At-Sea Monitoring of Commercial North Pacific Groundfish Catches: A Range of Observer Sampling Challenges

by Jennifer Cahalan

The Alaska Fisheries Science Center's Fisheries Monitoring and Analysis (FMA) Division is responsible for monitoring the commercial groundfish fisheries of Alaska. Each year more than 300 fisheries observers are deployed into the Alaska groundfish fisheries, spending in total more than 35,000 days at sea. Deployment of observers is broadly based on the size of the vessel, gear type, and the fishery in which the vessel participates. The sampling situations faced by Alaska fishery observers at sea are extremely variable and require that all observers are able to quickly assess and respond to a range of situations.

Fish on a catcher processor are shoveled into the factory by the vessel crew.

Observer coverage requirements are set by Federal regulation CFR 679.50 and range from no required observer coverage to requirements to have two observers on board at all times. Typically, approximately 50% of the commercial catch of groundfish is taken on observed trips. There are three sampling strata defined by vessel size and gear type: vessels 0–59 ft in length overall (LOA), vessels 60–124 ft LOA and all vessels fishing pot gear, and vessels 125 ft LOA and greater. Each of these strata is sampled by observers at different rates, if at all, and observer coverage rates are defined relative to fishing effort (days fished or gear retrieved). The 0–59 ft LOA vessel stratum is not sampled by observers. Catch and bycatch for these vessels is based, in part, on industry reports of harvest. All non-pot vessels between 60 and 125 ft are required to have 30% of their fishing days observed per quarter in a given fishery. Vessels of any size using pot gear are required to have 30% of their effort observed (30% of pots pulled). On the largest vessels (vessels 125 ft and larger), observers are aboard on all trips and typically sample between 50% and 100% of the fishing events. Two observers are required on processing vessels that participate in certain catch share programs such as the American Fisheries Act (AFA) pollock fishery. That high level of observer effort generally allows every haul fished to be sampled.

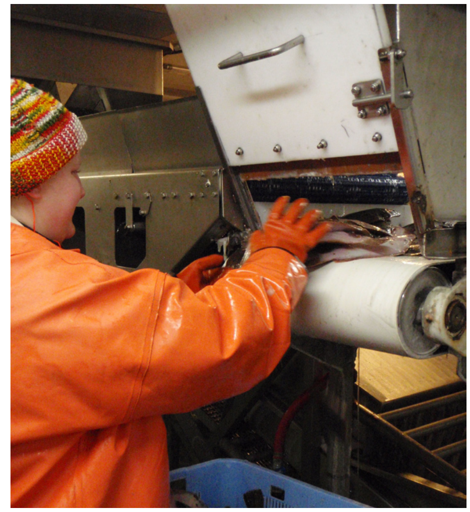
Observers deployed into the commercial fishery utilize a hierarchical randomized sample design. This sampling design was revised in 2008 to allow for greater data resolution and to facilitate the development of estimates of uncertainty associated with catch estimates used in fisheries management. The sampling methods used by observers vary by gear and vessel type, as do the percentages of the catch that observers are able to include in their samples (sampling fractions) on sampled hauls. When unable to sample every haul, observers randomly select hauls within an observed trip and then randomly sample the catch of selected hauls to determine the species composition of the catch. From within the species composition samples the observer randomly selects individual fish for sex and length determination. Finally, from within the population of fish selected for sex and length measurement, the observer randomly selects fish from which otoliths and other biological specimens are collected. This hierarchical design facilitates efficient sampling, maximizing the proportion of the haul that is contained within samples.

Deployment of observers to fishing trips is not currently randomized; for vessels that are required to carry an observer on some but not all trips, vessel operators determine where and when observers are deployed within a regulatory requirement. The North Pacific Fishery Management Council recently took action to correct deficiencies in this deployment model. Changes include randomization of observer deployment, and implementation is expected to begin in 2013.

At-Sea Sampling of Catch

Once an observer is deployed to a vessel, the observer's main sampling goals are to determine the total amount of the catch and the species composition of the catch and to obtain length data and biological specimens. Observers strive to sample all the hauls on a trip; however, in many instances when a single observer is deployed to the vessel, the observer randomly selects hauls to be sampled. If the vessel is fishing shorter sets or hauls, the observer will have less time to sample the catch and complete their duties for that haul (or set) before the next is retrieved. In general, because of the limited time and space available to observers onboard, observers cannot increase the time available for sampling a given set by decreasing the overall number of sets that they sample on a trip.

Observers are faced with varied sampling challenges, and each vessel on which an ob-



Pictured left: an observer on a catcher vessel measures fish on deck. Pictured right: an observer on a catcher processor collect a sample off a factory sorting belt.

server is deployed presents a different sampling situation. Observers receive extensive training from FMA staff in sampling methods and are responsible for assessing each sampling situation and determining the best methods to use (from those methods allowed by the FMA) to obtain the highest quality data possible. Vessel operations, deck or factory configurations, and fishing speed all impact the observer's ability to develop and implement a sampling design.

There are three general types of sampling situations that observers typically encounter: 1) sampling on trawl catcher vessels delivering to shoreside processors, 2) sampling on trawl catcher-processors and motherships fishing with variations between low and high diversity fisheries, and 3) sampling on fixed-gear (longline and pot gear) vessels. The differences between these sampling situations result from the differences in the gear types and fish handling processes used, tools available to the observer, the time and space available for the observers to select and process their samples, and the fisheries in which the vessels participate. In broad terms, the sampling situations are defined by gear and vessel type. Each of these sampling situations poses unique sampling challenges which are described in greater detail below.

Sampling on Trawl Catcher Vessels Delivering to Shoreside Processors

Catches from many commercial fisheries throughout Alaska are taken by relatively small vessels that deliver their catch to either shoreside or at-sea processors. These catcher vessels are responsible for approximately 33% of the total groundfish catch in Alaska and 23% of the sampled trawl hauls. Although the majority of these vessels are not required to carry observers on all fishing trips, a few vessels participating in the pollock fishery are required to carry one observer at all times. Individual hauls on these larger AFA pollock vessels may exceed 200 metric tons (t) of fish. In many other fisheries (non AFA), catch is sorted on deck by the crew before being placed in refrigerated saltwater (RSW) tanks. However, in the pollock fishery and other low diversity fisheries or where required by regulation, catch flows directly from the nets to the RSW tanks. This is potentially the most challenging situation faced by observers, in part because the flow of fish into the tanks can be chaotic, and in part because the suite of sampling tools available to the observer is limited. As a result, the sample fractions (fraction of the catch from an individual haul that is contained within the sample) are typically small on these vessels.

The total weight of each haul fished is determined using a variety of methods depending on the fishery and the equipment available to the observer. For catcher vessels participating in the AFA pollock fishery, haul weights are based on the vessel estimates of catch, generally obtained from the vessel logbook at sea. The total retained weight of the catch is based on the scale weight recorded on the fish ticket (receipt of sold fish required by the state of Alaska) after the landing is made.

On other catcher vessels where the observer estimates the total weight of the catch, volumetric methods are often used whenever scale weights cannot be obtained. The observer estimates the volume of the catch by: 1) measuring the codend of the trawl net, 2) measuring the depth of fish and dimensions of the trawl alley, or 3) measuring the depth of fish and dimensions of the below-deck bins or RSW tank. The total weight is obtained by multiplying the total volume of fish by the density of unsorted catch (weight of a known volume of fish). This equates to 27% of all the catcher vessel hauls on observed trips.

The sampling tools available to observers on catcher vessels are generally limited. Observers are issued a set of sampling baskets (51 × 36 × 24 cm measured at the bottom of the basket handle), which are used to store sampled fish or in many cases that define the size of the sample. Observers are also issued a set of hanging spring scales which they use to weigh sampled fish either in the aggregate or individually, and the observer may have access to a small platform scale. These are the main sampling tools available to catcher vessel observers; any additional tools they use are found on the vessel such as fish totes used to store sampled fish. The observer samples the catch on the vessel deck, often in inclement weather and sea conditions when the movement of the deck complicates both sample selection and measurement of fish weights.

In general, regardless of the types of trawl gear used, the flow of fish from the nets into the tanks is chaotic, and obtaining a well defined random sample of the catch is difficult. On catcher vessels the observer must sample the catch on deck, obtaining sampled fish from the trawl alley. However,

Table 1. Summary of 2009 sampling results on trawl catcher-only vessels using pelagic trawl gear: 14% of sampled trawl hauls.

	Total Haul Weight (t)	Total Sampled Weight (kg)	Number of Samples	Sample Fraction	Number of Species Detected	Predominant Species Percent
Mean	70.0	263.0	2.0	2.1%	3.5	93%
Median	60	263.3	2	0.4%	3	97%
Interquartile Range	27.2–100.0	181.0–333.7	2–3	0.3%–0.9%	2–5	92%–99%

Table 2. Summary of 2009 sampling results on trawl catcher-only vessels using non-pelagic trawl gear: 7% of sampled trawl hauls.

	Total Haul Weight (t)	Total Sampled Weight (kg)	Number of Samples	Sample Fraction	Number of Species Detected	Predominant Species Percent
Mean	13.3	282.1	1.5	6.6%	7	70%
Median	8.9	256.4	1	3.0%	7	72%
Interquartile Range	4.6–16.5	196.6–336.6	1–2	1.7%–5.4%	5–9	52%–90%

if the nets are emptied directly into below deck bins or RSW tanks, the observer places their sampling basket directly into the stream of fish. In either instance the observer has limited time to select and obtain sampled fish. Space on deck may be limited to bins on the side of the alleyway or other portions of the deck that are not being used by the crew or to store fishing gear.

Due to these constraints, the observer often is able to obtain only a single sample from which the species composition of the catch will be determined. Also, because the space available to store or place the sample fish may be limited to sampling baskets, totes, or checker-bins alongside the alley while the observer completes all the data collection tasks, the amount of fish contained within the sample is typically less than 600 kg. This is often the case regardless of the species diversity of the catch (Tables 1 and 2).

In less diverse fisheries that typically use pelagic trawl gear (gear fishing at midwater depths, such as that used in the pollock fishery), the catch is not sorted at sea, and fish are transferred directly from the nets to the RSW tanks. The observer is able to collect a limited amount of fish (~200–400 kg total) for each sample, and because the size of these hauls is larger than in high diversity fisheries, sample fraction is smaller than would be achieved in a high diversity fishery where total haul size is often smaller (compare Tables 1 and 2).

The fraction of the haul that is sampled is much larger on hauls taken with non-pelagic trawl gear (trawl gear fished on or near the bottom). Although the amount of fish in the sample is approximately the same regardless of the type of trawl gear used, the total haul weight is much lower on vessels using non-pelagic trawl gear, and the sample fraction is larger than for low diversity fisheries (Tables 1 and 2).

Sampling on Catcher Processors and Motherships: High and Low Diversity Fisheries

Catcher processors and motherships are vessels that have onboard factories to produce fish products such as fish filets, surimi, and fish meal. Catcher processors both catch and process catch onboard while motherships process fish that are caught by catcher vessels and transferred to the mothership. These two vessel types account for the bulk of the catch (55% of the total groundfish catch in Alaska) and the majority of the trawl hauls sampled by observers (77% of sampled trawl hauls).

Both vessel types present the same general sampling situation to the observer. Fish from the net flow directly into tanks where the fish are stored until the factory is ready to process them. The fish are moved from the tanks into the factory over a series of conveyor belts.

The tools available to the observer include sampling baskets and hanging scales, but in addition, the vessel's factory often is equipped with a motion-compensated flow scale from which the observer can obtain the cumulative weight of fish moving into the factory. Vessels participating in some fisheries are required to provide observer sampling stations. Sampling stations provide the observer with a motion-compensated platform scale for weighing samples, access to the flow scale readings, space to work and store fish, and may include video monitors showing other parts of the factory and the conveyor belts between the sample station and the tanks. The video monitoring capability allows the observer to ensure that all fish are attributed to the correct haul. The sampling station allows observers to store larger amounts of sampled fish until all data collection tasks can be completed. Motion-compensated platform scales, flow scales, and observer sampling stations are required on vessels participating in a limited access privilege program such as the AFA pollock fisheries. The configuration of the sampling station and scale requirements are specified in Federal regulation.

On catcher processors and motherships, the fish are available to the observer in a linear, consistent fashion. The fish flow past the observer, often over a motion-compensated flow scale, and into the vessel's factory. This configuration allows the observer to design and implement systematic sampling schemes with random start points. The total haul weight is determined using the vessel's motion-compensated flow scale. If a flow scale is not available, the total haul weight is determined using the vessel's estimate of total catch or an observer's estimate of the total volume of catch multiplied by an estimate of the catch density (similar to methods used on catcher vessels).

However, there is a distinct difference on these vessels in the sampling environment and the total size of collected samples with the degree of species diversity of the

Table 3. Summary of 2009 sampling results on trawl catcher processors and motherships using pelagic trawl gear: 24% of sampled trawl hauls.

	Total Haul Weight (t)	Total Sampled Weight (kg)	Number of Samples	Sample Fraction	Number of Species Detected	Predominant Species Percent
Mean	70	18,735	3	28.6%	9	95%
Median	65	18,000	3	30.3%	9	99%
Interquartile Range	47–95	8,205–27,672	3–3	17.4%–34.2%	7–11	94%–99%

Table 4. Summary of 2009 sampling results on trawl catcher processors and motherships using non-pelagic trawl gear: 53% of sampled trawl hauls.

	Total Haul Weight (t)	Total Sampled Weight (kg)	Number of Samples	Sample Fraction	Number of Species Detected	Predominant Species Percent
Mean	27	665	3	3.2%	12	64%
Median	19	375	3	2.0%	11	65%
Interquartile Range	10–34	269–512	2–3	1.3%–3.2%	9–14	47%–82%

catch. Vessels fishing pelagic trawl gear are typically participating in pollock or Atka mackerel fisheries, which tend to have relatively low species diversity of catch (Table 3). Over 95% of the catch is often attributable to a single species.

In many fisheries the observer can use the vessel's motion-compensated flow scale to determine the amount of fish that pass by on the conveyor; this may be used to determine the sample size and the total weight of the haul. The fish in the sample that are not the predominant species are sorted from the sample and put aside to be processed by the observer between samples. As a result, the total size of the sample can be very large, often over 8 t, and the sample fraction can be a third or more of the total catch (Table 3**).**

This can be contrasted with the situation when observers are assigned to vessels using non-pelagic trawl gear. This is typical of many flatfish and rockfish fisheries. In this situation, the amount of non-predominant species catch in the sample can be large and will limit the total size of the samples that can be taken. For example, a 10-t sample on a pelagic trawler may have 500 kg of non-predominant species catch while on a non-pelagic trawler a 10-t sample may have 4 t of non-predominant catch. Observers rarely have space to store, or time to process, 4 t of fish. As a result the size of the sample will typically be smaller on non-pelagic hauls.

When sampling hauls taken with non-pelagic gear, the observer is rarely able to collect more than 600 kg of total sample weight and sample fractions are generally less than 3% of the total haul weight (Table 4). A small number of vessels using non-pelagic trawl gear do not have flow scales, and on these vessels total haul weight is often determined using volumetric methods (1% of the observed hauls on catcher processors using non-pelagic gear).

Sampling on Fixed-Gear Vessels

In addition to the trawl fisheries, there are substantial fixed-gear (longline and pot gear) fisheries that occur throughout Alaska. These fisheries account for approximately 11% of the total catch in Alaska. The major sampling difference between trawl and fixed-gear for the observer relates to how the sampling is designed. On trawl vessels, sampling is usually weight based, and the observer randomly selects several equal weight sample units. On fixed-gear vessels, sampling is usually gear-based, and the observer randomly selects several sample units with equal numbers of hooks or pots.

The set of sampling tools includes, as with trawl vessels, sampling baskets and hanging scales. These are generally the only tools an observer needs on this type of vessel, with the common addition of tally-counters on longline vessels to aid in keeping count of the species as they come aboard the vessel one hook, or one fish, at a time.

Regardless of whether a fixed-gear vessel is delivering catch to shoreside processors or whether they are processing their catch at sea, the observer is presented with similar sampling environments. On both pot and longline vessels, the observer works on deck sampling the catch. Observers count the number of fish in a sample unit and obtain a subsample of fish from which weight–per–fish data are collected.

On vessels fishing longline (hook-and-line) gear, sampling entails standing at the ship's rail for approximately a third of the set counting the number of each species that is caught by the gear during each sample period. These sampling or "tally" periods are usually systematically distributed through out the set. On larger catcher processors, each individual sampling (tally) period may be in excess of 1-4 hours, and the total sampling (tally) effort may take up to 9 or more hours per set. Longline sets make up the bulk of sampling that observers conduct on fixed-gear vessels (90%; Table 5).

On longline vessels, the flow of fish presented to the observer is linear and consistent. Hence, the observer can develop systematic sampling designs with random start points. On these vessels observers usually collect two or more samples per set (maximum of nine samples achieved in 2009) and obtain only one sample in less than 25% of the sets (Table 5).

The total size of the set and the size of the samples are determined based on the number of hooks fished. This is determined from the total number of gear segments (skates or magazines) fished and the mean number of hooks per gear segment. Every 2-3 days, the observer counts the number of hooks on a portion of the gear equal to 20% of an average set to obtain a mean total of hooks per segment.

The sample fraction on these vessels is close to 33% (Table 5), with most of the deviations resulting from sets of gear where

Table 5. Summary of 2009 sampling results on vessels fishing longline (hook and line) gear: 90% of fixed gear sampled.

	Total Hooks Fished	Total Hooks Sampled	Number of Samples	Sample Fraction	Number of Species Detected	Predominant Species Percent
Mean	13,070	4,037	2.8	32%	13.8	73%
Median	10,845	3,360	3	33%	14	76%
Interquartile Range	6,780–16,380	2,004–5,312	2–3	28%–34%	11–17	64%–85%

Table 6. Summary of 2009 sampling results on vessels fishing pot gear; 10% of fixed gear sampled.

	Total Pots Fished	Total Pots Sampled	Number of Samples	Sample Fraction	Number of Species Detected	Predominant Species Percent
Mean	82	26.3	3.2	34%	6.7	84%
Median	53	18	3	33%	6	91%
Interquartile Range	40–102	12–33	3–4	30%–35%	5–8	76%–97%

the number of segments fished is not exactly divisible by three. On fixed-gear vessels, the sample fraction is defined by the percentage of the gear that is sampled, not the percentage of the catch. This high sample fraction is achievable in spite of the relatively high species diversity of the catch. Since observers tally the number of fish of each species on the gear and store only a fraction of these individuals, the size of the samples is not limited by the available storage space. Fish weights are determined from a subset of the sampled fish; the sampling protocol requires a minimum of 60 individuals of the predominant species and 15 individuals of each of the non-predominant species.

An observer sorts fish from collected sample on a longliner.

The sampling situation is similar on vessels using pot gear. Pot gear comprised 10% of the fixed-gear sets sampled in 2009. The total size of the set, in number of pots, is determined by the observer using information, such as the vessel's logbook or plotter, showing the number of pots to be retrieved on that day. The observer divides the set into equal-sized sample units and systematically selects sample units using a randomly determined starting point. The fish in all the pots in those selected units are counted and weighed by species. As with longline gear, the sample fraction is defined by the percentage of gear sampled and is generally close to the goal of 33% (Table 6). Again, similar to sampling on longline vessels, the size of the sample is not limited by storage space or the number of species present but rather by the observer's ability to work on deck for prolonged periods.

Summary

Regardless of the sampling challenges inherent in sampling at sea on commercial fishing vessels, the data collected by observers in the Alaska fisheries provide extensive, high quality data to fisheries managers, stock assessment scientists, and researchers. These data are available to NMFS staff in near real-time as observers transmit their data daily while they are at sea or weekly at the completion of their trip.

The sampling environment across the Alaskan fishing fleet is extremely varied, such that each vessel is a unique sampling situation, and observers themselves are responsible for tailoring the sampling designs they employ to the specific situations that they face. Samples are randomly selected in the majority of situations, and if several random samples cannot be taken, then some level of randomization is incorporated into the sampling design. The sample fractions that observers can achieve are dependent on the sampling environment and the available tools. Observers are trained to maximize the sampling fractions (and number of samples) within the limitations without compromising the data they collect. As a result, the data collected by observers is of the highest quality achievable given the sampling situations presented and the sampling designs that are available to be used.