NOAA Technical Memorandum NMFS-AFSC-288
doi:10.7289/V5MG7MFF

Evolution of Observer Methods to Obtain Genetic Material from Chinook Salmon Bycatch in the Alaska Pollock Fishery

by
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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

January 2015

NOAA Technical Memorandum NMFS

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This document should be cited as follows:

Faunce, C. H. 2015. Evolution of observer methods to obtain genetic material from Chinook salmon bycatch in the Alaska pollock fishery. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-288, 28 p. doi:10.7289/V5MG7MFF.

Document available: http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-288.pdf

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January 2015

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ABSTRACT

A well-designed sampling program addresses specified objectives under the realities of limited resources. Chinook salmon (*Oncorhynchus tshawytscha*) is a species of great importance to the people of the North Pacific. Concerns over the bycatch of this species have led to actions that increase the monitoring and data requirements for the trawl pollock (*Gadus chalcogrammus*) fisheries of Alaska. Since 2005, the North Pacific Observer Program (observer program) has collected tissues from Chinook salmon bycatch for genetic stock composition analysis. The sampling design used to collect these tissues has changed in response to regulations that dictate how observers are deployed into the fleet. In 2011, a systematic random sampling (SYS) of individual bycatch salmon from every trawl pollock delivery was adopted by the observer program. This method requires that a census of Chinook salmon bycatch is achieved. However, regulations that enable the observer program to confidently achieve a census are lacking for the Gulf of Alaska (GOA) compared to the Bering Sea and Aleutian Islands. Consequently, a census of pollock deliveries was not obtained in the GOA during 2012 or 2013. Restructure of the observer program in 2013 eliminated fixed regulations governing partial observer coverage allowing for alternative sampling designs to be explored. Simulations using seasonal data show that an alternative simple random sampling (SRS) method would have consistently resulted in the collection of more genetic tissues at a lower cost than SYS. The SRS was formally incorporated into the 2014 and 2015 sampling design of the observer program for the GOA. The new annual process of making revisions to the observer program based on priorities and policy allows for rapid changes to the observer sampling design to meet genetic stock composition analyses and other fishery management needs.

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INTRODUCTION

Chinook salmon and Alaska pollock represent a prominent example of a fisheries management conflict accompanied by political debate. On one side of the conflict is the trawl fishery that targets walleye pollock (*Gadus chalcogrammus*). This is the largest fishery by volume in the United States; at last assessment, 1.3 M metric tons (t) of total walleye pollock valued at more than $417 M was landed and processed in Alaska (USDOC 2014). Alaska pollock is made into a variety of products and is a source of relatively cheap protein for millions of meals around the globe. On the other side of the conflict are fishers for Chinook salmon (*Oncorhynchus tshawytscha*). This species is caught in low numbers in near-shore and riverine fisheries, demands a high price per pound, is highly prized by sport anglers, and is a species of great cultural importance to the people of the North Pacific. Chinook salmon harvest quotas are fully allocated among subsistence, commercial, and recreational fisheries in and off Alaska and Canada.

This fisheries management conflict arises because Chinook salmon are caught incidentally as bycatch with pollock. Chinook salmon are one of several species whose bycatch from within groundfish fisheries is limited and may not be sold. Chinook salmon is one of the two most often encountered species of salmon bycatch in the pollock fishery operating in the Bering Sea and Aleutian Islands (BSAI), and the pollock trawl fishery that operates in the Gulf of Alaska (GOA) has historically accounted for the greatest proportion of Chinook salmon taken as bycatch in the area's groundfish fisheries (NMFS 2009, NMFS 2011). Since National Standards require balancing optimum yield with minimizing bycatch and adverse impacts to fishery-dependent communities (USDOC 2007), balancing the impact of this bycatch to the benefit of people and the resource is a major priority of the North Pacific Fishery Management Council (Council) that oversees the federal fisheries of the region. Several bycatch reduction measures have been put into place in the pollock fisheries, and exceeding bycatch limits of Chinook salmon triggers area or fishery closures for pollock[1].

Bycatch is most easily measured in terms of total amounts. However, Chinook salmon bycatch in the pollock trawl fishery is an example of a mixed-stock fisheries management

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[1] See http://www.npfmc.org/wp-content/PDFdocuments/bycatch/Bycatchflyer913.pdf

problem that requires the identification of the stock of origin for salmon (Waples et al. 2008); only when stock size and bycatch amounts are compared does the latter become meaningful. Identifying the stock composition of Chinook salmon is especially important because some of the stocks of these species are in a depressed state (Ruckelshaus et al. 2002). For example, in 2010 the U.S. Secretary of Commerce announced that a fishery failure had occurred for the Yukon River Chinook salmon due to low salmon returns. The Acting Secretary of Commerce determined that a fishery resource disaster for Alaska Chinook salmon existed during 2010-2013 to varying degrees for three regions of Alaska.

The stock structure of mixture samples can be identified with genetic techniques (Ward 2000, Ovenden et al. 2014). As for any technique, the robustness of such techniques is dependent on the strength of the genetic signal used to differentiate stocks and the representativeness of sample data. The development of genetic baselines to identify stocks of Chinook salmon in the North Pacific has been well documented (Seeb et al. 2007, Templin et al. 2011), whereas the sample design used to collect genetic tissues from the bycatch has not.

This work describes the evolution of the sampling design used by federally-trained observers to collect the tissues that enable genetic stock composition analysis of salmon bycatch. Special emphasis is placed on the analyses that support the most recent sampling design change that took effect in 2014. Such analyses are necessary to gauge the adequacy of existing regulations and policies that support bycatch monitoring as well as the efficiency of the sampling program used to support mixed-stock fisheries management.

EVOLUTION OF THE SAMPLING DESIGN

The amount and distribution of biological tissues used to support stock composition analysis of Chinook salmon bycatch is a function of where observers are deployed within the fishery, how samples are collected from the catch, and the distribution of bycatch within the fishery. Of these, only the first two are elements of a sampling design since they can be known before fishing begins.

The North Pacific Observer Program

Observers in the North Pacific provide fishery discard information, seabird and marine mammal interactions with fisheries, and collect biological data such as species composition, weights, and tissue samples. Although observer tissue collections have historically focused on otoliths and gonads to support age and reproductive studies, more recently pelvic axillary processes for genetic testing of salmon bycatch have been added to observer duties. For resulting information to be relevant, it is paramount that observer data be representative and unbiased. Although fishers may behave differently when observed, observers in the North Pacific are required to report known violations to enforcement, and play an important role in monitoring the fisheries of the region (Porter 2009).

Observers in the North Pacific operate under the authority of the National Marine Fisheries Services' (NMFS) North Pacific Groundfish and Halibut Observer Program (observer program) that is administered by the Alaska Fisheries Science Center's (AFSC) Fisheries Monitoring and Analysis Division. The NMFS has observed fishing vessels operating in the BSAI since 1973 and in the remainder of Alaska since 1975 (Nelson et al. 1981, Wall et al. 1981). What began as foreign-owned operations became joint domestic and foreign operations in 1986, and in 1990 an exclusively domestic fishery was established. Between 2002 and 2013, an average of 38,404 working days (range 35,103 - 45,188) have been logged by observers in the North Pacific each year, making the program one of the largest of its kind in the world (Hall et al. 2000)[2].

Observer coverage requirements for the North Pacific fishing industry have remained largely unchanged for several decades. During 1990-2012, observer coverage requirements were specified (and could only be changed) in regulations that are initiated through Council action. Three at-sea coverage rates were set largely based on vessel size: 1) groundfish vessels under 60 ft. in length overall (LOA) were not required to carry observers, 2) those 60-124 ft. were required to carry observers for 30% of their fishing activity (defined as days for trawl and longline gear; pots for pot gear) in a calendar quarter in addition to one trip in each fishery the vessel participated in, and 3) those vessels 125 ft. or longer were required to carry observers for

[2] Annual summaries of observer programs can be found in National Observer Program Annual Reports available at http://www.st.nmfs.noaa.gov/observer-home/reports/nopannualreports/.

all of their fishing activities. Shoreside processor coverage was based on metric tons processed in a month. Those that processed between 500 t and 1,000 t were required to have observers 30% of the days that they received or processed groundfish, while those that processed 1,000 t or more were required to have observers for all of the days that they received or processed groundfish. In addition to these broad requirements, there were several actions to implement certain limited access programs with increased monitoring needs. One of these, the American Fisheries Act (AFA) allowed for the formation of fishing cooperatives in 1998, and full observer coverage for trawl vessels fishing pollock in the BSAI was initiated (Graham et al. 2007)[3].

Prior to 2013, all observers were paid for by industry and directly contracted through observer provider companies. The days or trips that were to be observed under the regulatory framework were also under industry control. Long-standing concerns that industry's ability to self-select observer coverage resulted in biased data was demonstrated in some cases (Faunce and Barbeaux 2011). In 2013 the observer program was restructured to change the way observer deployment was conducted and funded (NPFMC 2011). While the restructured program inherited mandatory 100% observer coverage for some operations that are industry-funded under a pay-as-you-go system (e.g., AFA), coverage rates or deployment methods for partial coverage are not specified in regulation (Faunce 2013). As part of the new annual process, the restructured observer program reports to the Council in June on the relative performance of the program in meeting its goals and objectives for the prior year, and in October and December provide their draft and final Annual Deployment Plan (ADP) for the coming year. The ADP specifies what operations are under partial coverage, the units of coverage (changed from days and gear to trips or vessels), and the anticipated rates of coverage. Sampling fractions in the partial coverage fleet depend upon available funds (that are available to NMFS from ex-vessel fee proceeds), deployment methods, anticipated effort, and NMFS policies. This approach offers the opportunity to make incremental changes to the sampling design of the observer program in order to meet its stated goals and objectives. Through its new ability to directly contract with an observer provider and deploy observers based on a sampling plan, the restructured observer

[3] American Fisheries Act summary available at http://alaskafisheries.noaa.gov/sustainablefisheries/afa/afa_sf.htm.

program was able to randomize observer deployments (to protect against bias)[4], and to tailor trainings by coverage category.

How Genetic Samples are Collected

The sampling design used by observers to obtain tissues to genetically test Chinook salmon bycatch has undergone considerable evolution with changes in observer deployment and sampling priorities (Table 1). The task to collect genetic tissues started in 2005 as a special project to be conducted by observers if time allowed. Between 2005 and 2008 the number of tissues observers were asked to obtain increased nearly five-fold from approximately 30 to over 120 per contracted deployment (typically 90 days). During this time tissues were haphazardly collected by observers. In 2008 the observer program formally adopted a hierarchical nested design (Trip>Haul>Species Compositions>Lengths>Tissues) with randomization at each level except the trip (at the time under industry control). From 2009 to 2010 observers were instructed to obtain genetic samples from any salmon that were contained within their species composition samples taken at sea. In addition, observers were instructed to sample salmon from every catcher vessel pollock offload made dockside. Offload sampling followed a Systematic Random Sampling (SYS) design. In SYS designs, the observer samples at regularly spaced intervals of n units- the first of which is randomly selected. In the 2009-2010 design, observers sampled 5 minutes of every hour (~8% sampling fraction, Table 1).

The collection of salmon bycatch tissues for genetic analysis was adopted into the regular duties of observers beginning in 2011, when regulatory Amendment 91 (A91) to the Fishery Management Plan of the BSAI was implemented for the trawl pollock fishery. Under A91, salmon bycatch limits were enacted, full at-sea and dockside observer monitoring was implemented, and shoreside processors were mandated to modify their activities to accommodate observer access to salmon bycatch. Coincident with A91, the observer program adopted SYS *with individual fish as the sampling unit* as part of its regular duties for observers following the recommendations in Pella and Geiger (2009, Table 1). The sampling interval was determined from the interplay between the desired number of samples needed to determine stock of origin

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[4] Randomized deployments are achieved through the Observer Declare and Deploy System (odds.afsc.noaa.gov).

from the fishery and the amount of bycatch anticipated to be caught, and was set at 1 in 10 for Chinook salmon (10% sampling fraction).

The SYS method using individual fish as a sampling unit ensures that sampling is well distributed throughout the population of bycatch (Pella and Geiger 2009). However, it also carries the requirement that each and every salmon is encountered by the observer. While this requirement can be assumed true for the BSAI under A91, such an assumption cannot be made for observers in the GOA since not all at-sea or dockside activities were observed. The decision to train all observers in 2011 under one design was a consequence of the way observers are deployed into fisheries; while the observer program trains and debriefs observers before and after their deployment, respectively, agreements made between industry and their observer provider companies determined where observers were deployed. In 2011 there was no way to discriminate between observer trainees that would be deployed into fully observed operations such as the BSAI trawl pollock and those that would not. Furthermore, there was some expectation that a census of salmon would be possible the following year when Chinook bycatch limits were placed on the GOA pollock trawl fishery. At the start of 2012, industry and NMFS engaged in a voluntary agreement whereby the GOA trawl pollock fishery would not discard salmon at-sea and would retain all salmon at the shoreside processing facility for observers. These rules governing the handling of salmon were codified later in the year as Amendment 93 (A93) to the Fishery Management Plan of the GOA. Since a census of the salmon would be made available to the observers upon dockside delivery, at-sea sampling by the observer program in the GOA was discontinued in 2012 and this SYS dockside only method in the GOA was continued for 2013 (Table 1)[5].

The provisions made for observers to obtain quality data collection greatly differ between Amendment 91 in the BSAI and Amendment 93 in the GOA. Although both A91 and A93 have placed limits on bycatch that close directed fishing opportunities for trawl vessels and prohibit the discard of salmon bycatch at-sea, not all at-sea or dockside operations required observation under A93. Without complete observer coverage, not all trips are monitored at-sea for compliance with the requirement to retain salmon bycatch, and the requirement that dockside

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[5] In 2014, salmon bycatch limits and retention rules similar to those in A93 were implemented in non-pollock trawl fisheries of the GOA as Amendment 97 (A97) to the Fishery Management Plan of the GOA.

processors retain salmon bycatch until inspected by an observer becomes moot if there is no observer available. Since the observer program was not able to obtain a true unbiased census from which to enumerate salmon and obtain genetic samples in the GOA due to a variety of reasons that include a lack of available funds, alternatives to the SYS method using fish as the sampling unit were explored. The following is a description of those analyses, and the resulting changes to the sampling design of the observer program.

EVALUATION OF ALTERNATIVE METHODS TO OBTAIN GENETIC SALMON BYCATCH TISSUES IN THE GULF OF ALASKA

Methods

A simple random sample (SRS) of GOA pollock trawl trips, where the trip is the primary unit, was evaluated as an alternative sampling design. Instead of trying to obtain a census of the deliveries and sampling from the individual salmon bycatch (the SYS method), this method randomly samples from trips and censuses the salmon bycatch encountered in each associated delivery to the processor (Table 2). Prior to the restructuring of the observer program, a SRS design was not possible.

Data were obtained from several sources. Catch estimates produced by NMFS' Alaska Regional Office and observer data from the AFSC were combined at the level of the delivery (trip) to create a dataset containing the identity of the GOA trawl pollock trips and deliveries made by partial coverage catcher vessels during 2012 and 2013, whether or not each trip was observed at-sea and/or dockside, the actual number of salmon enumerated by the observer on observed trips, the number of genetic tissues obtained by the observer from within observed deliveries, and the number of Chinook salmon caught as bycatch in the delivery (determined from the CAS) for all GOA trawl pollock trips.[6] Data were classified as belonging to either the January-June or the July-December seasons that correspond to the temporal prosecution of the GOA trawl pollock fishery. Data were summarized and compared for each season and year combination (n = 4). Logistics data from the observer program were used to enumerate the

[6] For detailed information on CAS imputation algorithms see Cahalan et al. (2014).

number of days observers were deployed in shoreside processing plants during each period. The at-sea sampling rate was derived as the sum of observed pollock trips divided by the total number of pollock trips.

The expected performance of SRS was explored through simulated sampling of past catch information. In each of 1,000 simulations, the data consisting of unique GOA pollock trawl landings in a given season and year combination was sampled at a rate equal to the at-sea sampling rate, where the number of salmon in deliveries made to a tender-vessel (a vessel that receives and transports the catch of others boats from fishing grounds to dockside processors) was set to zero to reflect the real-world difficulty with deploying observers into this vessel-activity type. The relative performance of the SRS and the SYS were compared using the following metrics: 1) the number of days required for the observation of deliveries, 2) the number of observer days to be paid under contract, 3) the number of tissues obtained, and 4) the cost to obtain a genetic tissue.

Estimates of the number of days required for the observation of deliveries from the alternative SRS design was conducted in several steps that follow the duties of observers. Observers are required to monitor the offload to make sure all of the salmon are made available, and subsequently to sample from the retained salmon. Therefore, as a first step, observer program staff at the AFSC with a history of monitoring GOA pollock deliveries were asked their opinion of how long this task takes. Since there is a 300,000 lb delivery limit in the GOA trawl pollock fishery, the times required were expected to have a similar maximum. A maximum value of 4 hours of observer work was the most common response. It was also assumed based on staff experience that it would take 5 minutes maximum to sample each fish. Therefore, for each trip in each simulation, the number of salmon expected to be in the delivery was multiplied by 0.08 hours and the value of 4 was added to the total. To calculate the number of observer days to be paid under contract, it was assumed that an observer day would equal a 12-hour shift. The hourly total workloads for each simulated trip were divided by 12 and rounded up to the nearest whole number to yield a number of observer days required per simulated trip. Summing this value across all trips within each simulation yielded the total number of expected observer days. The actual values for the number of tissues obtained and the days paid to monitor the GOA pollock offloads were compared against distributions of the simulated values for the alternative method. Finally, the cost of obtaining one Chinook salmon genetic tissue sample (i.e., efficiency) was determined by dividing the product of the total number of days by the cost of an observer day (obtained from the observer program) by the number of tissues obtained.

Results of Comparisons

Comparison of at-sea deployment strategies and achieved coverage rates from each season and year combination is of particular interest since the restructuring of the observer program in 2013 changed the way at-sea deployment was conducted, the at-sea sampling units, and the target rate (Table 3). At-sea sampling rates were consistently higher in January-June compared with July-December and were not always equal to the target rate. Dockside monitoring rates in the GOA fell short of the rate required by the SYS method (1.0) in all season and year combinations, with more stable coverage levels among seasons in 2013 than 2012. The weighted averages of dockside coverage rates were equal between years (77%).

The alternative SRS method in the GOA would have resulted in more genetic tissues collected over fewer days resulting in substantial gains in economic efficiency in all four combinations examined (Table 4). Compared to the (median) alternative SRS method, the SYS yielded between a quarter and a half of the tissues, required 1.39 to 2.84 times more days to monitor, and cost 2.69 to 10.22 times more per tissue (actual values divided by median alternative values). To better illustrate how data in Table 5 were derived, the actual values and simulated distribution of alternative values are depicted for the number of tissues in Figure 1.

DISCUSSION

Recent regulations represent a fundamental shift in the way Chinook salmon bycatch is managed in Alaska. Chinook salmon bycatch identified at-sea is now required to be retained (discards are “banned”), whereas prior to A91 and A93 any bycatch needed to be discarded (i.e. they were “prohibited” from being retained). These regulatory discard bans are meant to aid genetic stock composition analysis by providing observers increased access to Chinook salmon bycatch upon delivery of the catch from the trip. Discard bans have been implemented in a number of fisheries around the world, but they rely on a high level of monitoring or strong enough incentives to encourage selective fishing (Condie et al. 2014). In Alaska, information from the observer program is made available electronically daily or at the end of a trip to ensure effective management by NMFS and to maximize economic gain by fishers. For example, the BSAI pollock trawl fishery has employed a highly sophisticated data-sharing system among members of its cooperative since 1994 (Gilman et al. 2014). In this system, an independent consulting company uses observer data to generate and share warnings of high-bycatch areas to avoid. Complete at-sea and dockside observer coverage, combined with alterations to the way fish are handled in the processing plants allows the NMFS to allocate salmon bycatch to the individual fisher, monitor quotas and compliance in near real time, and enables cooperative data-sharing. Other cooperative data-sharing systems are in use in Alaska, and all have the following: high levels of observer coverage, a cooperative manager, and rapid and reliable communication among all participants (Condie et al. 2014, Gilman et al. 2014). In contrast to its counterpart in the BSAI, the trawl pollock fishery that operates in the GOA is not completely observed. Consequently the allocation of salmon bycatch cannot be made to the individual fisher, enforcing and monitoring a discard ban for Chinook salmon is problematic, estimation must be made based on expansion of observer data, and data-sharing agreements are not facilitated (Table 5).

The SYS method for collecting genetic tissues from Chinook salmon bycatch using fish as a sampling unit carries the requirement that a census of the population of bycatch is available to the observer. The method has been employed by the observer program with different success in the BSAI compared to the GOA. The full monitoring requirements combined with modifications to the way fish are processed under A91 in the BSAI provide the tools necessary for the observer program to meet the assumptions required by SYS in ways that A93 in the GOA do not. The regulations of A93 are intended to enable the collection of salmon genetic data in the pollock trawl fisheries (and facilitate reporting of salmon bycatch at the processor). Under A93, retention of salmon is required until the catch is delivered to a processing facility where an observer is provided the opportunity to count and collect biological samples from the salmon. Since not all GOA pollock fishery trips are selected for observation at-sea, the ability for the observer program to observe associated deliveries in remote locations is compromised. For example, achieved tissue sampling rates from observers were very close to the 10% target in the BSAI, but did not meet this target in the GOA in 2012 (Guthrie et al. 2014). The following year, a complete census of trawl pollock deliveries was accomplished in the BSAI full-coverage fleet but dockside monitoring in the GOA fell short of this requirement (Faunce et al. 2014, this study)[7].

Obtaining genetic tissue from Chinook salmon bycatch in the trawl pollock fishery is now one of the top priorities for observers in the North Pacific (AFSC 2014). The progressive increase in sampling effort and priority given to obtaining genetic tissues from salmon bycatch from the pollock trawl fishery has not been offset by a decrease in competing priorities for observers and the observer program. Given the multiple priorities of observers, the collection of genetic tissues must be conducted efficiently and effectively. The results of this study demonstrate that the alternative SRS method represents a much more efficient approach to obtaining Chinook salmon bycatch genetic tissues from observers in the GOA trawl pollock fishery given the limits to obtaining an observer census of deliveries in this region. Most importantly, the SRS method utilizes the randomization of trips afforded to the observer program since 2013 to obtain an unbiased sample of trips from the fishery and does not require that a census of bycatch salmon be obtained. The SRS method to obtain Chinook salmon genetics from the trawl pollock fishery should remain more efficient than SYS methods as long as at-sea deployment rates remain above 10%. This is not guaranteed, however, as at-sea deployment rates in the observer program since 2013 are set by the interaction between available budgets, cost of observer deployments, and anticipated fisher effort. Nonetheless, selection probabilities in the Gulf of Alaska trawl catcher vessel fleet have risen from 0.145 in 2013 to 0.160 in 2014 and to 0.240 in 2015 (NMFS 2014a).

The simulation analyses herein were originally included as an appendix to the 2014 ADP presented to the Council (NMFS 2013). For trawl vessels, trips for at-sea observer coverage will be randomly selected, and those trips in the GOA pollock fishery will be completely monitored for Chinook salmon bycatch by the same observer upon delivery of the catch dockside. This SRS design described herein was again adopted for use by the observer program in 2015 (NMFS 2014a, Table 6)

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[7] The dockside sampling rates within the GOA trawl pollock fishery between this study and that of NMFS (2014b) are not identical due to the difficulty in defining trips between the analyses. For this reason the results in Table 2 for 2013 should be interpreted with caution. While the results here are similar, for official results the reader is referred to NMFS (2014b).

Although the adoption of the SRS method by the observer program should be more efficient than the SYS method because it frees the program of the requirement of obtaining a census of GOA trawl pollock deliveries, the method is not without its shortcomings. For example, defining the primary unit of sampling is problematic because the amount of pollock in the delivery is unknown before a trip begins. However, this problem also exists for the SYS method. For this reason, the observer program relies on the observer to obtain the captain's intended target species for the trip.

Although more efficient for the observer program, changes in sampling methods can have unintended consequences for data-users. When the observer program made obtaining salmon bycatch genetic tissues an observer priority, the program stopped collecting lengths from every salmon encountered, and only collected sex, length, and weight from every 10th Chinook salmon in the delivery. Separate attempts to determine the magnitude of impact to the population of Chinook salmon in Alaska posed by salmon bycatch from the pollock trawl fishery uses salmon length information to infer age, and these efforts have been impacted by the loss of length information from the observer program (Ianelli and Stram In press). The data resulting from the SRS method will be more difficult for genetics laboratories to interpret because the method requires appropriate raising procedures (expansion from the sample to the fishery population) and sampling rates are not explicit in collected data. Genetic analysts will need to consider ancillary factors such as fishery effort and catch in order to provide proper weightings to expand sample results to the fishery. Such an effort was successfully carried out using the observer sample data from 2012 examined here. In that study, stock compositions that had been expanded to the fishery did not differ from those of the sample (Guyon et al. 2014), highlighting that the overall effectiveness of stock determinations in mixed population fisheries depends not only on the marker baseline to discriminate between separate stocks, but also the ability of the sampling program to provide adequate sample sizes in an unbiased manner (NRC 1996).

From the evolution of the sampling design shown in this study, the monitoring of salmon bycatch in the pollock trawl fishery will likely remain a priority for the observer program into the foreseeable future. In the North Pacific there is interest in placing the trawl fleet that operates in the Gulf of Alaska under 100% at-sea and dockside monitoring requirements (NPFMC 2014). These new requirements would go a long way to satisfying the SYS requirements for the GOA pollock trawl fishery, as well as address concerns about data-gaps in seafood supply chains that enable illegal, unreported, and unregulated (IUU) fishing (Jacquet and Pauly 2008, Pramod et al. 2014). If enacted, it seems likely that the observer program would revert back to the SYS sampling design that has been in place since 2011 in the BSAI.

Regulatory measures have been the predominant method to set observer coverage rates and units of deployment in the North Pacific. What makes the program in the North Pacific unique is that prior to 2013 it was the only program in the United States that had partial coverage rates specified in regulation and industry control over deployment. This means that the observer program in the North Pacific could only change coverage rates through additional regulations that could take up to 2 years to enact. The history of the Chinook salmon genetic sampling design employed in the North Pacific - documented here for the first time - has highlighted that mismatches between the regulatory specifications for observer coverage and the requirements of the sampling design leads to inefficiency at best and bias at worst. In contrast, the flexibility afforded to NMFS to deploy observers through restructuring has enabled the program to explore alternative designs for genetic Chinook salmon bycatch sampling in the pollock fishery that should result in representative data being collected cost-effectively. Through the annual process, the restructured observer program allows for iterative adaptation so as to make continuous improvements as recommended elsewhere, rather than rely on fixed regulation for change (Harrington et al. 2005).

ACKNOWLEDGMENTS

The simulations in this work originally appeared in: *Appendix B: An evaluation of current and alternative methods to sample Chinook salmon bycatch in the Gulf of Alaska (Walleye pollock fishery*). It would not have been possible without the hard work of trained observers who endure harsh conditions in sometimes hostile environments, and my thanks and respect go towards those who earn the title of observer. Collaboration and cooperation between the AFSC's Fisheries Monitoring and Analysis Division and the Sustainable Fisheries Division of the AKRO greatly facilitates meaningful and timely analysis of fishery-dependent information. Martin Loefflad and Jennifer Mondragon deserve credit for making this happen. Thanks to Jason Gasper and Glenn Campbell who provided the data queries necessary to conduct this analysis, and to Jennifer Cahalan (Pacific States Marine Fisheries Commission) for providing me the R simulation code that was the starting point for this analysis and for the many productive conversations we have had on this topic. I appreciate the education provided by Jim Ianelli, Diana Stram (NPFMC), and John Gauvin on their salmon bycatch research and mitigation work being done in the North Pacific. This manuscript was improved through the input provided by J.Guyon, J.Gasper, J. Mondragon, and C. Rilling.

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TABLES AND FIGURES

Table 1. -- Summary of observer sampling design changes for obtaining tissues for genetic analysis from Chinook salmon bycatch within the Alaska trawl pollock fisheries 2005-2015. This work is focused on the 2012:2013 sampling protocols in the GOA (bold).

Year	**Project type**	**Where (Sample Population)**	**FMP**	**Sample... (sample size)**	**Per.... (sampling unit)**	**From... (Trawl Pollock Target Population)**	**In this way (Design)**
2005	Special	NA	BSAI	25-30	Cruise	"B Season" (June-Nov)	Haphazard
2006:2007	Special	NA	BSAI	60	Cruise	"B Season" (June-Nov)	Haphazard
2008	Special	NA	Both	120	Cruise	Year	Haphazard
2009:2010	Special	At-sea	Both	Every Chinook Salmon	Species Composition Sample	Observed hauls	Census [within a Simple Random Sampling (SRS) of sampled hauls]
2009:2010	Special	Dockside	Both	Every Chinook Salmon	5-minutes every hour (max 60 min total)	All Deliveries	Systematic Random Sampling (SYS)
2011	Standard	At-Sea	GOA	1 in 10	Chinook Salmon	Observed hauls	SYS
2011	Standard	Dockside	GOA	1 in 10	Chinook Salmon	Deliveries from trips observed at-sea	SYS
2012:2013	**Standard**	**At-Sea**	**GOA**	**0**	**Chinook Salmon**	**Observed hauls**	**None**
2012:2013	**Standard**	**Dockside**	**GOA**	**1 in 10**	**Chinook Salmon**	**Deliveries from trips observed at-sea**	**SYS**
2011:2015	Standard	At-Sea	BSAI	1 in 10	Chinook Salmon	Observed hauls	SYS
2011:2015	Standard	Dockside	BSAI	1 in 10	Chinook Salmon	All deliveries	SYS

Table 2. -- A comparison of observer dockside deployment methods and required coverage rates in the Gulf of Alaska trawl pollock fishery evaluated in this study.

Year design	Method	Rate	
		Basis	Required by design
		Primary Unit: GOA trawl pollock deliveries	
2012	Regulatory	tonnage processed month^{-1}	1.00
2013	*Ad hoc*	anticipated locations of deliveries	1.00
Alternative simulations	SRS	at-sea observer coverage rate	NA
		Secondary Unit: Chinook salmon bycatch	
2012	SYS	0.10	NA
2013	SYS	0.10	NA
Alternative simulations	Complete enumeration	1.00	1.00

Table 3. -- A comparison of observer at-sea deployment methods used in the Gulf of Alaska groundfish fisheries. Actual rates are based on deliveries, which are akin to trips.

Year	**Method**	**Unit**	**Target rate: all fisheries**	**Actual rate: GOA trawl pollock**	
				January-June	**July-December**
			At-sea		
2012	Self-selection	Days	0.300	0.306	0.153
2013	Random	Trips	0.148	0.182	0.145
			Dockside		
2012	Regulatory	Deliveries	1.000	0.888	0.688
2013	*Ad hoc*	Deliveries	1.000	0.764	0.775

Table 4. -- Comparison of actual values for the number of genetic tissues obtained from Chinook salmon bycatch by observers, the number of days required to observe GOA trawl pollock deliveries, and the cost per tissue between actual sampling using the SYS approach of Pella and Geiger (2009) and the alternative SRS approach (Alternative). Min and Max values in the Alternative section correspond to the 0.025 and 0.975 percentiles of the distribution of outcomes from simulations and correspond to a 95% percentile bound. Simulated values for genetic tissues were rounded down to the nearest whole number, and those for contract days and cost per tissue were rounded up to the nearest whole number.

Season:Year	Genetic tissues			Contract days			Cost per tissue ($)		
				Actual values					
Jan.-June 2012		324			318			764	
July-Dec. 2012		625			304			378	
Jan.-June 2013		458			127			216	
July-Dec. 2013		257			116			351	
				Simulated values (under SRS)					
	Min	Median	Max	Min	Median	Max	Min	Median	Max
Jan.-June 2012	892	1,073	1,278	148	148	148	91	108	130
July-Dec. 2012	1,845	2,239	2,737	105	107	109	31	37	45
Jan.-June 2013	679	897	1,126	91	91	92	64	80	105
July-Dec. 2013	669	1,039	2,009	56	57	64	25	43	66

Table 5. -- Comparison between how Chinook salmon bycatch caps are managed according to different amendments to Fishery Management Plans in Alaska.

Aspect of salmon bycatch	**A91 to the BSAI FMP**	**A93 to the GOA FMP**
Allocation	Individual entity	Fishery Sector
Monitoring	Complete	Partial (random selection)
Estimation	Census	Expansion of bycatch rates from observed vessels
Enforcement action	Fine to fisher	Closure of the fishery

Table 6. -- Adopted observer sampling protocols for obtaining tissues for genetic analysis from Chinook salmon bycatch within the Alaska trawl pollock fisheries for 2014 and 2015. Protocols for the BSAI follow methods in place since 2011 (Table 1).

Year	Project type	Where (Sample population)	FMP	Sample size	sampling unit	Trawl pollock target population	Design
2014:2015	Standard	At-sea	GOA	Every Chinook Salmon	Species Composition Sample	Observed hauls	Census (within a SRS of sampled hauls)
2014:2015	Standard	Dockside	GOA	Every Chinook Salmon	Delivery	Trips observed at-sea	Census (within a SRS of trips)

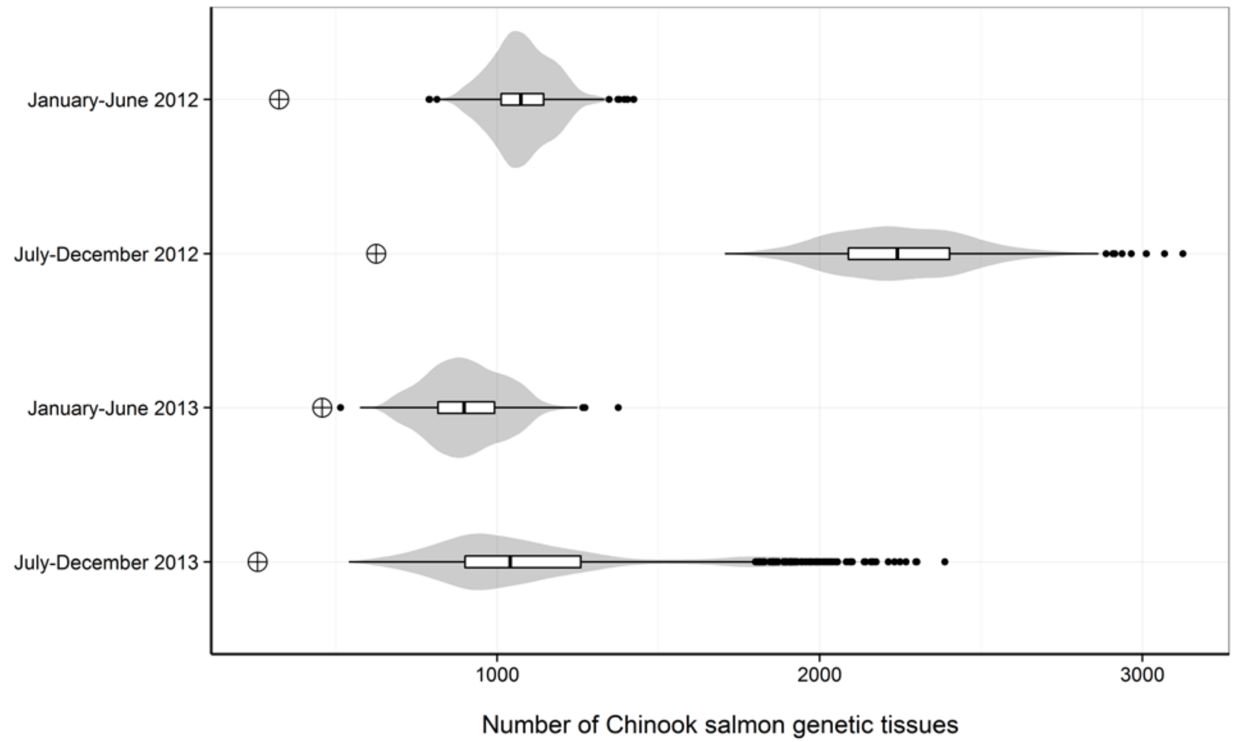

Figure 1. -- The number of Chinook salmon genetic tissues from the Gulf of Alaska trawl pollock fishery that were actually obtained (crosshatched symbols) and the distribution that would be expected from alternative sampling. Alternative sampling distributions result from 1000 simulated samples of pollock deliveries and are depicted both as a boxplot and as a violin plot where the width of the shaded area denotes the density of the distribution. In all season and year combinations, the actual number of samples is less than would be expected from the alternative sampling design.

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