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An Innovative Approach to Sampling Catch in the North Pacific Groundfish Fisheries.

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ABSTRACT
Observer sample selection and collection are subject to human and mechanical biases. Electronic monitoring (video) and automated catch sampling systems have been proposed as potential approaches for reducing these sources of bias. The National Marine Fisheries Service (NOAA Fisheries Service) partnered with the International Pacific Halibut Commission, the Marine Conservation Alliance Foundation, and the fishing industry to conduct a two-week cooperative research cruise to test technologies that may mitigate sample bias and automate sample collection. The research was conducted aboard the 70 m trawl catcher/ processor, *Seafisher* during the 2005 fishery for yellowfin sole (*Limanda aspera*) in the eastern Bering Sea. We evaluated the functionality of a prototype automatic catch sampling system based on hardware and software modifications of the vessel's motion-compensated electronic flow scale. The system was operated by entering estimated catch weight, number of desired subsamples, and desired individual subsample weights into the scale's control unit and the system's computer determined when random subsamples would be diverted from the catch and delivered by conveyor to the sample processing location. Six 100-kg subsamples were collected from each of thirty hauls and video equipment was used in a pilot study to explore the utility of using video technology to monitor for potential presorting. The system functioned as intended and automated the sample selection and collection processes to a substantial degree. Data collected during this study will also be useful for determining accuracy and precision of estimates of target and non-target species catch.

INTRODUCTION
For nearly 10 years, the National Marine Fisheries Service (NOAA Fisheries Service) has required the use of electronic motion-compensated flow scales for weighing catch and species composition samples in certain Alaskan trawl fisheries (Fisheries of the Exclusive Economic Zone off Alaska 1998). Motion-compensated scales have improved haul and sample weight estimates and, compared to other methods, they provide very precise estimates of catch (Dorn et al. 1997). In addition, certain vessels are required to provide observer sampling stations that meet standards for available work space, configuration, lighting, and equipment (Equipment and

Operational Requirements 2006). These tools, however, have done little to improve sample selection and collection efficiency for observers and they do not mitigate potential sources of sampling bias.

Observers use random sampling to eliminate subjectivity in sample selection and they are trained to maximize sample sizes to the extent possible (AFSC 2006). In spite of this, observer samples may be biased through mechanical or human actions (Anonymous 2004) and observers may unknowingly introduce bias by using flawed sampling methods. Of particular concern is the potential for vessel crew to introduce sampling bias as they move catch from nets to tanks and facilitate catch movement through vessel factories (McElderry et al. 1999; Karp and Ferdinand 2005).

Fish of different species and sizes may stratify before being landed or be subjected to differential handling effects when catch is transferred to holding tanks and conveyed through hatches and along belt systems. Incline conveyor belts can introduce bias when some individuals of species with certain characteristics (e.g., stiff spines or large size) tumble down incline belts and accumulate prior to the point of sample collection. Observers mitigate mechanical presorting by clearing incline belts at the beginning and end of their sampling events, but in many cases they must rely on crew to confirm that the base of the belt has cleared because this location cannot be seen from their sampling station.

The following describes a cooperative research project designed to investigate an approach for mitigating bias resulting from human interference with sampling or caused by the aforementioned mechanical factors. NOAA Fisheries Service partnered with the International Pacific Halibut Commission (IPHC), Marine Conservation Alliance Foundation, and Cascade Fishing Inc. to conduct this work. The project involved the design and testing of an automated catch sampling system that was integrated with a motion-compensated flow scale. The catch sampling system used software to determine when subsamples were collected and included mechanical devices that reduced the physical effort required to collect samples of catch. Electronic monitoring (EM or video) was used to monitor for mechanical presorting and was evaluated as a tool for detecting and discouraging human presorting. EM equipment was used to track catch throughout the catch handling process and allowed the field crew to verify that mechanical and human presorting had not occurred. Further details of the EM system and associated research are presented by Williams et al. (2006)[1].

Automation of sampling procedures and application of advanced technologies such as video may be effective in improving observer data quality and the efficiency of the data collection process. The system tested during this study has potential for reducing the amount of effort required to select and collect samples of catch, while also reducing the potential for human and mechanical bias in observer data. The research objectives were to evaluate the functionality of a prototype automatic catch sampling system and to evaluate the potential for using EM to assist observers in monitoring catch handling to ensure that sorting does not occur prior to the location where samples are collected.

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METHODS

The *F/V Seafisher*, a 70 m trawl catcher/processor owned by Cascade Fishing Inc., served as the research platform. The cruise was conducted over a two week period in October 2005 while targeting yellowfin sole (*Limanda aspera*) in the eastern Bering Sea (Figure 1). The target weight for each haul was 30 t and the automated catch sampling system was tested using 30 individual hauls. The study design required a total of six, one-hundred kg random subsamples to be selected from each haul. EM equipment monitored catch and crew activities from the point of landing to the point of discard. Three NOAA Fisheries Service scientists, two observers, an Archipelago Marine Research Ltd. (AMR) technician, and a Cascade Fishing Inc. representative served as the scientific staff.

AMR installed nine closed circuit TV cameras to monitor catch and crew activities. Monitored areas included the trawl deck, fish holding tank, flat conveyor belt, incline conveyor belt, sorting belt, and locations within the factory where fish were discarded (Table 1, Figure 2). Video records were stored on hard drives and viewed in real time and after-the-fact. A waterproof monitor was located above the observer sampling station to allow observers to monitor activities at multiple locations; the system was designed to allow observers to select among the operational cameras and display up to nine images simultaneously.

After each haul was landed, one observer, with assistance from a scientist or crew member, measured the codend, calculated the estimated volume of the catch, and applied a density of 1 t/m^3 to determine the approximate catch weight. The codend was then emptied into a holding tank and a crew member facilitated the transport of catch from the tank onto a conveyor belt. At the end of this conveyor, fish flowed through a 90 degree turn and were transported up a 45 degree incline conveyor belt to a Scanvaegt[2] model 4674 flow scale where all catch was weighed. Fish tended to accumulate at the base of the incline belt (mechanical presorting). A pneumatic diverter board, installed on the conveyor downstream of the flow scale, directed subsamples of catch to the observer sampling station (Figures 2 and 3).

A Scanvaegt 8564 MKIII Scale Computer Indicator (control unit) was installed at the sampling station. Catch weight estimates and subsample specifications were input through this unit (Figure 3). The system selected random subsamples and diverted them from the sorting belt to the observer workstation using this information. The system included two indicator lights (sample start and sample stop), a solenoid that controlled the conveyor belt that transported fish from the holding tank, and a solenoid that controlled the pneumatically operated diverter board. A laptop computer connected to the system displayed information on upcoming sampling intervals and was used to review sampling histories for each haul.

Actual subsample weights tended to exceed those specified to the computer because fish that accumulated at the base of the incline belt during the subsampling process were not weighed automatically during subsample collection. Operators adjusted their specifications accordingly and determined that a specified subsample weight of 50-70 kg would result in an actual subsample weight close to the 100 kg target when fish at the base of the incline was included. Within the sampling station, the video display monitor was used to observe crew activities and catch as it proceeded to the point of sampling (Figure 3). The system control unit was used to

[2] Mention of trade names or commercial firms does not imply endorsement by the NOAA Fisheries Service.

monitor how much catch had passed over the flow scale and displayed the start weight for the next sampling interval and an estimate of time remaining before the next subsampling event.

When subsample collection was about to start, the system turned on a yellow warning light and turned off the belt that conveyed fish out of the holding tank. The incline conveyor belt, flow scale, and sorting belt continued to run, but it was possible to manage their speed or shut them off manually. The video display monitor was used to confirm that the base of the incline belt was cleared of catch before the subsample collection was initiated. Subsampling commenced by pressing a function key on the control unit; this restarted the conveyor belt and directed the sample to the sampling station with the pneumatic diverter board (Figure 3).

As catch passed over the flow scale, the control unit displayed both the total amount of catch weighed for that haul (subsamples included) and the running total for the subsample being collected. When the system reached the pre-determined subsample weight (50 or 70 kg) the yellow light turned off and a red light began flashing. The system again turned off the belt from the holding tank, but the diverter board continued to direct fish to the sampling station until all the fish that had accumulated at the base of the incline conveyor had reached this location. At the conclusion of subsample collection, the operator pressed another function key on the control unit and this closed the diverter board and restarted the conveyor belt from the holding tank. This process was repeated six times for each haul to provide a total sample size of approximately 600 kg.

RESULTS

Thirty hauls were completed during the research cruise. Flow scale catch weights ranged from 10.48 to 48.50 t and averaged 27.76 t. Independent estimates of the catch weight were made for all hauls, but the estimate was not recorded for the second haul. The average estimated catch weight for 29 hauls was 27.94 t and ranged from 10.47 to 52.20 t (Figure 4). With the exception of three hauls, all catch estimates were made by measuring the codend, calculating the volume of the catch, and applying a density of 1 t/m^3. Poor weather prevented measuring the codend on three occasions, therefore, visual estimates of the catch weight were made (e.g., five tons per codend segment). For 17 of 29 hauls the catch weight was overestimated by 0.20 – 8.33 t and underestimated by 0.07 – 5.35 t for the remaining 12 hauls (Figure 4). The process of estimating the catch weight and entering the sampling parameters into the control unit took approximately 10 minutes per haul.

While estimates of catch were relatively accurate, over or underestimation of catch at this initial step resulted in an incorrect determination of the number of units (100 kg portions) available for sampling and this may have introduced some bias into the sampling process. For hauls 10 and 25 only four of six subsamples were collected and for hauls 12 and 23 only five of six subsamples were collected before running out of catch (i.e., we overestimated the catch). Conversely, for the 12 hauls where the catch weight was underestimated, sampling ceased once the scale weight reached the initially-estimated weight. For example, if the estimated catch weight was 15 t, but the haul was actually 20 t, the last 5 t could not be selected for sampling by the system.

The target individual subsample weight for the automated catch sampling system was 100 kg, but actual subsample weights ranged from 63.08 to 216.90 kg with an average of 105.07 kg (Figure 5). A programmed subsample weight of 70 kg was used for the first haul, but most of the subsamples were well above the 100 kg target. Therefore, a programmed subsample weight of 50 kg was used for hauls 2 – 24, 27, and 30. A programmed subsample weight of 70 kg was entered for hauls 25, 26, 28 and 29. As our scientists and observers became familiar with the system and worked with the crew to provide a uniform flow of catch onto the conveyor belt, we were more accurate at obtaining our target subsample weight (Figure 5). Cumulative subsample weights for individual hauls ranged from 386.64 to 874.18 kg with a mean of 609.43 kg. Similar to individual subsample weights, as the cruise progressed we became better at collecting the target total sample weight of 600 kg (Figure 6).

The automated catch sampling system performed well, however, on two occasions it failed to collect the first subsample. On the first occasion, the system was reset and the haul and sampling information was re-entered. This generated a new set of random subsamples and processing and sampling of the haul was restarted. One the second occasion, the samplers used the control unit manually to initiate collection of the first subsample and the system worked properly for the remainder of the haul.

EM provided useful information to those working at the sampling station. By glancing at the video display it was possible to see if a haul was being landed and observe the deck crew emptying a haul into the holding tank. It was also possible to view crew activities prior to the sample collection point to ensure that mechanical or human pre-sorting had not occurred. Video observation of the base of the incline belt allowed samplers to determine exactly when to start and stop sample collection, which improved efficiency (Figure 7).

DISCUSSION

Observers have been sampling catch in the North Pacific for over three decades and while the data collection protocols have changed, the physical process of collecting subsamples has remained relatively the same. With the advent of flow scale and EM technologies, automated catch sampling systems are a viable alternative that may enable observers to expend less effort and collect higher quality data. The prototype system facilitated the collection of random subsamples of catch and the EM component enabled samplers to monitor multiple locations for human and mechanical biases. The combined system removed subjectivity from the sample selection process and streamlined sample collection through automation.

Following a basic training provided by Scanvaegt, the system was relatively easy to use and reliable, but there were several issues and improvements that should be considered prior to future research. The system was designed to select true random subsamples and this was problematic when the subsamples were closely spaced (e.g., Figure 8, haul 13). On several occasions, samplers were overwhelmed when back to back subsamples had to be collected. One potential solution is to program the system to select a random start weight and collect systematic subsamples thereafter. While this would alleviate the issue of closely spaced subsamples, it may not be a viable option for all monitoring programs.

The system was programmed to collect six subsamples of equal weight, but it may be desirable to allow different subsample weights for select species or species groups within a haul. This flexibility would allow for smaller subsamples of common species and larger subsamples for uncommon or potentially limiting species within a fishery. Another consideration is that the location of the flow scale relative to the incline conveyor belt constrained the ability of the system to provide samples that always weighed 100 kg. Vessel motion (a heavy roll to port) and overzealous crew members caused catch to accumulate at the base of the incline belt which resulted in samples that exceeded the specified weight of 100 kg.. During calm weather and as the crew members became accustomed to providing a uniform flow of fish, large or small sample sizes were less common. Regardless of fish-kicker activity or weather conditions, having the flow scale located prior to the incline conveyor belt would have provided consistent subsamples of the desired weight.

We believe the mere presence of an EM system serves as a deterrent to human pre-sorting and it was a useful tool for mitigating mechanical pre-sorting. Human pre-sorting was not an issue during this study, but it has been documented in the North Pacific (Anonymous 2004) and is an issue that other monitoring programs may be concerned with. Both the automated catch sampling system and EM were useful tools that enabled samplers to perform their work more efficiently while also monitoring for bias in their data collection.

Figures and Tables

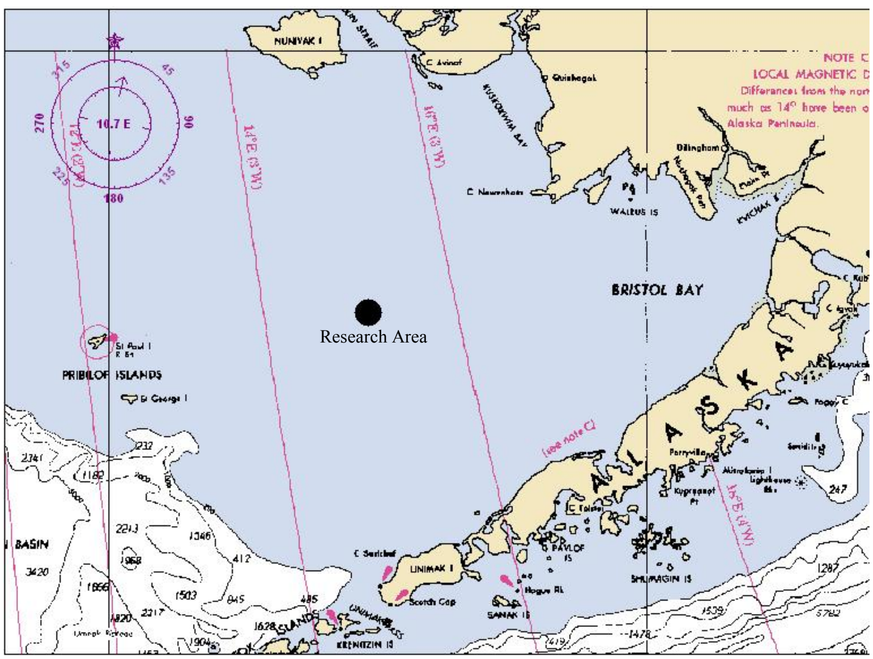

Figure 1. Location of research in the Eastern Bering Sea

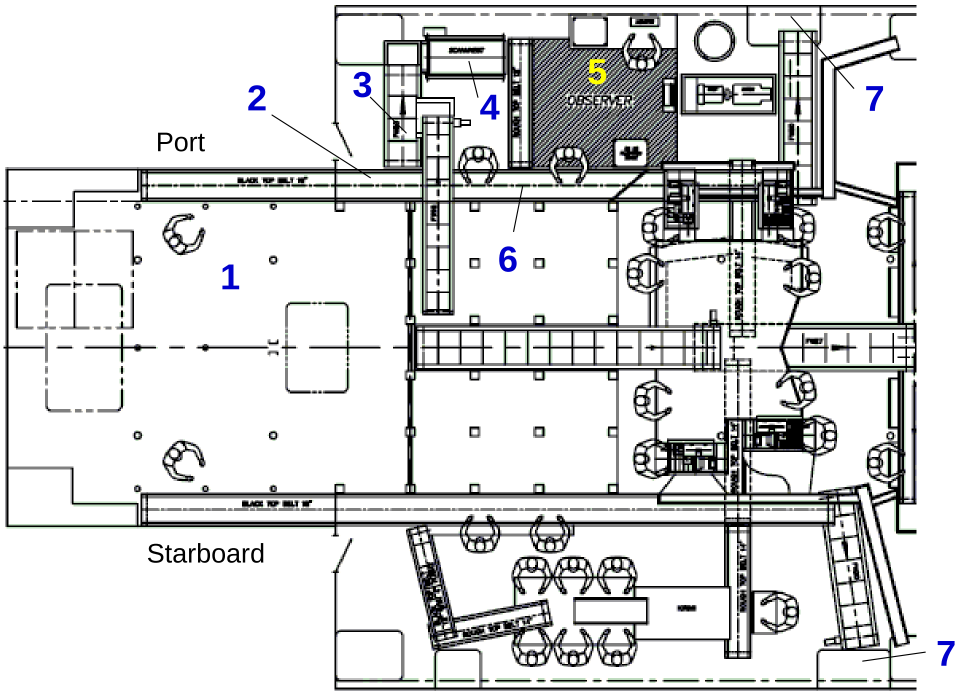

Figure 2. Factory and sampling area illustrating the holding tank with crew member (1), flat conveyor belt (2), incline conveyor belt (3), flow scale (4), sampling area (5), sorting belt (6), and points of discard (7).

Figure 3. Samplers and sorters working within the sampling station and the equipment layout within the station.

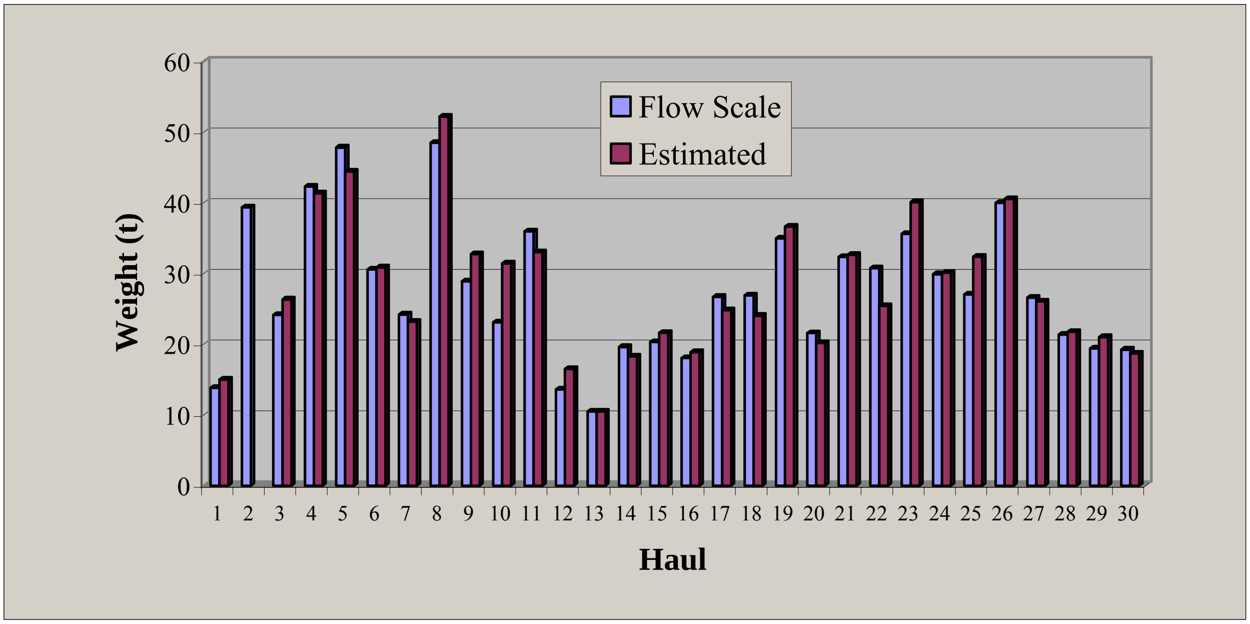

Figure 4. Flow scale and estimated catch weights (t).

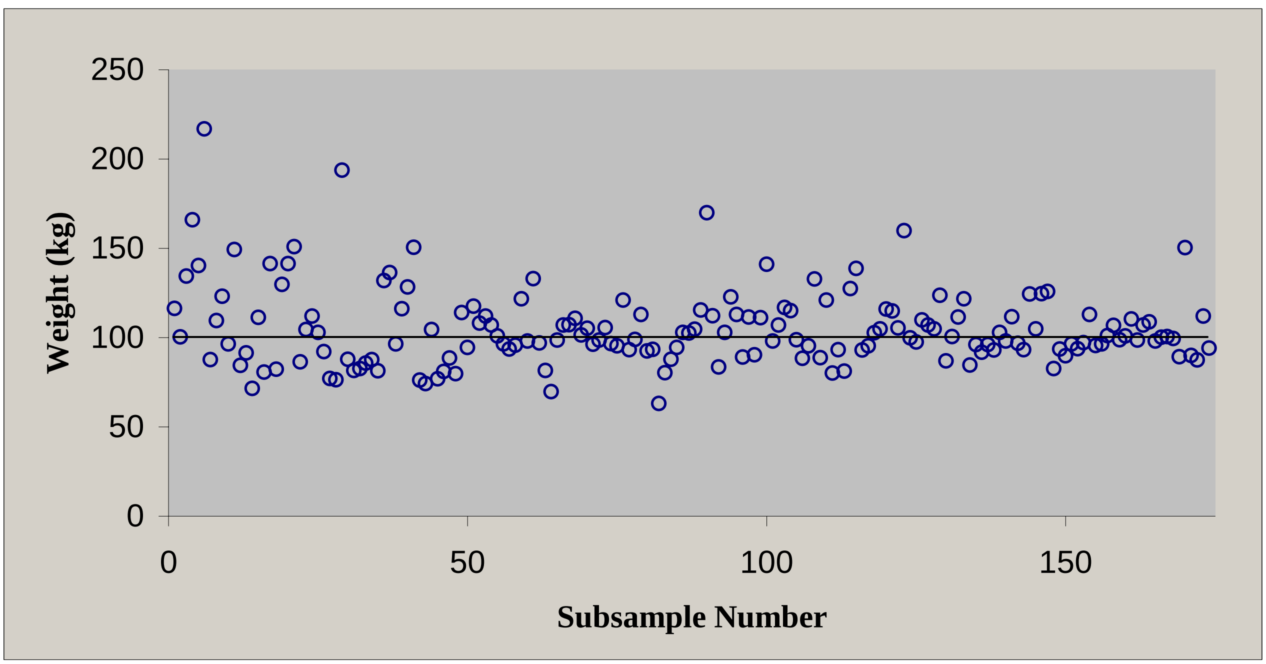

Figure 5. Individual subsample weights collected by the automated catch sampling system over 30 hauls. The target subsample weight was 100 kg.

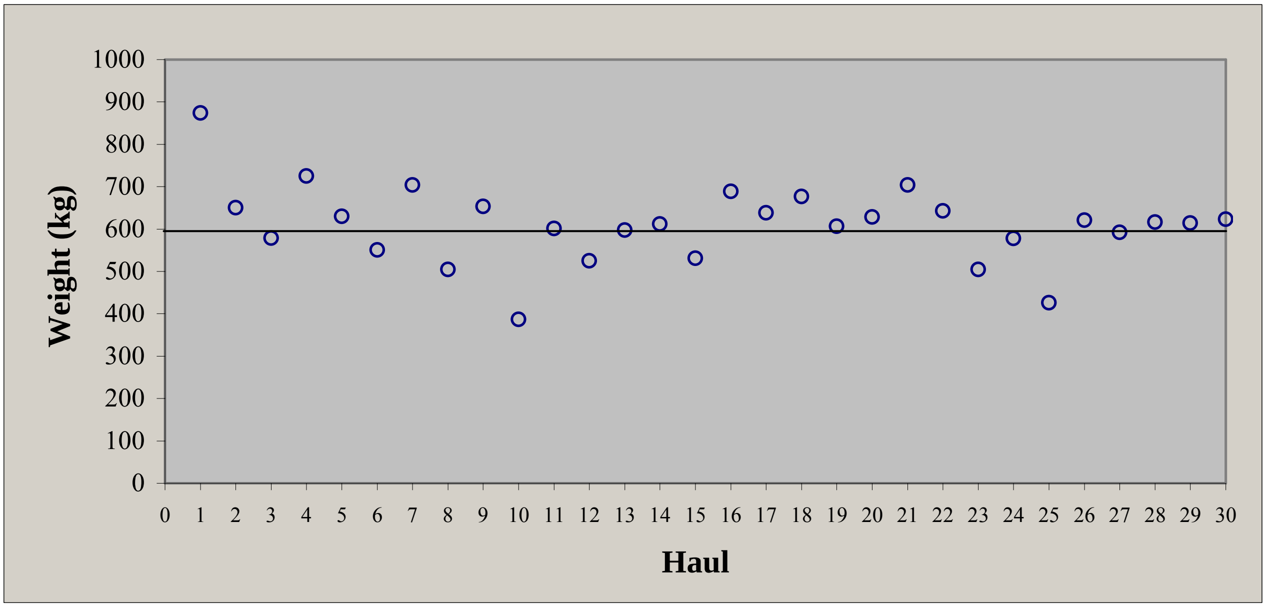

Figure 6. Total sample weights collected by the automated catch sampling system over 30 hauls. The target total sample weight was 600 kg.

Figure 7. Camera views commonly displayed in the sampling station: Incline conveyor belt (1), port fish holding tank (2), aft trawl deck (3), and the flat conveyor belt with crewman (4).

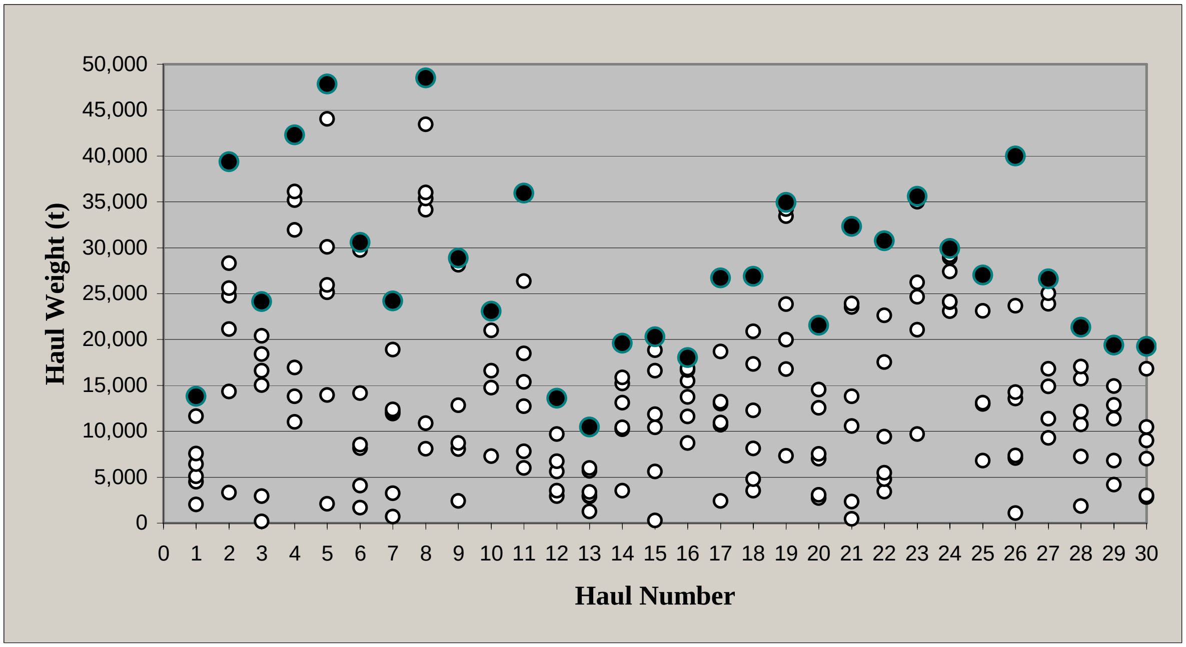

Figure 8. Flow scale catch weight (●)and random subsample points (○) for each haul.

Camera Number	Camera View
1	Fore part of trawl deck
2	Aft part of trawl deck
3	Port side of fish holding tank (area crewman worked in)
4	Starboard side of fish holding tank (relocated to flat conveyor belt)
5	Inline conveyor belt
6	Flow scale
7	Sorting belt
8	Port discard
9	Starboard discard

Table 1. Location of electronic monitoring cameras placed on deck and in the factory to monitoring catch handling activities.

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