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A pilot study to evaluate the use of electronic monitoring on a Bering Sea groundfish factory trawler

by

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Abstract

Archipelago Marine Research Ltd. was contracted by the International Pacific Halibut Commission to investigate the use of video monitoring technology in the groundfish trawl catcher processor fleet operating in the Bering Sea and U.S. Exclusive Economic Zone. This pilot study involved field testing a digital video monitoring system consisting of nine closed circuit television cameras, GPS, and on-board data storage. Cameras were installed in key fish handling areas, providing a full view of trawl deck and closer views of the interior factory and discard chutes. Using the series of cameras installed throughout the factory, individually tagged halibut were tracked through the factory sorting process to discard. The tests using video monitoring equipment provided promising results for the use of this technology. The system performed reliably and provided the scientific personnel and vessel crew with a useful real-time monitoring tool. Post-cruise data analysis demonstrated that halibut were readily detectable throughout the factory. However, imagery was not suitable for making detailed assessments of catch composition. We believe that video monitoring offers opportunities to improve observer's abilities to monitor catch on factory trawlers. Further work is needed to evaluate the benefits of video monitoring in terms of the various monitoring issues in the fishery and decide on appropriate specifications for the equipment, how it should be configured, and appropriate methodology for use of video data. In particular, we highlight the need for careful consideration for the data issues surrounding the use of this technology.

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Introduction

The International Pacific Halibut Commission (IPHC), an international agency formed between the governments of Canada and the United States in 1923, regularly conducts projects aimed at improving Pacific halibut conservation and stock management in the U.S. north Pacific Ocean (online IPHC, accessed 24 March, 2006). Trawl fisheries for flatfish off Alaska often close before reaching annual catch quotas for target species because of the attainment of bycatch limits on incidentally caught halibut. The IPHC wishes to advance approaches for monitoring halibut bycatch in these fisheries in the northeast Pacific and is interested in the process of bycatch reduction.

In Alaskan flatfish fisheries, halibut is a prohibited species that vessels are required to discard for regulatory and conservation reasons. Although not retained, halibut and other prohibited species count against annual limits and can reduce a vessel's economic yield. As a result, vessel operators often compete to maximize target species catches as fast as possible before the fishery is shut down. Improving management of groundfish fisheries will require a shift from monitoring fleet-wide catches to monitoring individual vessel catches, and in some cases individual hauls (NOAA, 2005). Hauls usually comprise many different species, and at-sea fishery observers currently estimate catch quantity and document species composition through catch sampling. However, several factors contribute to the difficulty of observer catch sampling on factory trawlers. These may include issues such as non-stop fishing operations, complex factory and deck layout, catch pre-sorting by crew, large catch volumes, and high species diversity of the catch. To improve monitoring efficiency on factory trawlers, fishery managers recommended that an automated catch sampling system in conjunction with video surveillance be tested.

In order to test these technologies, a scientific research cruise took place in the fall of 2005, consisting of a two-week field component in the eastern Bering Sea and Aleutian Islands. Cascade Fishing Inc. owns and operates the 230-foot (70 m) factory trawler F/T *Seafisher*, which was the host vessel for this project. With the intention of simulating normal fishing conditions, the charter targeted yellowfin sole (Limanda aspera) and arrowtooth flounder (Atheresthes stomias). The main objective of the research cruise was to test an automated catch-sampling system for collecting random subsamples for species composition, and science staff from the National Marine Fisheries Service (NMFS) remained onboard to investigate the methodologies. The automated sampling system integrated sampling software with a certified motion-compensated flow scale installed on the factory's port conveyor system, and included a mechanical gate and drive motor components. Additional holding bins and belts were added to the factory to facilitate separating and re-weighing of non-target catches to attain each haul's target species weight.

The secondary objective of the research cruise was to determine how video monitoring technology could be used to monitor catch handling and discarding practices on the vessel. Archipelago Marine Research Ltd. (Archipelago) was contracted by the IPHC to carry out this portion of the study. This was the first time video monitoring technology had been implemented on a factory trawler operating off Alaska (Williams and Leaman, 2005). Archipelago has successfully used video monitoring on a variety of gear types to address a range of fishery monitoring issues (McElderry et al. 2004, McElderry et al. 2005, McElderry et al. 2007).

The specific video monitoring objectives of the project were to install a video system with several cameras placed in key locations on deck and throughout the processing areas in order to:

- Assess the suitability of using video monitoring technology as part of the ongoing monitoring regime;
- Assess the ability of video to identify and track halibut as they move through the factory; and,
- Examine imagery of fish on conveyors to assess feasibility of sampling for catch composition.

Materials and methods

Pilot vessel

While vessel size and factory layout vary among the fleet of Alaskan groundfish trawl catcher processors, F/T *Seafisher* was representative in overall catch volume (Fig. 1). The vessel normally operates as a commercial trawler in the Bering Sea sole fishery and processes fish at sea. F/T *Seafisher* personnel were experienced in hosting scientific studies and the vessel easily accommodated fishery scientists and technical equipment. As well, management from Cascade Fishing Inc. played an active role in planning and organizing this research project.

Figure 1. The chartered factory trawler F/T Seafisher, tied up in Dutch Harbor, Alaska.

Description of video monitoring system

The video monitoring system used for the pilot charter was a Honeywell, Digital Video Management System, Duplex 1600 (DVMS). This off-the–shelf equipment is designed for security applications, providing simultaneous recording for up to 16 cameras, and provided secure, high-resolution video at a maximum capture rate of 60 frames per second (all cameras combined). Imagery was stored on lockable 120-gigabyte internal hard drives that were easily removed for image preservation. Live or recorded video could be reviewed without stopping recording, and simultaneous multi-screen viewing was possible through monitor video output (Fig. 2).

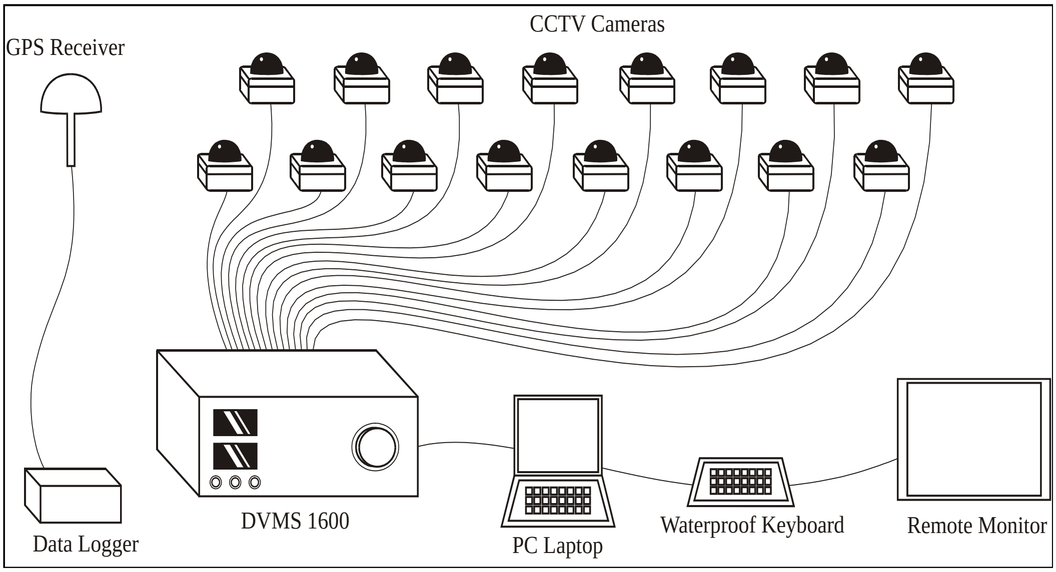

Figure 2. Simplified overview of video surveillance equipment configuration on F/T Seafisher.

Closed circuit television (CCTV) cameras used in this study were Honeywell cameras (Magnaview model V28), each with 480 TV lines of resolution (high resolution) and low light capability. The camera lenses were capable of colour images in daylight, and clear, monochrome images in low light (down to 0.13 lux). The gimbal mounted camera electronics were encased in Honeywell cast aluminum armoured domes. This tamper-resistant design has proven reliable in extreme environmental conditions on long-term deployments on vessels in other fisheries. A choice of lenses from fisheye to telephoto enabled optimal adjustment of the field of view and image resolution throughout the vessel. Each of the CCTV cameras was equipped with a universal stainless steel mount that facilitated easy mounting of the cameras in a variety of locations with simple stainless band straps (Fig. 3).

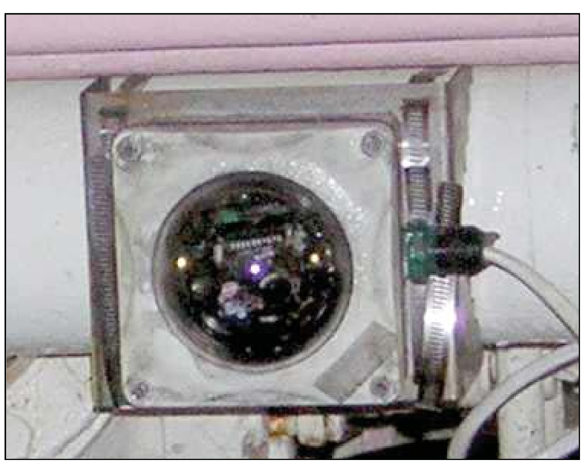

Figure 3. Photograph of an installed CCTV camera on F/T Seafisher encased in a cast aluminum armoured dome, showing stainless steal mount and band straps.

An independent GPS receiver (Garmin, model 17) was used to obtain a spatial reference during the research cruise. The GPS receiver was mounted on the vessel gantry away from other antennas and radars. According to produce specifications, the GPS receiver monitors up to 12 channels and delivers a positional error that is less than 15 m for 95 percent of the position fixes. The GPS receiver delivers a NMEA digital data stream that can be received by the DVMS for captioned video images. In this study the GPS signal was also recorded at 10 second intervals to provide an accurate time base vessel position, speed, heading and positional error, throughout the research cruise.

Imagery from the CCTV cameras was displayed live using a waterproof 24-inch (60-cm) LCD colour display screen mounted in the sampler/observer workstation (Fig. 4). The monitor provided views of all cameras as a composite, or larger size views of individual cameras. Remote control of the display and DVMS unit at the observer sampling station was through a waterproof keyboard, interfaced with a networked laptop PC (Fig. 2).

Figure 4. LCD screen available to crew in sorting area (left) and close up photograph of the LCD screen showing nine camera views simultaneously (right).

Installation of video monitoring system

Two Archipelago technicians were on site in Dutch Harbor for installation of the video monitoring equipment. The installation procedure began with a meeting aboard the vessel between Archipelago staff, lead cruise scientist, and vessel personnel. The groups were consulted regarding positioning the equipment, wiring, and onboard electrical power supply. Following CCTV camera and GPS receiver installation, the technicians performed a dockside simulation using fish moving on conveyor belts to insure the system was functioning correctly. One of the Archipelago technicians remained onboard for the entire trip to make changes to equipment settings as needed, to ensure proper equipment function, and to gather independent catch data. Upon completion of the charter, the technician removed the video monitoring equipment from the vessel. The DVMS and video hard drives were shipped directly to Archipelago's head office in Victoria, BC, for image processing.

Installation plan

A total of nine CCTV cameras were installed in all fish handling areas, providing a full view of the trawl deck and closer views of the interior fish tanks, factory conveyor belts and discard lift conveyors (Fig. 5).

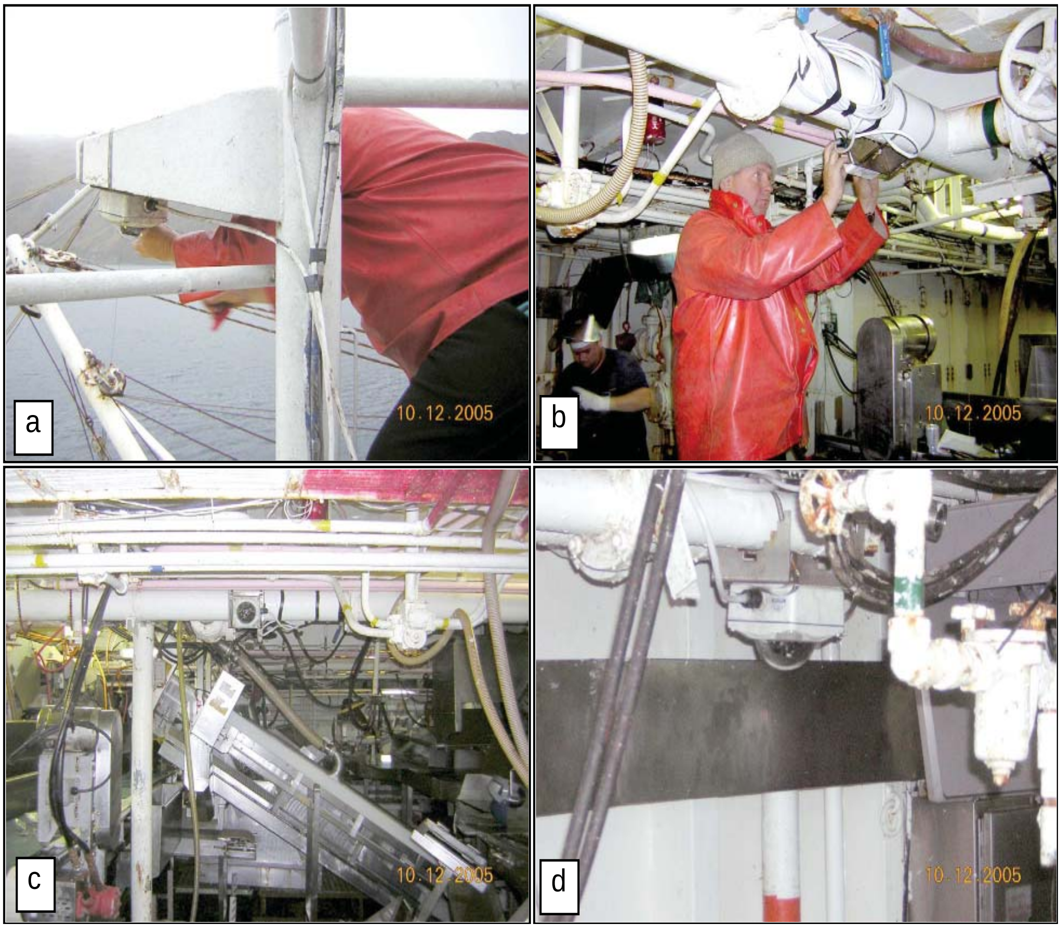

Figure 5. Camera installations on the deck gantry (a) and in the factory's starboard discard area (b), and cameras mounted in the port discard area (c) and over the flow scale conveyor (d).

Cameras were installed in key locations; with image capture rate set at 2 frames per second for the two gantry cameras, and 5 frames per second for the seven cameras in the factory. Gantry cameras were intended to monitor sorting on deck and not speciation of catch; therefore frame rates were set lower on these cameras to increase available recording time on the hard drives. Each camera was individually wired directly to the DVMS located on the engineer's storage shelf on the starboard side of the vessel (Fig. 6). The GPS data logger was also located with the DVMS unit.

While at sea, video recording was continuous, except for brief periods to check the DVMS system and replace hard drives. Video capture required about 3 GB per hour of drive space for a total capacity of 40 hours for each drive. The DVMS hard drives were replaced during factory non-processing times, requiring the onboard field technician to power down the system for approximately five minutes only during each drive change.

A detailed diagram of F/T *Seafisher's* factory layout is provided in Figure 7. The vessel has two conveyor lines although only the port conveyor system is normally used during regular fishing operations. Accordingly, video surveillance covered the path of fish movement from the trawl deck to the fish holding tank, and fish conveyor views through the factory, ending with the lift conveyors where unwanted fish are discharged. Normally all discarded fish pass through the

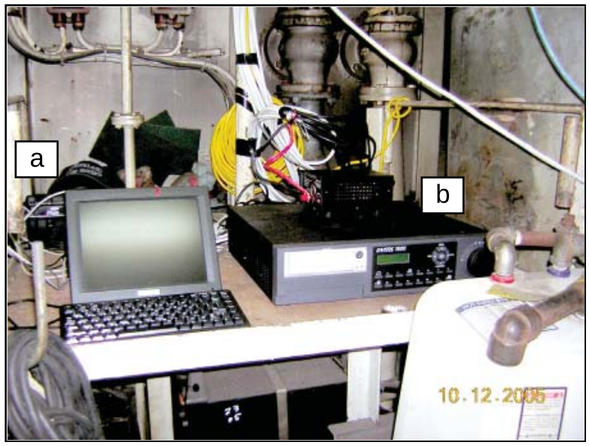

Figure 6. Technician video-review computer with data-logger box behind the monitor (a), and DVMS with camera wires connected to rear ports (b).

port lift conveyor; however, the starboard discard lift, normally used for offal discharge, was also monitored as this lift provided a point of egress for discarded halibut.

Camera positions were identified prior to the cruise for optimal views of key control points within the factory (Fig. 8). The nine camera locations were as follows:

Topside gantry – Two cameras were installed on the main trawl deck gantry. One camera was aimed to cover the stern ramp and aft section of the trawl deck (Fig. 8a) while the second was aimed to view the forward portion of the trawl deck (Fig. 8b).

Fish holding tank – Two cameras were mounted in the large holding tank where catch is received prior to processing in the factory. One camera was positioned on the port side and the second on the starboard side of the tank with views of the entire fish tank (Figs. 8c and 8d).

First lift conveyor – One camera was installed close to the holding fish tank with view of catch being transported from the holding tank to the flow scale (Fig. 8e).

Flow scale – One camera was mounted directly above the flow scale conveyor to view unsorted catch as it entered the sorting area. This area afforded good opportunistic mounting and the flow scale belt moved faster than the first lift conveyor, which was assumed to spread out the catch (Fig. 8f).

Sort station – One camera was mounted over the sorting area with views of retained catch going into the processing area and halibut discarded onto the discard conveyor (Fig. 8g).

Port discard lift conveyor – One camera was installed over the port discard lift conveyor with a wide view of discards as they moved from the horizontal port discard conveyor to the port discard lift conveyor to the discard scupper (Fig. 8h).

Starboard lift conveyor – One camera was installed near the starboard lift conveyor to view discards on the starboard side of the vessel (Fig. 8i).

Assessment of system performance

Halibut marking experiment

The main video monitoring objective of the research cruise was to evaluate the use of video technology for monitoring catch handling. Using the series of cameras installed throughout

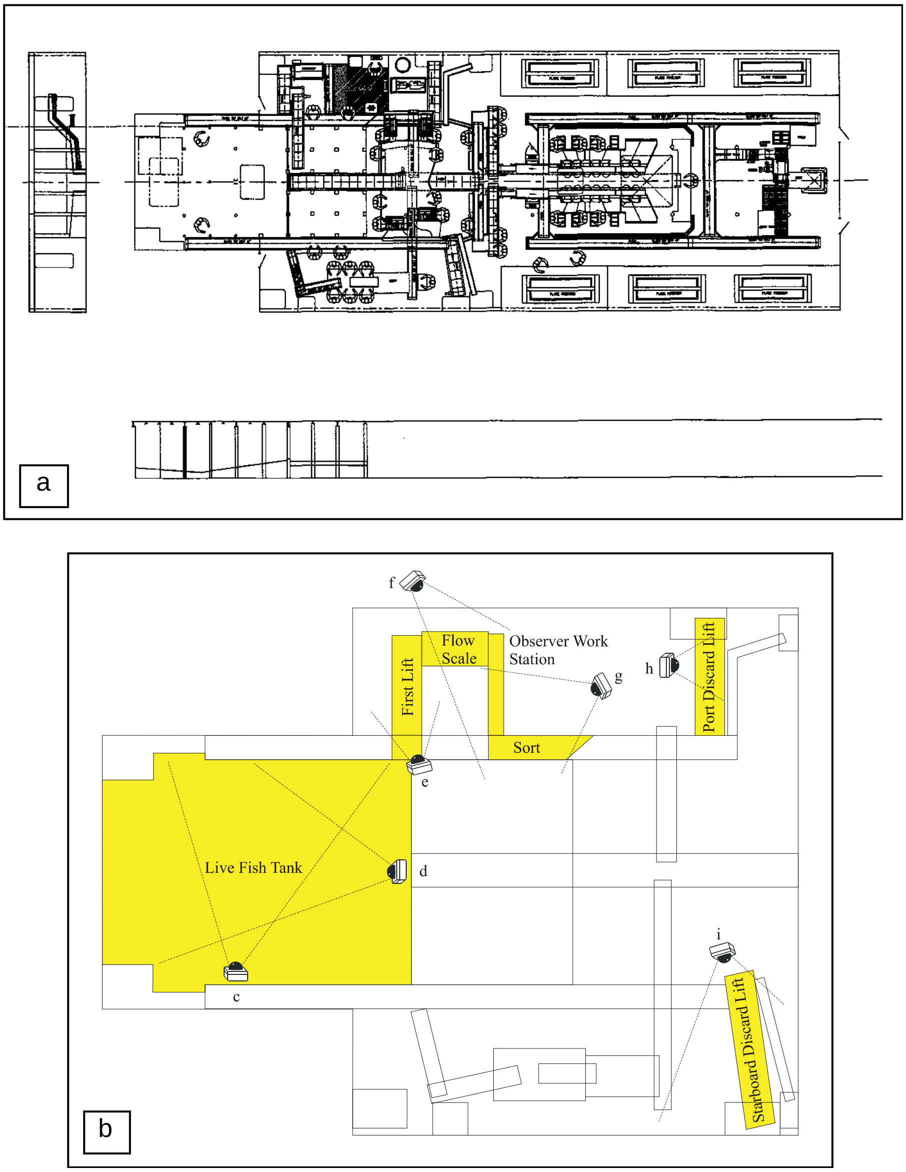

Figure 7. Detailed drawing of *F/T Seafisher* factory deck (a), and a simplified, closer view of the electronically monitored port conveyor system (b). Factory camera positions and their respective fields of view are included, and the letters c – i correspond to camera images in Figure 8. Gantry cameras (a and b) not shown. (Detailed schematic courtesy of Cascade Fisheries Ltd.)

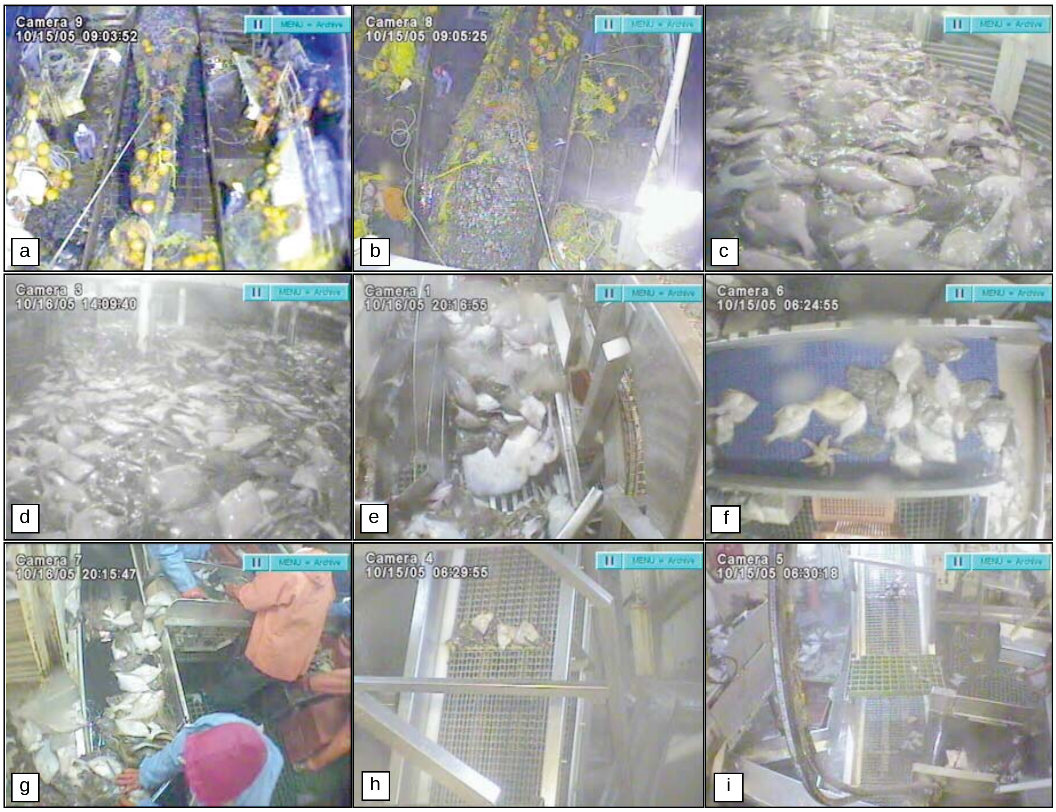

Figure 8. Nine CCTV camera views showing fish moving through the factory. Catch is first seen by the aft (a) and forward (b) facing gantry cameras, then by two holding tank cameras as the codend is emptied into the tank (c and d). From the fish holding tank, the first lift conveyor camera (e) records unsorted catch being carried to the flow scale (f), past the observer sampling station (g) and forward to the port discard lift conveyor (h). The starboard discard lift conveyor was also monitored (i), although whole fish discards were generally directed along the port discard lift

the factory, individually tagged halibut were tracked through the factory sorting process to the point of discard. Four halibut from each haul were measured, individually marked with either a blue, yellow, pink, or orange nylon cable tie wrapped around the caudal peduncle (Fig. 9). Due to the difficulty in obtaining halibut prior to sorting, halibut were obtained from previous hauls, tagged, and added to unsorted catch in the fish tank immediately following the dumping of succeeding hauls. The on board video technician recorded the time when marked fish were added to the fish tank.

CCTV Camera image quality

Imagery was monitored regularly during the research cruise to ensure optimal camera placements. Camera location and field of view were modified from the initial placements as required, especially in areas where crew tended to block a camera's view in the normal course of their duties, or if repositioning the camera would reduce water on the camera dome and improve the image quality.

Figure 9. Halibut with orange nylon tag moving up the port discard lift conveyor.

Image interpretation procedures

Video interpretation involved a careful review of the camera imagery and recording the time and color of each tag observed from each of the four CCTV cameras downstream of the fish holding tank (lift conveyor, flow scale, sorting station, and port discard lift). Two procedures were used. The first procedure involved a random selection of four hauls containing tagged halibut for a complete video review to detect tagged halibut and count total halibut seen. No information was provided to the reviewer other than there being four tagged halibut in the catch contents.

The second procedure involved examining the imagery, starting from the time that tagged halibut were seeded into the fish holding tank. Halibut were not counted in the latter procedure. Image quality was noted for each camera for every tagged halibut event, using the following criteria:

Clear – Camera lens properly focused, fish clearly visible.

Water drops, clear – Some loss of resolution in spots with water, but overall view not obscured.

Water drops, not clear – Moisture on lens obscuring majority of view, but imagery is still useable.

Crew temporarily blocking view – Temporary loss of view of some fish due to crewmen standing within camera view for a few seconds.

Blurry – Camera focus reduced; imagery useable.

Crew blocking lens – Intermittent total obstruction of view by crew; imagery not useable.

Water drops and crew blocking view – Some image blur from moisture, and view totally blocked by crew. Imagery not useable.

Water drops and bright light blur – Some loss of resolution from moisture on lens with bright light blur. Imagery not useable.

Blurry and loss of color – Imagery not useable.

Catch monitoring

In addition to tracking tagged halibut, video imagery was also assessed in terms of the ability to census catch from CCTV cameras positioned along the factory conveyor system. Imagery was examined during a selection of observer sampling intervals with the aim of comparing with observer data. Observers take 100-kilogram samples of unsorted catch randomly during catch processing operations. Samples are pooled to estimate catch composition.

Video monitoring system evaluation

A few months following the research cruise, research cruise participants were contacted to solicit feedback regarding the video monitoring equipment and its use. A structured questionnaire survey included overall assessment of utility, determining the strengths and weaknesses in this application, effects of surveillance on the crew and observers, and possible steps for improvement. The survey was intended to provide a perspective of ideas rather than an actual measure of performance. Responses were collected by telephone interview, and in some cases by email or fax.

Results

Research cruise summary

The research trip completed 37 sets spread over 13.5 days, equating to roughly three hauls per day with near continuous 24-hour processing of catch. Despite inclement weather, approximately 80% of the trip was spent on the fishing grounds. The balance of time was in transit between the fishing grounds and to and from the port. The cruise track for the F/T *Seafisher* is shown in Figure 10, using fishing event detail from GPS data at one-minute temporal resolution.

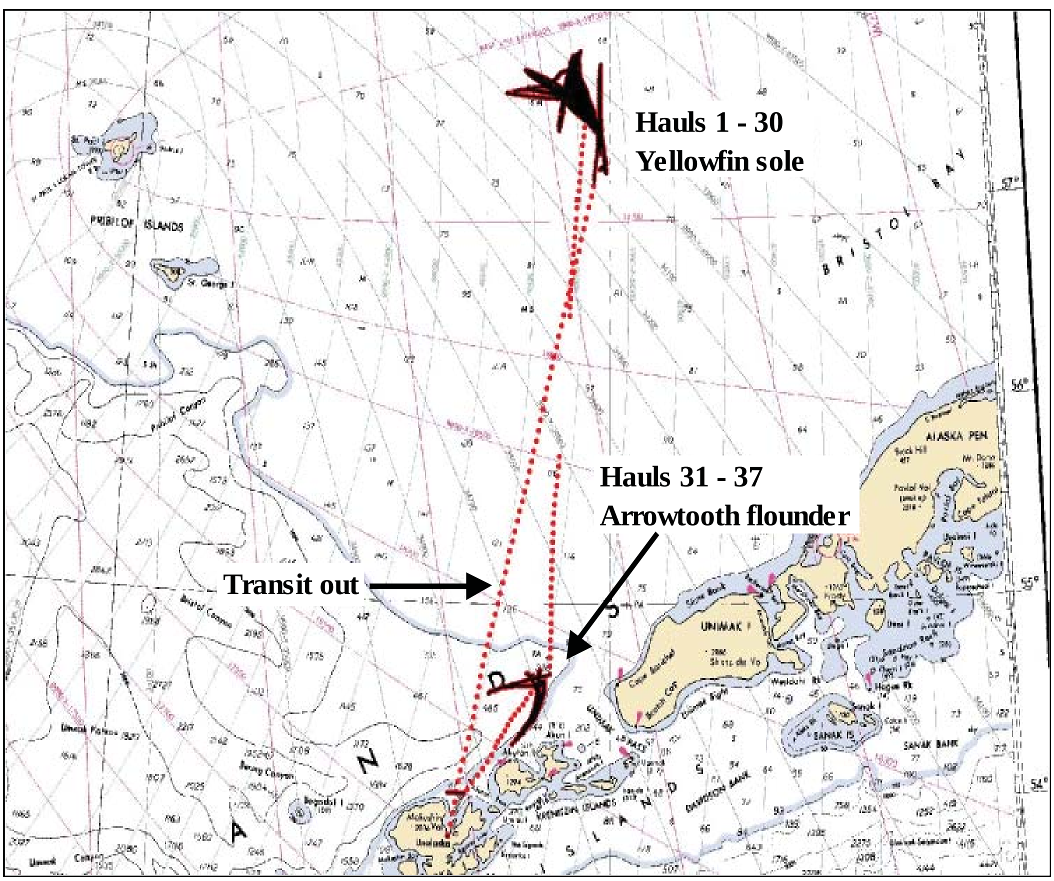

Figure 10. Spatial plot of vessel cruise tracks while traveling (dashed line, red), and hauling catch (solid lines, black).

Data collection summary

In general, the video monitoring system provided a very high rate of reliability for collecting both image and GPS data. Out of approximately 325 monitoring hours (13.5 days), and the use of seven 120-GB hard drives, video capture success was approximately 98% (about 5.5 hours missing). GPS data capture success was over 98% (4.91 hours missing). Loss of image data was from two sources. An error in loading an unformatted hard drive in the DVMS unit resulted in no image recording for haul 36, or approximately 5 hours. As well, image recording was purposely interrupted for an approximate total of 30 minutes to check the DVMS system and replace drive media. The video interruption occurred only during non-processing times, as it was necessary to power down the DVMS before removing a hard drive. The largest loss of GPS data was from a 3.85-hour power shut-off to selected areas of the vessel during an engine room repair. No factory processing was occurring at this time, but gear was in the water and net haul back was delayed by approximately one hour. The DVMS was not affected by the power loss. Additional data loss from the GPS receiver was due to periodic instances of satellite signal loss. In all cases, equipment reliability was not a factor in data loss.

The simultaneous, multiple camera view using the display monitor provided information on general vessel activity, but the composite view showing all nine images were smaller in size and detailed monitoring was impractical at this level. Analytic video review at sea and in Victoria was therefore limited to a single camera view on the display screen with the ability to toggle between cameras. Although a single view sometimes made it more difficult to consecutively follow fish on the conveyor belts, straightforward toggling between camera views simplified tracking individual fish and interpretation of imagery.

Technical difficulties encountered during the research cruise were minor and did not adversely affect the project. Overall the DVMS unit functioned well; however, the video technician encountered difficulties using the laptop PC for remote access of video imagery. This limitation resulted in having to review imagery directly on the DVMS unit, temporarily interrupting the camera views displayed at the observer sampling station monitor. Another problem encountered was the inability to title the imagery. This result could be due to a wiring fault or from an incorrect software configuration. As a result none of the CCTV imagery was titled with vessel name or position. Another problem encountered was with the waterproof keyboard and built-in mouse. This was likely a manufacturer’s defect and was remedied with replacement equipment, although not waterproof. Toggling between camera views was thus complicated throughout the charter, as the laptop and mouse had to be used while under a protective cover.

Adjustments to camera placement

Initial CCTV camera placements were made without the benefit of fish moving in the factory, so it was expected that repositioning would be necessary when the factory was in full operation. One such change involved relocating the starboard-side tank camera to a position where crewmen could be observed feeding fish from the tank onto the first lift conveyor (Fig. 11). It was then possible to better monitor the potential for crew bias of the sampling process by holding back selected species.

CCTV camera positioning on the flow scale was based on the notion that the faster speed of the belt would spread catch and improve presentation of individual fish. However, early viewing of flow scale imagery revealed that the color of the conveyor belt (blue/black) made species identification difficult, and there was still some overlap of fish that further limited identification. To improve species recognition and to monitor crew handling of prohibited species, the flow scale camera was re-positioned to capture the end of the flow scale where fish dropped onto the sort conveyor, and included most of the at-sea observer station (Fig. 12).

As well, the port discard camera also required changing from a wide field of view, covering the horizontal discard conveyor and the discard lift conveyor. This change was necessary as crew

Figure 11. Adjusted fish holding tank camera view, showing kicker feeding unsorted catch onto the first lift conveyor belt (compare with Fig. 8c).

Figure 12. Modified flow scale camera view, showing unsorted catch transferring from the flow scale to the sort conveyor belt at the observer work station (compare with Figure 8f).

carrying out their normal duties regularly obstructed the view. The camera was repositioned directly above the port lift conveyor with a close up view of the conveyor. This change more clearly resolved individual discard items and eliminated the potential for crew obstruction of the view (Fig. 13).

Halibut marking experiments

Tagged halibut detection

The population of tagged halibut available for assessment of detection by camera imagery was influenced by a few factors. The first haul provided the initial source of halibut and therefore did not contain tagged fish. As well, no imagery was recorded on haul 36 due to hard drive failure. Haul 33 consisted of only three seeded halibut, and thus the total number of tagged halibut available for examination was 139 from 35 hauls. Of these, subsequent image examination resulted in 136 (98%) tagged halibut being detected in at least one of the four possible cameras. There were only 59 tagged halibut (42%) seen in all four factory cameras. Interestingly, a fifth

Figure 13. Adjusted port discard lift conveyor camera view, with discarded catch and processed pieces moving up the lift to the discard scupper (compare with Figure 8h).

tagged halibut was detected on haul 17, likely one that had been previously discarded and then recaptured. This tagged fish was excluded from the analysis.

After seeding, tagged halibut were among the unsorted catch in the fish holding tank but were not detectable in the two fish tank cameras. Tagged halibut first entered CCTV camera view at the first lift conveyor. From here they were carried with unsorted catch to the flow scale belt and then transported through the observer and sorting areas to the discard lift conveyor. Although the starboard lift camera was installed specifically to spot halibut not discarded by the port discard lift, it was used only when a halibut was 'lost' from the conveyor stream.

The first lift conveyor was inherently difficult to monitor for tagged halibut because fish piled and slid back as the belt lifted fish to the top of the conveyor (Fig. 14, left). As a result, single tagged halibut were difficult to detect within the tumbling mass, and viewing was often complicated by moisture on the camera dome. Imagery from the sort area camera (Fig. 14, right) could easily distinguish tagged halibut, although the view was obscured by moisture on the camera dome and by crew working in the field of view sorting catch.

Figure 14. An orange-tagged halibut mixed in with unsorted catch on the first lift conveyor (left), and crew handling a tagged halibut at the sort area (right).

In contrast, the cameras monitoring the flow scale/observer station (Fig. 15, left) and the port discard lift conveyor (Fig. 15, right) were generally very good for the entire cruise. Halibut detection was relatively uncomplicated in either view, and these cameras were less prone to moisture accumulation on the camera dome.

Table 1 provides a summary of image interpretation using the first procedure where the entire fish processing duration was viewed without reference to seed times. Four randomly selected hauls from a total pool of 35 provided the sample for this analysis. The analysis to real time ratio represents the proportion of actual time required for a video viewer to count halibut while searching for tagged halibut. The four hauls with 28.71 hours of catch processing imagery required about 19 hours for image processing. This equates to analysis being completed at approximately 76% of real time, or an average of 46 minutes per one hour of imagery. Variation in analysis ratios from 0.54 to 1.3 was high due to the density of fish on conveyors, and the larger number (haul 33) resulted from the viewer searching for four tagged fish when only three were seeded.

Figure 15. A pink-tagged halibut in the flow scale/ observer station (left), and the same pink-tagged halibut moving up the port discard lift conveyor (right).

Table 1. Imagery review time requirements for randomly selected hauls, with no reference to tag seed times. Catch processing times were determined from the time fish started flowing out of the fish holding tank until all catch was sorted in the factory.

Haul Number	Est. Catch Size (tons)	Catch Processing time (hrs)	Video Review Time (hrs)	Analysis to Real Time ratio	No. of Tags Seen by EM
5	47	9.80	6.00	0.61	3
7	25	6.03	3.25	0.54	4
8	48	9.80	5.83	0.59	3
33	23	3.08	4.00	1.30	2
Total	**143**	**28.71**	**19.08**	**0.76**	**--**

Detection of tagged halibut was considerably faster when seed times were used as a reference. Additional time savings were achieved, as image interpretation using this method did not include halibut enumeration. As a result, detecting all tagged halibut from each haul processing interval averaged less than one hour, or roughly 30% of real time. Recognition of tagged halibut was aided by observing crew or observer handling of catch. Tagged halibut were often handled differently than the rest of the catch.

Table 2 provides a summary of transit time for tagged halibut from their initial release in the holding tank through to travel between all four cameras to discard (Table 3). Using the 59 tagged halibut seen by all four cameras, fish sat in the holding tank for an average of 3.68 hours, with a minimum sitting time of 0.12 hours (7 minutes) and a maximum of 9.52 hours. Upon entering the conveyor stream, halibut moved from the first lift to the port discard lift conveyor relatively quickly, with a minimum travel time of 0.6 minutes (35 seconds) and maximum of 4.9 minutes. However, the average time for a halibut to move through the factory was 2.0 minutes, with a median travel time of 1.7 minutes (Fig. 16).

Taken as a whole, the largest delay in the factory conveyor system occurred at the first lift conveyor (Fig. 17). The nature of this lift resulted in tagged halibut tumbling sometimes four or five times before catching and being carried to the top of the lift and deposited on the flow scale belt. As well, the first lift conveyor was frequently stopped by the kicker to clear fish jams at the base of the lift, which increased travel time to the flow scale. In contrast, the transfer time between the flow scale and the sort area was the fastest, but this was mostly due to a straight conveyor

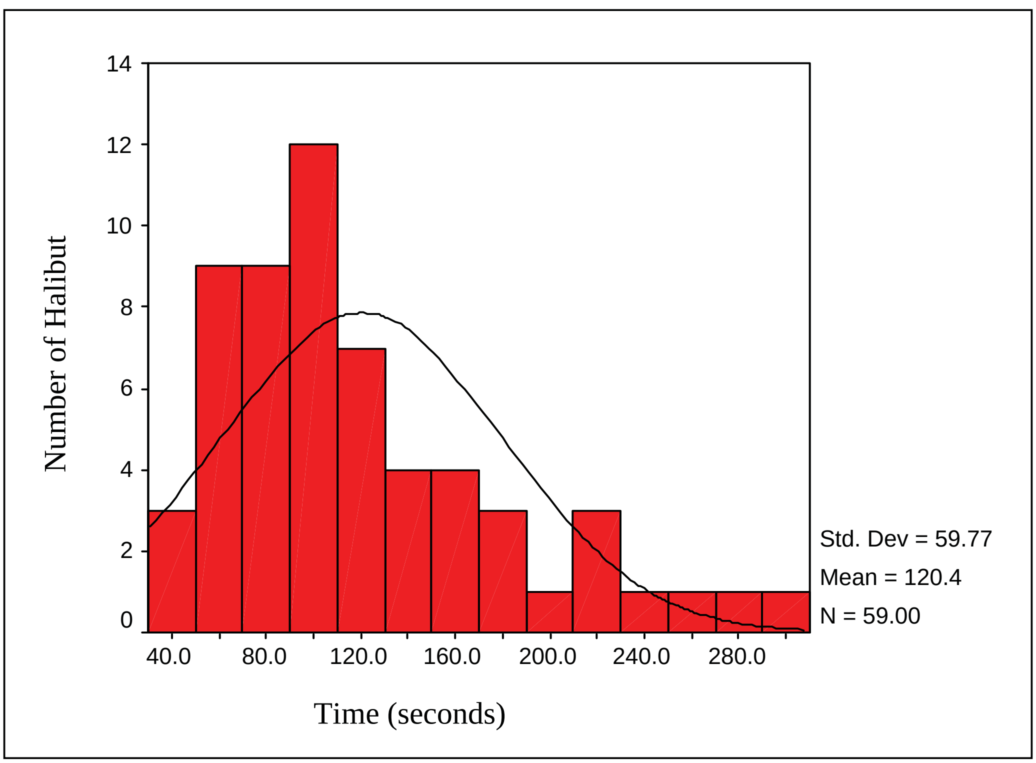

Figure 16. Overall travel times for marked halibut moving through the factory conveyor system. Time started at first sighting by the first lift conveyor camera, and stopped at initial detection by the discard lift conveyor camera.

Table 2. Summary of tag seed times, and times that tagged halibut were consecutively detected by all four cameras as they traveled through the factory, showing lapse times in the fish holding tank and between cameras (no seed time for haul 13) (n=59). Tagged halibut not seen by one or more cameras were excluded from the table.

		Time Seen By Camera				Lapse	Lapse Time Between Cameras (sec)			Total
Tow No.	Seed Time	First Lift Conveyor	Flow Scale	Sort Station	Discard Lift	Time In Tank (h)	To Flow Scale	To Sort Station	To Discard Lift Conveyor	Time (sec)
2	13:02	20:32:05	20:32:25	20:32:41	20:33:04	7.50	20	16	23	59
4	3:20	12:51:43	12:52:42	12:52:55	12:53:15	9.52	59	13	20	92
4	3:20	11:49:19	11:50:06	11:50:19	11:50:35	8.48	46	13	16	75
4	3:20	12:33:28	12:33:39	12:33:51	12:34:10	9.02	11	12	19	42
6	1:55	4:44:02	4:45:13	4:45:18	4:45:46	2.82	71	5	28	104
6	1:55	6:22:00	6:26:00	6:26:17	6:26:46	4.45	240	17	29	286
6	1:55	7:18:24	7:20:37	7:20:59	7:21:37	5.38	133	22	38	193
7	6:46	11:44:34	11:46:31	11:46:43	11:47:06	4.97	117	12	23	152
7	6:46	10:15:14	10:16:34	10:16:55	10:17:16	3.48	80	21	21	122
8	14:50	22:29:51	22:30:24	22:30:35	22:31:12	7.65	33	11	37	81
8	14:50	20:53:10	20:55:13	20:55:20	20:55:45	6.05	123	7	25	155
8	14:50	20:45:23	20:45:47	20:46:04	20:46:40	5.92	24	17	36	77
8	14:50	23:18:17	23:19:13	23:19:31	23:20:03	8.47	56	18	32	106
9	0:55	7:02:29	7:06:05	7:06:15	7:06:43	6.12	216	10	28	254
10	7:29	12:36:18	12:36:51	12:37:01	12:37:47	5.12	33	10	46	89
11	20:11	20:40:19	20:44:33	20:44:44	20:45:15	0.50	254	11	31	296
11	20:11	22:48:50	22:49:56	22:50:06	22:50:51	2.62	66	10	45	121
12	4:00	5:35:40	5:37:37	5:37:46	5:39:10	1.58	117	9	84	210
12	4:00	4:47:40	4:49:31	4:50:00	4:50:25	0.78	111	29	25	165
12	4:00	5:54:43	5:55:48	5:55:57	5:56:23	1.90	65	9	26	100
13	--	10:26:55	10:29:53	10:29:56	10:30:25	--	178	3	29	210
13	--	9:08:22	9:08:58	9:09:06	9:09:35	--	36	8	29	73
14	12:56	15:28:34	15:29:30	15:29:37	15:32:08	2.53	56	7	151	214
15	18:16	18:40:49	18:41:02	18:41:15	18:41:58	0.40	13	13	43	69
15	18:16	21:11:43	21:12:04	21:12:10	21:12:18	2.92	21	6	8	35
15	18:16	20:52:01	20:52:27	20:52:36	20:53:20	2.60	26	9	44	79
16	23:52	23:56:29	23:57:56	23:58:03	23:58:51	0.07	87	7	48	142
16	23:52	1:22:32	1:23:02	1:23:08	1:23:38	1.50	30	6	30	66
17	6:43	8:56:16	8:56:55	8:57:44	8:59:11	2.22	39	49	87	175
17	6:43	10:36:56	10:37:16	10:37:25	10:38:01	3.88	20	9	36	65
17	6:43	7:19:14	7:19:39	7:19:43	7:20:18	0.60	25	4	35	64
17	6:43	8:15:38	8:16:40	8:16:49	8:17:25	1.53	62	9	36	107
18	12:34	14:37:31	14:37:44	14:37:51	14:38:18	2.05	13	7	27	47
18	12:34	16:20:21	16:21:12	16:21:21	16:22:02	3.77	51	9	41	101
19	19:06	0:47:53	0:49:33	0:49:42	0:50:08	5.68	100	9	26	135
19	19:06	23:52:22	23:54:42	23:54:57	23:55:27	4.77	140	15	30	185
19	19:06	23:29:30	23:30:06	23:30:22	23:30:50	4.38	36	16	28	80
20	3:15	4:20:22	4:20:40	4:20:48	4:21:25	1.08	18	8	37	63
21	9:21	13:13:28	13:14:04	13:14:14	13:15:12	3.87	36	10	58	104
22	15:34	18:53:02	18:54:07	18:54:12	18:54:45	3.32	65	5	33	103
22	15:34	20:14:08	20:14:46	20:15:41	20:16:15	4.67	38	55	34	127
22	15:34	20:27:12	20:28:21	20:28:53	20:29:41	4.88	69	32	48	149
23	22:02	2:17:11	2:17:19	2:20:41	2:21:12	4.25	8	202	31	241
23	22:02	1:20:59	1:21:14	1:21:52	1:22:22	3.30	15	38	30	83
23	22:02	22:56:05	22:56:28	22:57:03	22:57:39	0.90	23	35	36	94
25	11:25	14:00:47	14:01:07	14:01:28	14:01:51	2.58	20	21	23	64
27	0:42	3:38:37	3:39:48	3:40:17	3:40:31	2.93	71	29	14	114
27	0:42	1:41:27	1:41:52	1:42:18	1:42:36	0.98	25	26	18	69
28	6:13	8:13:37	8:14:04	8:14:40	8:15:21	2.00	27	36	41	104
32	0:05	0:48:19	0:49:05	0:49:10	0:50:12	0.72	46	5	62	113
33	6:24	8:09:25	8:09:58	8:10:15	8:10:45	1.75	33	17	30	80
34	13:14	17:48:50	17:49:53	17:50:01	17:51:34	4.57	63	8	93	164
34	13:14	17:31:16	17:31:34	17:31:40	17:32:49	4.28	18	6	69	93
34	13:14	17:28:43	17:29:46	17:30:22	17:31:04	4.23	63	36	42	141
34	13:14	19:24:00	19:24:12	19:24:23	19:26:04	6.17	12	11	101	124
35	23:32	1:20:15	1:20:28	1:21:01	1:21:48	1.80	13	33	47	93
35	23:32	0:50:26	0:51:13	0:51:43	0:52:31	1.30	47	30	48	125
37	11:56	17:25:31	17:25:54	17:26:00	17:28:25	5.48	23	6	145	174
37	11:56	15:13:12	15:13:40	15:13:45	15:14:07	3.28	28	5	22	55

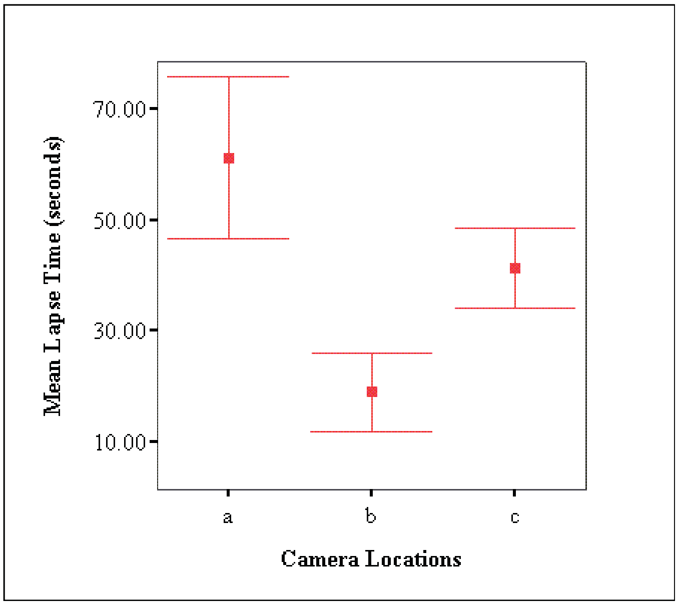

Figure 17. Mean lapse times for detection of marked halibut traveling between the first lift and flow scale cameras (a); flow scale and sort station cameras (b); and sort station and the port discard lift conveyor cameras (c). Time was recorded at first sighting by each camera, and error bars show 95% confidence intervals (n=59 halibut).

belt that moved fish from the flow scale, past the observer station to the sort area. Increased lag time between the sort area and the discard lift was largely the result of crew selecting marked halibut and carrying them to the observer station. Most of the variability in time between the flow scale and the discard lift was a consequence of inconsistent handling of marked and unmarked halibut. For example, tagged halibut were usually removed at the observer station for weighing and measuring, or infrequently from the sort station, and the fish's return to the conveyor system seemed uncoordinated and was regularly delayed.

Halibut size was evaluated against total travel time to determine if size affected speed through the factory. The average and median length of tagged halibut was 65 cm, with minimum and maximum lengths of 40 and 85 cm, respectively. Although larger halibut were more easily detected, the results showed no relationship between size and speed through the factory processing system, as illustrated in the scatter plot below (Fig. 18). The larger halibut were neither consistently delayed nor faster than small halibut; therefore time through the factory was considered independent of size. However, the narrow size range of these experimental halibut may not represent all halibut in a catch. Substantially different sized halibut (i.e. <30 cm or >100 cm) may show different results.

The success in detecting tagged halibut through the factory was also assessed in terms of tag color and camera (Table 3). The flow scale and port discard lift cameras showed the greatest success in detecting marked halibut (97% and 94%, respectively), while the first lift conveyor and sorting cameras detected fewer tags (66% and 68%, respectively). The difficulty in detecting tags at the first lift conveyor was largely the result of halibut being buried by unsorted catch. However, any failure in detection at the sort station was mostly attributable to marked halibut being removed from the conveyor, carried past the sort camera and placed directly on the discard conveyor belt.

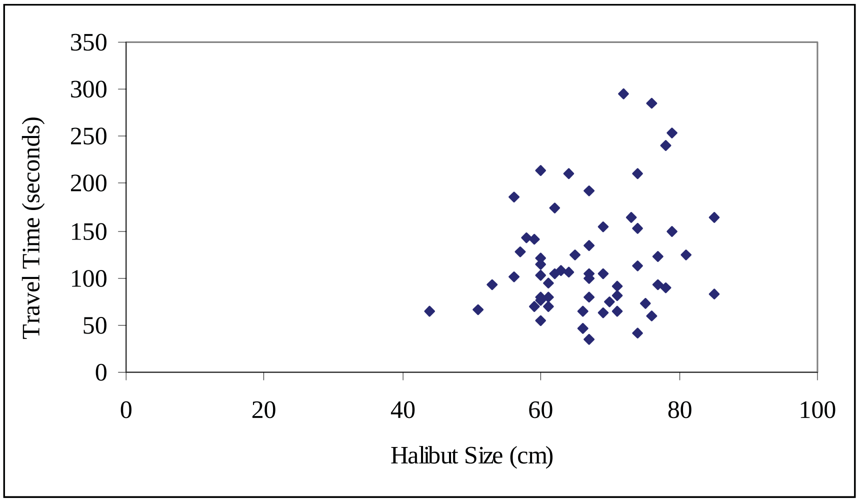

Figure 18. Scatter plot comparing halibut size with travel time through the factory (n=59).

Although the port discard lift camera provided a consistently clear view of fish, this camera missed nine tagged halibut (6%). Three of these halibut were seen by the sort camera but were never recovered by the starboard or port discard lift cameras. It was noted, however, that one of these was included with the retained catch and not discarded. The sorting process was relatively efficient throughout the charter, and it appeared that this one halibut was unintentionally missed during the sort and was likely discarded later. Of the remaining six halibut missed by the discard lift camera, three of these halibut were not detected at the sort station prior to discard, and three halibut were not seen by any camera. Possible factors contributing to 'lost' halibut included halibut falling off the discard lift in poor weather, or slipping off when piled with large amounts of fish waste on the conveyor, or tag loss. Consequently, it is conceivable that any tagged halibut not detected may have accidentally fallen off a lift, or re-joined the catch as an unmarked halibut.

Table 3. Summary of the percentage of tagged halibut seen by EM at each camera location, with tag color and camera success shown as overall percentages in their respective categories.

Tag Color	Total Number of Tags	Proportion of Tags Seen by Camera Location (%)				Overall Success
		First Lift Conveyor	Flow Scale	Sort Station	Port Discard Lift Conveyor	
Blue	33	55	94	64	94	77
Orange	35	71	100	60	89	80
Pink	35	83	100	80	100	91
Yellow	36	56	94	67	92	77
Total	239	--	--	--	--	--
Camera success		66	97	68	94	--

Camera obstruction

Table 4 provides a summary of image quality from the four CCTV cameras during the 136 instances where tagged halibut were detected. Overall, 99% of video was of useable quality of which 71% was clear, especially at the flow scale and port discard lift conveyors. However, moisture droplets on a camera dome seemed inherently problematic given the damp environment (25%) although most imagery was considered usable. Crew blocking the view occurred in 3% of the instances and 1% was considered unusable for detecting tagged halibut. Crew sometimes stood directly in front of the camera in areas with low overhead; however, this kind of interference was temporary as crew regularly repositioned themselves.

Table 4. Image quality summary for all four cameras at the time each tagged halibut moved through the factory (n=136).

Quality Category	First Lift Conveyor	Flow Scale	Sort Station	Port Discard Lift Conveyor	Overall Frequency of Quality
Usable Imagery:					
Clear	70	115	67	134	71%
Water drops not obscuring view	41	15	62	--	22%
Water drops, not clear	11	1	6	--	3%
Crew temporarily blocking view	10	1	--	--	2%
Blurry; imagery still usable	--	2	--	2	1%
					99%
Unusable Imagery:					
Crew Blocking lens	3	--	1	--	1%
Water drops; crew blocking view	1	--	--	--	0
Water drops; bright light blur	--	1	--	--	0
Blurry, loss of color	--	1	--	--	0

Catch monitoring

Camera imagery was examined to assess its use in determining catch composition. The two fish tank cameras provided a good view of catch quantity and graduations on the vertical support structures could be an aid in measuring volume. Given the variability in the height of piled fish, estimating volume by this method would likely be imprecise and imagery would not provide the resolution to discern all species. Along the conveyor cameras unsorted catch could be resolved to morphological categories such as flatfish and roundfish. Species like halibut, yellowfin sole, arrowtooth flounder, skate, and Pacific cod were generally distinctive provided other fish were not overlapping. Overall, halibut were relatively easy to identify due to their distinct size and shape. The largest problem with species identification and enumerating catch was that most often the conveyors are loaded with layers of fish, often overlapping one another. Consequently, the camera views were useful in characterizing catch but not for quantification. The discard lift camera was an exception to this as discard items were fewer and more spaced out. It would be possible to census the discarded catch using camera imagery.

Video monitoring system evaluation

Questionnaire responses were received from the onboard video technician, NMFS scientists and observers involved in the research cruise. The overall response to the video monitoring system was positive; however, it was recommended that should this technology be applied, the role of video monitoring must be clearly defined. The equipment setup and type of data collected could be different depending upon how the data are used and the type of monitoring issues to be addressed.

Survey respondents felt that video monitoring was especially useful for observing important locations within the factory that were otherwise obscured from observers. The live display monitor was deemed most helpful, as the different camera views confirmed uninterrupted flow of fish through the conveyor system. In addition, the monitor increased the general level of awareness of vessel fishing activity for the crew and science staff. One could monitor the status of deck and fish tank activity while processing catch. In particular, observers could see fish being fed onto the first lift conveyor, which facilitated crew efficiency during catch sampling processes. The live video display therefore provided crew with visual knowledge of vessel activity and seemed to improve factory morale. Other noted strengths of the video monitoring system included 24-hour monitoring of operations.

In contrast, video monitoring was unable to observe all blind spots within the factory, and the quality of imagery was especially poor in the fish tank. Low lighting and wide camera views resulted in poor resolution of fish, as well as individual catches from fishing events were often indistinguishable. Furthermore, DVMS servicing by the onboard video technician temporarily halted the camera display monitor, which seemed a source of disappointment for the crew.

It was not possible to determine if the video monitoring equipment changed the behavior of vessel crew as this was a research cruise and there was a high presence of scientific staff. The vessel already has some CCTV equipment in the factory and vessel crew seemed to be unconcerned about the additional cameras.

Technical difficulties encountered with the operation of the video system were also surveyed. The leading criticism was due to camera placement, as the factory had many corners and tight spaces with low overhead. Consequently, some camera placements required adjusting during the first few days of the cruise to improve views. Although surveillance equipment did not appear to physically interfere with the normal duties of vessel crew, it was indicated that cameras might pose a problem on other vessels with lower overhead and tighter factory layout. On those vessels, it is conceivable that cameras would be physically in the way and get bumped, or crew may work closer to cameras and regularly block imagery. Another problem mentioned included the inoperable waterproof keyboard mouse that would have enabled toggling different camera views on the display monitor. While the simultaneous view of all nine cameras was useful, being able to select certain cameras would provide higher resolution when needed. For example, the two trawl deck camera views are needed only periodically and otherwise show very little activity.

Respondent recommendations for improving the monitoring system included making the monitoring system user-friendly, providing better camera labeling to improve orientation, and better control of camera monitor views as previously mentioned. Remote control (e.g., pan tilt zoom) of individual camera lenses would also be useful in situations where camera placement is optimal but intermittent adjustment of lens angle would be required. In a similar way, placement of a camera on a track would provide more control of camera angles on incline lifts. It was also suggested that observers be able to time-stamp video to flag isolated events for use during observer debriefings, or for evidence purposes. Also noted was the need for more cameras and improved lighting in the fish tank. The addition of vessel sensors such as a winch rotation counter and hydraulic pressure transducer would aid in establishing fishing positions.

Discussion

Technology assessment

The video monitoring equipment performed very well with a data capture success of over 98% of possible imagery during the research cruise. The result is due to several factors. Firstly, large fishing vessels such as the F/T *Seafisher* tend to have very stable power systems and ample dry space for placement of electronics. The success was also achieved by having an experienced video technician on board for the fishing trip. There were no major system malfunctions, although the technician was busy monitoring system performance, cleaning camera domes and moving cameras to improve image quality. Thirdly, the quality of equipment contributed to the high data capture success. We used a high quality video recording system specifically designed for the security industry where reliability is essential. The main sources of data loss were when the vessel shut off power supply to make repairs and by technician error in use of an unformatted drive. In our view, the data loss was insignificant in terms of the overall data collection effort and equipment performance.

In terms of its applicability in a fishery monitoring application it is important to consider whether a video monitoring system could be deployed without a dedicated video technician. In pilot studies where experimentation is necessary, an on board video technician is very useful to ensure the best possible equipment configuration. This would not be necessary in ongoing use of the equipment and we usually deploy video monitoring equipment unattended on fishing vessels. However, a factory trawler video monitoring system is more complex and the duration at sea is longer. As well, many of the camera placements are in areas where periodic cleaning of the lens surface would be required. We believe that EM system maintenance activities would be shared by observers and the fishing vessel engineer, the former to regularly monitor image quality and provide serving as needed, and the latter to oversee system operation and troubleshoot problems.

The DVMS unit has the capability to simultaneously record imagery with up to 16 cameras although nine CCTV cameras were considered sufficient for the F/T *Seafisher*. The waterproof casing was well suited to the wet conditions of the factory and trawl deck gantry and the equipment worked continuously. In discussing the equipment specifications with the vessel owner, we were cautioned that the powder coated cast aluminum camera housing could corrode quickly in the continuous salt environment of the factory (T. Meintz, Cascade Fisheries Ltd., 3600 – 15th West, Suite 201, Seattle, Washington 98199, personal communication). While we have not experienced this problem with exterior camera placements on fishing vessels, the camera manufacturer provides a similar waterproof camera with a high impact plastic casing that would be corrosion free.

The location of CCTV cameras strongly influenced image quality. Most notable factors influencing image quality were moisture on the camera dome, crew activity and light levels. The most consistently clear imagery was from the discard lift conveyor cameras while the other factory cameras were more susceptible to water on the lens. Fish handling activity was especially busy at the sort station and flow scale cameras. The primary lift conveyor camera was particularly affected by water and crew activity, although this resulted in unusable imagery in only 1.5% of the instances when reviewers were looking for tagged halibut. Among these four factory conveyor cameras, reviewers felt that imagery was considered usable for 99% of the tagged halibut incidents.

CCTV camera placements were set for either a wide panoramic view or narrow field close up view of fish on conveyors. The panoramic views in the fish tank and trawl deck provided a good overall perspective of activities in an area of the vessel but resolving detail such as individual fish was not possible. The trawl deck cameras provided clear detail of net retrieval operations and events such as catch pre-sorting could be clearly distinguished in the imagery. The fish tank cameras provided a clear view of unsorted catch but it was difficult to resolve individual catch species. Lower light levels in parts of the fish tank also reduced image clarity. In contrast, the close up camera views on conveyors provided good image resolution, particularly at the flow scale and discard lift cameras where catch density was lower. The high density of fish at the primary lift, and to some extent the sort station, made it difficult to discern specific catch items. A shortfall of the close up cameras is the difficulty of putting the imagery into context with activities in the rest of the factory, or connecting imagery from one camera to another. It would have been beneficial to use at least one other panoramic camera on the conveyor system, perhaps aimed down the length of the main conveyor. In this way the specific imagery from several cameras could more easily be linked. One questionnaire respondent suggested that adding pan, tilt, and zoom (PTZ) capability to some of the cameras, particularly the panoramic cameras, would better tailor imagery to specific conditions.

In this installation, data from a GPS receiver was also recorded regularly. This information was useful to inform observers of vessel location and after the research cruise to position the cruise track and general location of fishing events. In our view, other data should be included in the data record to assist in overall data interpretation and in the identification of anomalies. For example, more precise fishing event detail can be obtained by using a winch rotation sensor and hydraulic pressure transducer (McElderry et al., 2005). As well, a sensor to record when observer catch sampling occurs would aid in conducting a forensic review for catch pre-sorting. Similarly, an event trigger for observers to use would enable them to place mark an event in the data record for later reference. We strongly recommend that data recorded by the video monitoring system include both imagery and data from GPS and other sensors.

The user interface was also an important part of the video monitoring system. The large display monitor, placed in the observer sampling station, proved to be an especially valuable tool for observers and factory personnel in getting a better understanding of activities elsewhere on their vessel, outside their immediate view. The live CCTV camera views enabled observers to monitor fish entering the primary lift when samples were being taken to eliminate the possibility of crew-induced bias in samples. As well, camera images of the trawl deck enabled observers and crew to monitor fishing activities and better plan their time for on deck duties during net retrieval. As well, these views enabled the observer to ensure that all fish in the cod end were placed in the fish tank and not discarded.

The value of the display monitor will be in the flexibility in configuration to the specific needs. While video monitoring on a factory trawler could require nine or more cameras, not all imagery is of the same importance. Trawl deck views are only necessary for short intervals throughout the day, while factory conveyor views are important most of the time. In this study the display was set up with all nine camera images in a small image three by three composite view. Later, this was changed to a two by two composite view with the four more important camera views. The interface for selecting camera views in the display was awkward and could be improved. The interface could also include other pertinent information, such as vessel location, and the status of other sensors. If PTZ were included, this could also be controlled from the user interface. Another possible improvement would be to provide the same display monitor on the bridge for the benefit of the vessel officers.

Important considerations in the use of video monitoring systems are the data volume requirements. In this study, the nine CCTV cameras required about 3 GB per hour, or about 500 GB per week of fishing. Maintaining a permanent data record of the fishing trip would require periodic changing of hard drives and a process to secure all archived data drives. Additional cameras would increase the data storage requirements and reduce frame rates (i.e., images per second), and more efficient image compression algorithms would lower data storage requirements. Technology is developing rapidly in this field but it is safe to conclude that keeping a permanent record of factory trawler operations would involve very large quantities of data. It would be beneficial to project the data storage requirements for the fleet and develop a data management plan.

Finally, in assessing the technology used in this study, it is useful to consider the applicability for the factory trawler fleet in general. As previously mentioned large vessels generally have very stable power systems and adequate space for the equipment. As the specific layout of each vessel differs, there is likely no standard set up for the video monitoring equipment. Each vessel would need to be considered separately and, as occurred in this study, trial and error in camera placements would be necessary. In our view, the technology tested in this study would be suited to the factory trawler fleet.

As previously mentioned, we used off the shelf video monitoring equipment from the security industry in this study. The equipment was reliable and well suited to a number of the project needs, however we remain neutral in endorsing specific video recording products. There is a wide selection of video recording equipment available and a specific product choice would be better made when the overall objectives of video monitoring are determined. In general, most video recording systems do not have the capability to record ancillary data (e.g., GPS, winch, hydraulics, etc.), which would lead to using a dedicated data logger or a more custom monitoring system that records both video and sensor information (McElderry et al., 2005).

The pilot study involved temporary placement of components, balancing the cost and labor in custom preparations with the optimal functionality of the equipment. Permanent installation of a video monitoring system would likely differ from the configuration in the pilot in order to improve system performance, reduce clutter and provide more security for sensitive components. Rather than opportunistic placement, cameras would be located to provide the best view and the lowest possibility of interference. Similarly, more careful consideration would be given to the location of the display monitor, video control box, wire runs, and other sensors. There are also opportunities to create value for the fishing vessel. For example, as was evident in this study, camera displays in the factory assisted the crew in understanding deck operations. The display of such imagery would likely be of importance on the bridge and elsewhere on the vessel.

Halibut tagging experiments

While halibut were generally distinctive and easily recognizable in the close up CCTV cameras, the halibut tagging experiments provided a more descriptive way of assessing their detection by video monitoring equipment. In this study, 98% of tagged halibut were identified in at least one of the four factory conveyor cameras. Tagged halibut were not discernable in the fish tank camera views, although halibut could be clearly seen. The best locations to detect tagged halibut, or halibut in general, were at the flow scale and discard lift where fish are more spaced out. Halibut detection at the primary lift conveyor was more problematic, owing to tumbling fish and reduced image clarity. Pink tags seemed to be the most distinctive, while blue or yellow were less easy to detect. Detecting tagged halibut was greatly aided by referencing the seed times as the catch processing times were generally long (6-9 hours) and reviewers easily fatigue watching that much imagery.

While nearly all tagged fish were detected, in only about 43% of the instances were tagged fish seen in all four factory conveyor cameras. The inability to consistently detect tagged halibut was because reviewers were looking for the tag that could be covered by other fish or arms of crew working on the conveyor, or simply that the tag color was not that distinctive. Consequently, the tag results under-represent the reviewer's ability to discern halibut. Without tags, the ability for reviewers to follow a specific halibut from camera to camera along the conveyor would mostly be dependent on the density of halibut. Overall throughput of halibut in the factory varied from one to five minutes independent of fish size, with most variation caused at the first lift conveyor.

CCTV cameras in the factory were very effective at detecting halibut. The reviewer time required to spot tagged halibut was about 30% of real time. In order to spot tagged halibut and provide an overall census of halibut required analysis effort that was 76% of real time. Given factory operations that typically run 20 hours a day, review times could be fairly large, depending upon the monitoring objectives.

Possible uses of the technology

The results of this study indicate that video monitoring technology could be a very beneficial monitoring tool for the factory trawl fleet. While there are a few options for use, we do not see the technology replacing an observer but, rather, being a tool to improve observer capabilities. Video monitoring does not clearly resolve catch to a level where quantitative estimates of species composition could be derived. In theory, many species of groundfish could be identified from video imagery, however the quantity of fish on factory trawlers is very high and the conveyors are generally too full with several layers of fish to resolve catch reliably. Modifications to the conveyor system to reduce the density of fish for video identification purposes would interfere with factory production requirements unless such operations were performed for purposes of periodic sampling. Groundfish trawling may also have high species diversity that would take time to identify properly. Catch recording by video is also by piece counts, requiring an additional computational step of converting pieces to weight. If the process were improved to a level where catch composition could be derived, it is doubtful that the video review labor would provide savings over the observer labor it would replace.

The most beneficial use of video monitoring technology would be for simultaneous real time displays of different parts of the vessel. The quality of observer data improves when observers can monitor several places on the vessel at once. The trawl deck and fish tank cameras provide a clear view of fish handling operations and the potential for pre-sorting activities. Placement of cameras in these areas provides a deterrent for such activities. Provision of display monitors at the observer sampling station and on the bridge provides the opportunity for both observers and vessel officers to monitor catch handling activities.

The ability for storage of image data provides the opportunity to review imagery after the fact. This would be a useful tool for the observer (or vessel personnel) to review certain events that could not be seen in real time. For example, observers could replay imagery from the factory to examine fish handling practices when they were not present. The image data could also be examined after the fishing trip for various purposes including pre-sorting, specific events noted by the observer, factory operations in general, and monitoring observer performance.

The role of video monitoring as a compliance monitoring tool has not been fully investigated. There is no question that video monitoring certain areas of the vessel provides a significant deterrent for illegal activities such as presorting and discarding. However, there are no precedents for the use of such data for prosecuting fisheries violations while clearly in other disciplines video data is widely used in judicial process.

An issue that arises with event replay capability is how much imagery should be recorded. As mentioned, data volumes are very large, as are the time requirements for subsequent review. The simplest option for data storage would be to record the most recent events, continuously overwriting older image data. Video monitoring in most security applications follows this practice as events of interest (e.g., a store robbery) are generally self-evident and the video system can be stopped and the data removed. Depending upon hard drive capacities, the loop cycle could be a few days to a few weeks. Moving toward full data storage for a fishing trip would involve a process of cycling hard drives every few days, a process that is very easy to perform but leads to higher data storage cost. As well, periodic replacement of drive media may lead to chain of custody issues if access to the data storage devices is not carefully controlled.

Conclusions

The tests using video monitoring equipment on the F/T *Seafisher* research cruise provided promising results for the use of this technology. The system performed reliably and provided the scientific personnel and vessel crew with a useful real time monitoring tool. Post cruise data analysis demonstrated that halibut were readily detectable throughout the factory. However, imagery was not suitable for making detailed assessments of catch composition. We believe that video monitoring offers opportunities to improve observer's abilities to monitor catch on factory trawlers. Further work is needed to consider the benefits of video monitoring in terms of the various monitoring issues in the fishery and determine appropriate specifications for the equipment, how it should be configured, and appropriate data analysis methodology for video data. In particular, we highlight the need for careful consideration for the data issues surrounding the use of this technology.

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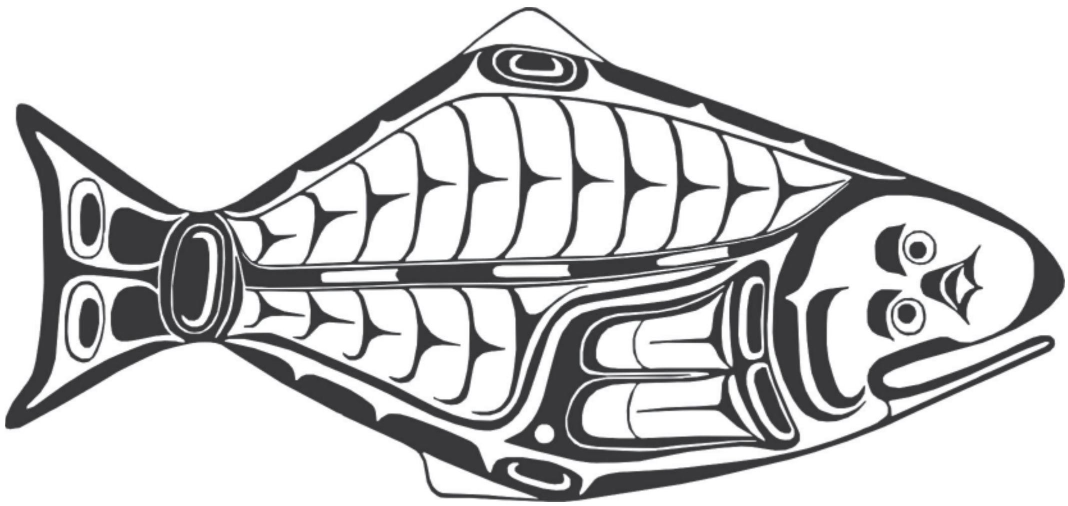

HALIBUT CREST - adapted from designs used by Tlingit, Tsimshian and Haida Indians