Pacific Islands Fisheries Science Center

SAMPLING THE HAWAII DEEP-SET LONGLINE FISHERY

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1. INTRODUCTION

Quantifying bycatch in the Hawaii deep-set longline fishery is required by the Magnuson-Stevens Fishery Conservation and Management Act (MSA), Endangered Species Act (ESA), Marine Mammal Protection Act (MMPA), and Migratory Bird Treaty Act (MBTA) and their implementing regulations. As over a hundred species, some of them listed as endangered or threatened, have been recorded as being caught in the Hawaii deep-set longline fishery, reliable estimates of each species' total bycatch need to be computed in a relatively quick manner on a yearly basis. A probability sample and corresponding design-based estimators provide the framework for producing such estimates. Characteristics of the NOAA Fisheries Pacific Islands Observer Program (PIOP), established to monitor bycatch, and the Hawaii deep-set longline fishery require a sampling design that can adapt to fluctuating observer coverage and does not require a complete list of deep-set trips prior to drawing the sample.

As so many of the bycatch estimates are legally mandated and used for management purposes, a probability sample design that is expected to provide the best average efficiency over all species seems preferable. The simple random sample (SRS) is often the sample design that satisfies this criteria and has the advantage that data analysis is more familiar and straightforward. This design is not practical or cost effective for sampling the DSLL fishery, as it requires keeping enough observers on staff to cover the clumps of samples in a brief time period that can naturally occur when drawing a SRS or when the fleet becomes very active. This document describes the unique sampling design created to sample the DSLL fleet in a cost effective manner while accommodating the practical constraints that are inherit in sampling the fleet and aiming for a probability sample.

2. Sampling Design

When a trip is selected to be sampled, an observer is placed aboard the vessel for the duration of the trip and instructed to observe the complete haul back of every fishery operation. Our problem is to determine how to select trips for observer placement, preferably using a probability sampling design. To begin addressing this question, a sampling frame needs to be chosen. Two lists that are readily available for use as the sampling frame are the list of permitted vessels and the list of notifications. Notifications are recorded sequentially in the order they are accepted, and since they are accepted prior to a trip's departure, they can be used as a sampling unit. Once a notification is selected, the trip linked to it is considered selected for observation. A drawback to using the list of notifications is that the list is not complete until the year's end. In contrast, the list of permitted vessels is available prior to the new year. There are disadvantageous with using this list. First, a permitted vessel may not be active in the DSLL fishery throughout the year. Furthermore, all trips by the selected vessels would need to be observed (likely to be perceived as unfair by the selected vessels) or a secondary random sample of trips from each selected vessel is needed. As a list of a vessel's DSLL trips does not exist prior to the new year, drawing a probability sample is difficult unless we use the list of notifications. After considering both lists, we decided to use the list of notifications as the sampling frame.

The next problem to resolve is how to randomly select the notifications. A systematic sample is a natural design to consider in this circumstance as it can be easily drawn using the sequential list of notifications. Using this design, all notifications have a probability of being sampled and this probability is positive and known. Regarding placing observers, the benefits of this design are that the selected notifications are spread out evenly among the notifications and it is known when the next selected trip is approaching. There are two characteristics of the systematic sample that do not meet our needs. First, the systematic sample maintains a constant level of coverage. Therefore, enough observers need to be available to cover all selected trips during the periods of higher fishing activity. Second, the systematic sample will not accommodate the periods when there are more observers ready for deployment than required to cover the systematic sample. For example, when an observer training class is completed or when the fishery is not very active. To maintain the systematic sample at the required 20% coverage level would increase the cost of the observer program as more observers would need to be on staff and paid when they are not deployed. These requirements typically cannot be met under the current level of funding. To reach a balance between obtaining a probability sample and being cost effective, the sampling design used since mid-year 2002 has a two-stage sampling protocol. This two-stage design accommodates fluctuating coverage levels while utilizing observers efficiently.

2.1. **The First Stage.** For reasons stated above, the first stage of the sampling protocol is a systematic sample. The systematic sample is drawn at approximately 5% lower coverage than the targeted coverage level specified by the PIOP and contractor. Drawing the systematic sample at this level balances the need to insure that observers are available to cover the selected trips while maximizing the percent coverage by the systematic sample.

A detail to be resolved concerning the systematic sample is the number of starting points. Once a starting point is selected, every k^{th} unit thereafter is chosen to be sampled. A systematic sample is a special case of a cluster sample with k clusters in the population. For example, suppose there are a total of 100 trips and a systematic sample at 20% coverage with 5 starting points is to be drawn. Using sets of notification numbers, the 25 clusters that define the population are $\{1, 26, 51, 76\}, \{2, 27, 52, 77\}, \ldots, \{25, 50, 75, 100\}$. To draw a sample of 5 clusters only 5 starting points between 1 and 25 need to be drawn to define the selected clusters. If one starting point is used only one cluster is being sampled and it is not possible to obtain an unbiased estimate of the variance of the estimated bycatch.

When drawing a systematic sample for sampling the DSLL fishery, 5 starting points are selected from the integers 1 to k using simple random sampling without replacement (SRSWOR). Using 5 starting points provides the benefits of multiple starting points while preventing too many randomly selected trips being clumped together by random chance. For m denoting the number of starting points and C denoting the targeted percent coverage of the systematic sample, $k = 100m/C$. As an example, for $C = 15\%$ and $m = 5$, $k = 33.33$. Rounding k down to the integer 33 provides approximately 15.15% coverage by the systematic sample. This level of coverage has been the most commonly targeted level of coverage by the systematic sample. Hereafter, let M denote the number of clusters, the rounded value of k.

In summary, the systematic sample by itself constitutes a probability sample of the fleet. The systematic sample is a one-stage cluster sample where all elements in the selected clusters are sampled. Hereafter, the clusters defined by a systematic sample will be referred to as the systematic clusters. Hence, the primary sample units are the systematic clusters and the notifications are the primary elements of the systematic clusters. The primary sampling units are selected by SRSWOR.

2.2. **The Second Stage.** Now, let's consider drawing the additional samples required to achieve the targeted coverage level. Only after all upcoming notifications selected by the systematic sample are assigned an observer and there are still observers ready to be deployed should additional samples be drawn. The method for drawing these samples needs to be straightforward as they are needed quickly and with little forewarning. Drawing the additional notifications using SRSWOR from the list of notifications still eligible for observer placement is straightforward and the method that PIOP is instructed to use.

Because the occasions when secondary samples are drawn are not randomly selected but determined by the need to deploy observers, the probability a notification is selected by the secondary sample is unknown and needs to be approximated. To approximate these probabilities, the contractor's list of notifications is used. Examination of this list reveals periods when coverage appears to have been greater or less than the full targeted coverage. Further details regarding approximating these probabilities are provided in Section **??**. Regarding the complete two-stage sample, notifications are selected with unequal probability as a result of the secondary sample. For example, notifications that are in the sampling frame of the secondary sample will have a greater probability of being selected than those not in this sampling frame.

2.3. **Systematic-Plus Sample.** Hereafter, this two-stage design is called a systematic-plus (SYSPLUS) design. The samples selected by the secondary samples are referred to as the plus sample. The scheme used to derive the plus sample is referred to as the day scheme (samples are drawn on days when additional samples are needed), and a day sample refers to the occasion when a secondary sample was drawn from all eligible notifications. The plus sample typically consists of several day samples. The SYSPLUS sample is not a traditional two-stage sample as the term "two-stage design" typically refers to a design where primary units are selected during the first stage and elements within the selected primary units are selected during the second stage. The second stage of the SYSPLUS sample selects notifications that were not selected by the first stage systematic sample.

2.4. **Implementation of the Systematic-Plus Sample.** Since 2013, a new systematic sample is drawn yearly at a level of coverage that can be maintained, typically 15% coverage. If the percent coverage of the systematic sample needs to be adjusted during the year, a new systematic sample is drawn. This strategy encourages maintaining at least 15% observer coverage while allowing for a quick reaction to a shortage of observers. For example, as a consequence of having to delay an observer training course at the end of 2013, there was a shortage of observers at the beginning of 2014, so a systematic sample was drawn at 10% coverage. After newly trained observers passed the required exam and were ready to be deployed, a new systematic sample was drawn at 17.25% coverage and maintained until the 2015 systematic sample began. When more than one systematic sample is drawn in a year, the year's sample is stratified with SYSPLUS sampling within stratum. Hereafter, this design is referred to as a stratified SYSPLUS design.

This current strategy differs from the original protocol. When the SYSPLUS sample was first used in 2002 there was some interest in quarterly bycatch estimates, so a new systematic sample was drawn quarterly. Additionally, this quarterly draw allowed the coverage to be lower the first quarter of the year when the SSLL fishery is usually most active. During years 2005-2009, the first quarter systematic sample was drawn at 10% coverage to ensure observers were available to cover this sample and the SSLL fleet. The lower coverage in the first quarter was offset using the day scheme throughout the year so that the required annual 20% coverage was achieved. This strategy allowed for greater variability in the level of coverage throughout the year at the expense of precision. In an effort to increase the precision of the annual estimates with minimal additional cost, the observer program was encouraged to reduce the variability in observer coverage and maintain a systematic sample at 15% coverage throughout the year.

2.5. **Accommodating Research Trips.** In previous years, there were trips that participate in one of several NOAA research projects. Except for a few small research projects, all trips that participated in a project had a NOAA observer aboard performing their normal responsibilities and tasks required by the project. Trips involved in projects with 100% observer coverage were excluded from the sampling frame. Because these trips fished within the DSLL regulations and under the incidental take permit for the DSLL fishery, their bycatch was considered part of the bycatch for the fishery. For the years where there were research projects with 100% coverage, the estimated bycatch was the sum of the bycatch on the research projects and the estimated bycatch for the remaining fleet's effort.

Most projects without observers aboard did not interfere with the normal fishing operation and involved no more than a couple trips per year. For these projects, the participating trips were considered part of the sampling frame and treated as if they were not selected by the SYSPLUS sample. For the projects without observers aboard that did interfere with the normal fishing operation, there was a NOAA scientist aboard that recorded the bycatch for the trip. Trips with a NOAA scientist aboard recording bycatch were treated in the same manner as those with a NOAA observer aboard. Trips involved with research projects in the future will likely be handled in the same manner.

2.6. **Exclusion Bias.** On 27 August 2012 there was a change in the regulations of the Hawaii DSLL fishery that imposed new limits on swordfish landed. The new limits are as follows: (1) With a NMFS observer aboard, there is no limit on the number of swordfish landed or possessed on a trip, regardless of the type of hook used; (2) With no NMFS observer aboard, the limit is 25 swordfish landed or possessed on a trip, if the vessel uses only circle hooks; (3) With no NMFS observer aboard, and if the vessel uses any hooks other than circle hooks, the limit is 10 swordfish landed or possessed on a trip. In essence, this regulation created three components of the DSLL fishery defined by the number of swordfish a trip can keep. Regardless what design is used to select notifications, the first component (no limit on swordfish kept) will have 100% coverage and the other two components will have no observer coverage. Prior to the new regulations, all DSLL trips had a trip limit of 10 swordfish landed. The regulation limiting number of swordfish landed was put into place to discourage trips from targeting swordfish, which typically implies setting the gear shallow. The shallow setting of gear has historically resulted in different observed catch rates for the protected species. The exclusion of part of the fleet from the sample gives rise to the potential of exclusion bias and places limits on how much information our sample can provide about the total effort of the DSLL fleet. Extrapolating from our sample to the population requires making assumptions about the population that cannot be confirmed from the sample.

Although the SYSPLUS sample is still used to sample the notifications, the new regulations changed what the sample represents. Prior to the new regulations, the sample was a random sample of all DSLL trips fishing under a uniform set of rules and requirements. Under the new regulations, what is being randomly drawn is a selection of trips that will have an observer aboard and not have a trip limit on swordfish landings.