Catch Estimation Process for Electronic Monitoring

Overview of Potential Approaches

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Introduction

The North Pacific Fishery Management Council (Council) and National Marine Fisheries Service (NMFS) have established a goal to integrate electronic monitoring (EM) tools into the Observer Program. The Council's intent is to develop EM to collect data to be used in catch estimation for the fixed gear small-boat groundfish and halibut fisheries in Alaska. In 2016, NMFS and the Council initiated pre-implementation of EM in the small boat (40-57.5 feet length overall) longline fleet, focusing on vessels that have trouble carrying an observer. Along with the pre-implementation of EM onto vessels in 2016, NMFS is developing estimation methods so that data collected from those vessels can eventually be used in the NMFS Catch Accounting System (CAS) to generate catch and bycatch estimates for the EM stratum.

The purpose of this discussion paper is to describe the potential estimation methods and outline tradeoffs that NMFS is considering between the different estimation approaches. Once the estimation methods have been developed and the infrastructure has been put into place to move data from the video reviewers (currently occurring at Pacific States Marine Fisheries Commission) to the Observer Program at the Alaska Fisheries Science Center, and then to NMFS Alaska Region then the data will be used for management of the fisheries.

In the sample design currently used by the Observer Program there are three sampling strata (small-vessel trip selection, large-vessel trip selection, and full coverage). Within each stratum, the sampling and associated catch and bycatch estimation are hierarchical. Catch and bycatch estimation follows the sampling hierarchy by expanding sample data to the haul, haul data to the trip, and the trip data to the fishery within each stratum. Strata estimates are then combined to produce overall estimates.

As with estimation based on observer data, the EM stratum methods will depend of the sample design used to collect the data and the estimation needs. In 2016, there are approximately 60 vessels that opted-in to the EM stratum. In each of four sampling periods (Jan-Feb, March-June, July-Oct, Nov-Dec), a set of randomly selected of vessels will have EM systems installed. In 2016, a full review of all video (or stereo camera) imagery associated with all trips on the selected vessels will be conducted. Data that will be recorded during the video review are summarized in Appendix 1.

Within the EM sampling stratum, the vessel is the primary sample unit and all estimation will follow up the sample hierarchy to the individual (monitored) vessel before being extrapolated to the fishery within each of the four temporally defined EM sampling periods. Fishery estimates will then combined across these temporal sampling periods to generate overall estimates of at-sea discards for the EM stratum. These stratum-specific estimates will ultimately be combined with catch estimates from the observer strata to generate overall catch estimates.

Estimators

For trip, vessel, and fishery levels of the sampling hierarchy there are two estimation routes available: design-based estimation and ratio-based estimation. Overall, there are tradeoffs and pros and cons to each of these estimators (Table 1). Design-based estimators are unbiased if data are collected in an unbiased (e.g. randomized) fashion; however, they can suffer from higher variance than ratio-based estimators. Design-based estimators tend to weigh each sample unit (e.g, haul on a trip) equally so each haul would contribute equally to the overall estimate, regardless of how much discard (or catch) occurred. Ratio-based estimators take into account the size of the sample unit (hauls or trips) so that larger sample units contribute more to the overall estimate than smaller sample units. For example, the amount of discard per unit of haul-size (e.g. foot of groundline) is multiplied by the total size of the set (length of groundline). Ratio estimators can have lower variance if: 1) the size of hauls fished varies greatly, and 2) there is a relationship between the amount of discard and the size of the haul.

Post-stratification of sample units can also decrease variance of the final estimates for both design-based and ratio estimates. By post-stratifying sample units (e.g., hauls or trips) into groups with similar characteristics, the between unit variability (e.g., haul-to-haul) within the post-strata is decreased. Post stratification does add some variance to the catch estimation; however, if post-strata are chosen appropriately, the increase in variance due to post-stratification will be offset by the decrease in variance within post-strata (i.e. an overall decrease in variance). Potential post-stratifying characteristics could include area fished, target fishery, or time of year.

Table 1. Summary of basic data needs and potential tradeoffs that NMFS is considering between design and ratio based estimators

	Design-based estimator	**Ratio-based estimator**
Data needs	• Species-specific counts of discarded catch • Total number of hauls and trips fished on vessels with EM • Total number vessels for entire EM stratum	• Species-specific counts of discarded catch • Species-specific counts of at-sea retained catch • Accurate measure of haul size for all hauls on a trip • Total landed catch for each trip in the entire EM stratum
Pros	• Don't need at-sea retained catch or landed catch • Potentially less time required for video review (only need discarded catch) • Simpler approach if it is easier to only monitor discards	• Potentially lower variance than design-based estimator • Takes into account the size of the sample unit (e.g. hauls or trips) so that larger sample units contribute more to the overall estimate than smaller sample units • Better estimates of catch and discards if there is a lot of variability between size of sample units
Cons	Potentially higher variance than ratio-based estimator if the size of sample units (e.g. hauls or trips) varies	Potentially more time required for video review (to obtain data on both retained and discarded catch)

In the following sections we describe the data collection needs and estimation at each level of the sampling hierarchy for each estimation approaches. NMFS is evaluating these estimators and comparing the tradeoffs of both of these estimation methods. It is likely that the ratio-based approach to estimate catch from EM data in the longline fishery will provide better estimates and hence will be used.

Haul-level Estimates

To complete estimation at the haul-level, a representative portion of the haul must have imagery so that counts of each species caught and the disposition of each species can be obtained. Although the EM systems are expected to be recording data for the entire haul, technical issues may arise which will prohibit the capture of either imagery or sensor data. For the hauls with some missing imagery, species composition data (counts of fish) from the available video within the haul will used to expand to the entire haul.

In order to expand to the haul, it is necessary to have a measure of the portion of the haul that was sampled. There are several methods for quantifying to size of hauls on EM trips and each of these has some tradeoffs. The number of hooks sampled is often used as a measure of the size of a haul. In review of the EM data in 2014, we determined that counting hooks per haul from video images is difficult and time consuming. In 2016, vessels are recording effort information into a logbook (length and number of skates, number of hooks per skate, and hook spacing) so this information can be used to determine the size of the haul. A drawback to this approach is that it requires vessels to maintain an effort logbook. In addition, there is no mechanism for validating the self-reported information (i.e. there is no independent measure of these variables). As an alternative, we are considering using the length of the groundline as a measure of haul size. For this approach, haul size will be defined as the length of the groundline as computed from the GPS data collected during haul retrieval[1]. A concern with this approach is that wind and water current may affect how the boat moves during gear retrieval (e.g. if the boat is pulling gear with the current it may drift a longer distance than the length of the groundline). It would be preferable to calculate the length of the groundline during haul setting; however, the EM sensors rely on hydraulics and do not reliably record the haul setting activity. Given the tradeoffs with the various methods, NMFS plans to look at both the self-reported effort data (skates and hooks) and the length of the groundline as computed from the GPS data collected during haul retrieval to evaluate haul size.

In cases where some haul imagery is missing, ratio estimators will be used for the expansion; the species composition, by number, will be expanded to the total haul based on the proportion of the haul for which imagery and sensor data are available. Here we provide an example where the length of groundline will be used and the number of each species enumerated for each haul will be divided by the proportion of this groundline length for which species composition data are available.

Haul-level estimate of discards using ratio-based estimator:

$$\text{Estimated discards of a species for haul} = \text{Number of discards for a species enumerated during portion of haul with imagery} \times \frac{\text{Total length of groundline for the haul}}{\text{Fraction of groundline with imagery and/or sensor data}}$$

[1] Another option could be to use haul-back time if the length of groundline is not available.

Note that if the mean length per species is available from individual hauls (e.g. from stereo cameras where length of fish could be derived from video), it would be incorporated into the estimation process at this point.

If a ratio estimator is going to be used at the higher estimation levels, then estimates of set-specific estimates of catch retained (at-sea) would be required and therefore estimates of retained catch will be generated following the same process.

Haul-level estimate of retained catch using ratio-based estimator:

$$\text{Estimated retained catch of a species for haul} = \text{Number of retained catch for a species enumerated during portion of haul with imagery} \times \frac{\text{Total length of groundline for the haul}}{\text{Fraction of groundline with imagery and/or sensor data}}$$

If no sensor data or video data are available, the haul will be marked as not-sampled.

Trip Level Estimates

Although the goals for 2016 are for every haul on an EM monitored trip to have imagery and sensor data available, in some cases hauls may be marked as not-sampled or technical problems may limit the amount of data available for a trip. In addition, to decrease costs of image review in the future, imagery for all hauls on a trip might not be reviewed and hence some hauls will not be sampled.

For trips where one or more hauls are marked as not-sampled, discarded and retained amounts will be estimated based on data collected for the sampled hauls. Either a ratio or design based estimator could be used depending on available data and the variability between hauls in both discards and amount of gear set. If there is large variability, ratio estimators would likely provide better estimates.

In design-based estimation, the mean discard of a given species will be expanded against the total number of hauls fished on trip. Note that if estimates of mean length per fish are available from the trip (i.e., from hauls within the trip), it would be incorporated into the estimation process at this level.

Expand to trip using design-based estimator:

$$\text{Estimated discards for a species for a trip} = \frac{\text{Sum[Number of estimated discards for a species] for hauls with imagery}}{\text{Number of hauls with imagery}} \times \text{Total number of hauls fished in trip}$$

The minimum data requirements for design-based estimation at the trip level are estimates of discard (*weight or number*) for at least one haul on the trip and the total number of hauls fished for that trip (independently known, i.e. based on sensor data). Covariate information for post-stratification of all hauls within the trip (e.g. NMFS area, etc.) will also be necessary if post-stratification will be used in the estimation process.

In estimating discards using a ratio estimator, the ratio of at-sea species-specific discard to retained catch for all sampled hauls is expanded against total landings (all groundfish species and halibut) for the monitored trip.

Expand to trip using ratio-based estimator:

$$\text{Estimated discards for a species for trip} = \frac{\text{Sum[estimated discards for a species] for hauls with imagery}}{\text{Sum[estimated retained catch] over all species for hauls with imagery}} \times \text{Landed Weight for trip}$$

The ratio-based estimator has potential for lower variance if the at-sea discard number of fish (weight, if available) is correlated to landed weight or if there are large haul-to-haul differences in size of haul or size of discard. This estimator cannot be post-stratified within the trip due to its reliance on total landings, which cannot be post-stratified within the trip. However, this ratio estimator assumes that the ratio of the number of discards for a given species to the total number of groundfish retained is the same as the ratio of the weight of discards of that species to the total weight of groundfish retained. In other words, it assumes that the ratio based on numbers is the same as the ratio based on weight. For some species this assumption will not be valid (e.g. sleeper sharks). For this reason, it would be better to convert the number of fish of each species to weight at this level in the estimation process if possible (e.g. if length data are available for discarded and retained fish from the trip). Alternatively, if mean weight per fish is not available at a lower level in the hierarchy, then estimates would be adjusted by the species-specific mean weight per fish when expanded from the vessel to the fishery.

The minimum data requirements for ratio estimation at the trip level are estimates of discard (*weight or number*) for at least one haul on the trip, estimate of either total retained catch or total catch (*weight*) for those hauls with species-specific discard estimates, landed catch of groundfish species and halibut for the trip, including catch from all deliveries if there are partial offloads at multiple locations.

Vessel-Level Estimates

Since randomization occurs at the vessel level, estimates of discard are computed for each vessel before combining estimates across the selected vessels and applying those rates to the un-monitored vessels within the EM stratum.

It is expected in 2016 that on selected vessels there will be few trips where no EM data are collected and thus expansion won't be necessary from the monitored trips to the unmonitored trips on individual selected vessels for a given time period. However, in the situation where fishing occurs for a trip and none of the video imagery is sufficient to allow collection of species composition data or there is no sensor data that can be used to estimate set sizes, expansions will be required.

Expansion from monitored trips to all trips taken by a vessel within the time period will be required for vessels where every trip is not monitored. Using a design-based estimator, the total discards for a vessel will be computed by multiplying the post-stratified discard per trip by the total post-stratified number of trips made by that vessel. Any post-stratification covariates must be available for the entire trip (resolution of the landings data) for both monitored and unmonitored trips. This estimator has potential for high variance if trips are of differing duration, post-stratified sample sizes are small or vary greatly between post-strata, or discard amount varies between trips. At a minimum, use of this

estimator will require post-stratified estimates of discard number (or weight) for at least one trip for the vessel and the total number of trips made by the vessel in a post-strata.

Expand to vessel using design-based estimator:

$$\text{Estimated discards for a species for vessel} = \frac{\text{Sum[Estimated discards for a species] over trips with imagery}}{\text{Number of trips with discard estimates}} \times \text{Total number of trips fished}$$

Alternatively, a ratio estimator can be used to expand the ratio of post-stratified discard number (or weight) per trip, to post-stratified landed weight for monitored trips against the post-stratified weight of all landings by that vessel. Similar to the design-based estimator, any post-stratification covariates must be available for the entire trip (resolution of the landings data) for both monitored and unmonitored trips. The ratio estimator has potential for lower variance if trip discard weight is correlated with landings or if there is a lot of variation in the size of the trips made by a vessel. The ratio estimator requires, at a minimum, post-stratified estimates of the ratio of discard to landings for at least one trip for the vessel as well as the total post-stratified landings for unmonitored trips made by that vessel.

Note that this ratio estimator, similar to the ratio used at the trip level, assumes that ratio based on numbers is the same as the ratio based on weight. And, as mentioned above, this assumption will not be valid for all species (e.g. sleeper sharks). Thus, if length data were available from the vessel, the conversion to weight would be applied at this level. Alternatively, estimates would be adjusted by the species-specific mean weight per fish when expanded from the vessel to the fishery.

Expand to vessel using ratio-based estimator:

$$\text{Estimated discards for a species for vessel within a fishery} = \frac{\text{Sum[estimated discards for a species] for trips with imagery}}{\text{Sum[estimated retained catch] over all species for trips with imagery}} \times \text{Landed Weight of all species for all trips by vessel}$$

For both estimators, the conversion from numbers of fish to weight of fish would be made using post-stratified observer data from the same post-strata on similar vessels.

Fishery-level Estimates

Lastly, at-sea discards for a fishery will be estimated by expanding from the monitored vessels in the EM stratum to the unmonitored vessels. Using the design-based estimator, the mean catch per vessel for the time period is multiplied by the total number of vessels in the EM stratum that fished in the time period. To use the design-based estimator, at a minimum, post-stratified estimates of discard weight or number for at least one vessel and the known number of vessels that fished in a post-strata must be available.

Expand to fishery using design-based estimator:

$$\text{Estimated discards for a species within a sampling period} = \text{Sum[Estimated discards for a species] over vessels with imagery} \times \frac{\text{Total number of vessels in EM stratum that fished}}{\text{Number of vessels with EM deployed (assuming some imagery)}} \times \text{Mean weight per fish of a species}$$

The ratio estimator expands the ratio of weight discarded per trip to landings expanded to total landings for both unmonitored and monitored vessels. The minimum data required to use this estimation method are post-stratified estimates of the ratio of discard to landings for at least one vessel and total post-stratified landings unmonitored vessels.

Expand to fishery using ratio-based estimator:

$$\text{Estimated discards for a species within a sampling time period} = \frac{\text{Sum[estimated discards for a species] for vessels with imagery}}{\text{Sum[estimated retained catch] over all species for vessels with imagery}} \times \text{Mean weight per fish} \times \text{Landed weight of all species for all vessels in EM stratum in the time period}$$

For both estimators, conversion from estimated number to estimated weight within the post-strata will be based on mean weight per fish from monitored (human or EM) trips within the same post-strata. In cases where the ratio estimator was used at the trip or vessel level, the mean weight per fish will be applied to adjust the estimates.

Assumptions

We will assume that any gaps in video coverage resulting in missing data are completely random, and hence expansion from the remaining imagery will not introduce bias to the estimation process. As possible, this assumption will be verified. We are also assuming that the disposition (retained or discarded) of all catch is known at the haul level when catch is recorded. This includes situations where video imagery is not available for the entire time that fish are handled; we will assume that no fish are discarded during the time period after gear retrieval and before all fish are stored below deck.

Similarly, for all haul-level expansions we will assume that the haul size proxies represent the actual haul size (in terms of catch, groundline length, or time). Similarly, if the length of groundline is used for the expansion, we will assume that the estimated groundline length is an accurate, unbiased estimate of the total amount of groundline fished. For all haul level expansions, we assume that the species identifications are accurate.

At the higher levels, we also need to assume that post-strata assignments are accurate (data can be assigned to post-strata unambiguously). Imagery for trips and vessels are representative of trips and vessels where data are not available. Lastly, at all levels where the mean weight per fish is used, we assume that this mean weight per fish is representative of the true mean weight per fish at that level in the hierarchy.

Appendix 1: 2016 Alaska EM imagery review protocols for EM selection pool

Among video reviewer quality:

- Follow standard reviewer quality control protocol (blind reads every 3 months) to ensure consistent review.

For each drive, capture:

1. Drive Metadata:
    a. ADFG permit #
    b. Date drive retrieved
    c. Field assessment notes (Saltwater/Archipelago notes when drive was picked up)
    d. Logbook: Y/N
    e. Vessel Attributes:
        i. vessel configuration (covered deck vs deck uncovered); fishing gear (conventional, snap, auto line); deck gear; camera location; EM configuration; fishing characteristics (day vs night fishing; side-haul vs stern haul)

2. Initial review of drive imagery to answer the following:
    a. Is sensor data complete? Y/N
    b. Is imagery/video complete? Y/N

3. Data for each Trip:
    a. Trip start and end date and time
    b. Trip start and end ports (locations)
    c. Time gaps – characterize type of time gap, location within trip, and duration / number of missing sets (as possible)
    d. Target fishery: Trip targets will be assigned by using standard Catch Accounting System protocols based on the predominant retained species.
    e. Streamer line used (Y/N)
    f. Number of fished sets as determined by the sensors
    g. Paper logbook data (effort logs, IPHC logs)
        i. Key punch all data and maintain data tables. If an IPHC logbook is provided, then enter the same information that is collected on the effort log ***plus*** *the lat/lon of each set*.

4. Data for each set retrieval:
    a. Retrieval start and end date and time as determined by the EM reviewer
    b. Retrieval distance: use the latitude and longitude from sensors during the retrieval to derive a haul distance
    c. Gear type (within longline, differentiate snap and fixed gear)
    d. Time to review imagery for the set
    e. Time gaps, GPS gaps, sensor gaps, video gaps (Y/N)
        i. No video (Y/N) and why if No
    f. Reviewer confidence in data captures. EM reviewers will provide a data confidence rating (high, medium, low).
    g. Image quality: EM reviewers will provide an image quality assessment (high, medium, low).

i. For low image quality, they will assign a reason for the low image quality. Note that AMR will provide field assessment notes that might provide more information about why there was low quality.

5. Effort & catch data for 100% of set retrievals (in the future, the following items could be collected from a sub-set of randomly selected hauls):
    a. Effort Data
        i. Size of each set
            1. Amount of time to retrieve set
            2. Use the time & lat/lons from the sensors to calculate the length of the set
        ii. Any unusable or missing portions of set: Quantify the portion of set with missing or unusable image data (where catch and disposition cannot be identified). Quantify start/stop times for data gaps.
            1. Reason for low quality image data
            2. Reason for missing image data; portions of set retrieval without imagery
    b. Catch Data (including inverts, birds, and mammals)
        i. Species IDs to lowest level
            1. When a partial fish is caught (e.g. fish head, lips) and the reviewer can tell what species it is, then the species code will be used with a note designating a partial fish. If the species cannot be determined because too much of the fish is missing, then the "lips or heads" species is used. For halibut, it will be recorded as species halibut with a Discarded-Damaged disposition.
            2. If a seabird is caught, then capture a still image for post-hoc species ID confirmation. Record if the bird was <u>not</u> held in front of the camera for enough time for a still image to be captured.
        ii. Counts of each species
        iii. Disposition of catch using the following categories:
            1. Retained – General
            2. Retained – Damaged
            3. Discarded – General
            4. Discarded – Damaged
            5. Drop off below water
            6. Drop off above water
            7. Utilized onboard
        iv. For discarded Halibut Catch
            1. Injury key/Release condition
            2. Release method