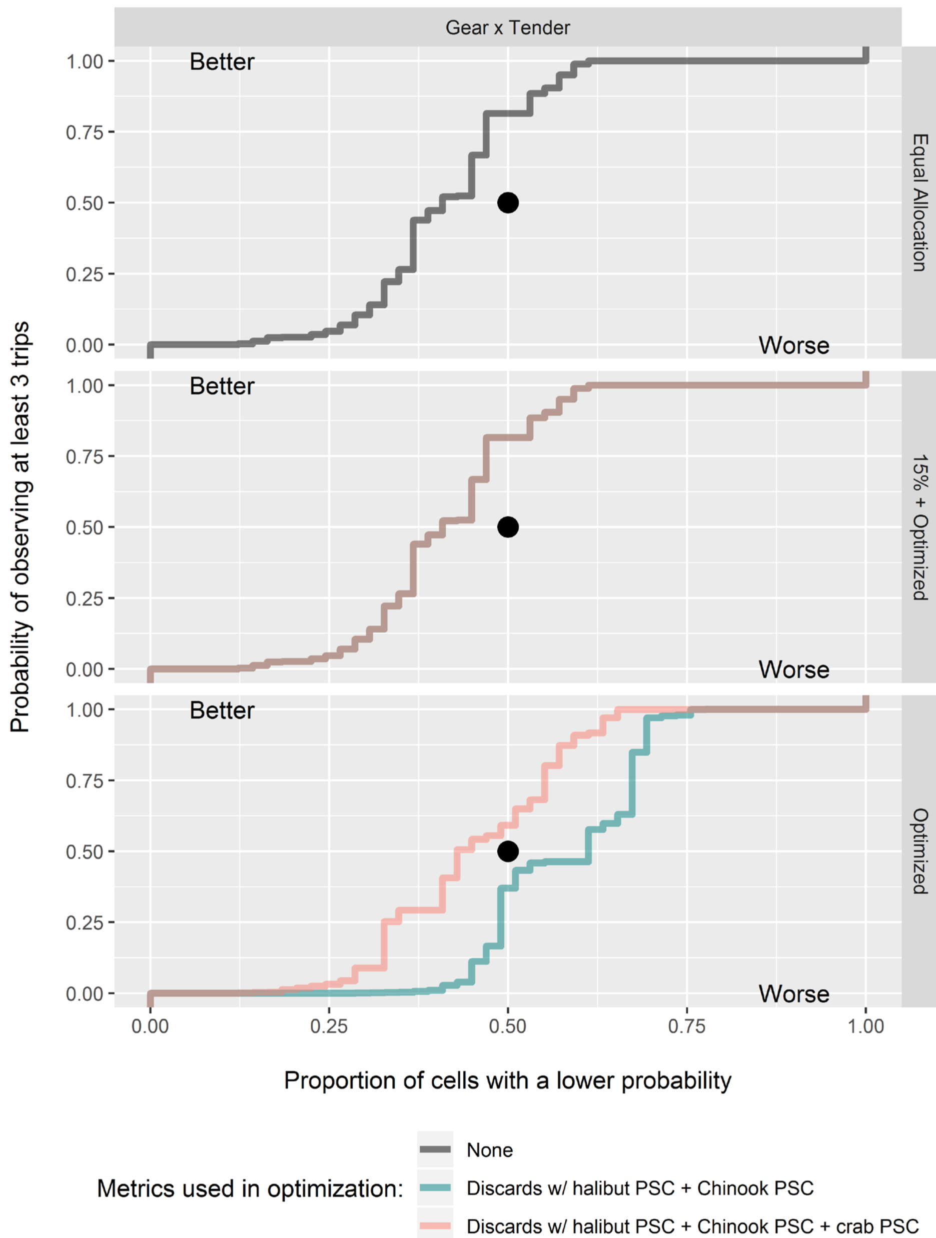

Figure 4. -- Empirical cumulative distribution curves for the probability of observing at least three trips in a domain defined by NMFS Area and stratum for the Gear × Tender stratification scheme and three allocation designs (Equal Allocation, 15% + Optimized, and Optimized). Metrics used for optimization included discarded groundfish catch with Pacific halibut and Chinook prohibited species catch (PSC) (teal) and discarded groundfish catch with Pacific halibut, Chinook, and crab PSC (pink). 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 center plot has two semi-transparent lines superimposed nearly perfectly on top of one another.

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