Gulf of Maine Research Institute
Science. Education. Community.

Maximized Retention Electronic Monitoring in the Northeast Multispecies Groundfish Fishery

Year 1 Preliminary Report

September 20, 2019

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Introduction

In August 2018, the Gulf of Maine Research Institute (GMRI), with its partners, launched a Maximized Retention Electronic Monitoring (MREM) program, in which a dockside monitoring (DSM) component run by the NEFSC works in tandem with an electronic monitoring (EM) component to provide a complete monitoring program of kept and discarded fish on vessels operating in the Northeast Multispecies Fishery. The following preliminary report describes program execution and the first year of data collection, spanning August 1, 2018 to July 31, 2019, and focuses only on the EM component and the primary review conducted by GMRI. It does not include analyses by the NEFSC or an evaluation of the dockside monitoring component. All future reports will be aligned with the NE Multispecies fishing year.

Program Overview

In 2013 GARFO and the NEFSC outlined the potential use of EM in a "maximized retention model" in the Northeast groundfish fishery where instead of recording discards at sea, fish are retained and accounted for during offload. Therefore, GMRI has designed the Maximized Retention Electronic Monitoring (MREM) program to evaluate an EM protocol feasible for large vessels in the NE Multispecies fishery and to ensure precise and accurate catch estimation, while reducing regulatory discards and increasing efficiency and accountability in the fishery.

Instead of recording discards at-sea, vessels in this program are exempt from minimum size requirements for allocated species, and all catch (both legal- and sublegal- sized) of allocated species are landed, documented through dealer reports, and verified by a dockside monitor. EM in this program is used as a means of documenting allocated species, if any, that are discarded at sea with the idea that in an operational program, EM would be used to determine compliance with MREM protocols rather than as a catch accounting tool.

First proposed in 2016, GMRI spent its first year of the program securing project permits, recruiting participants to the program, partnering with industry and the Agency to design the Maximized Retention program protocols, and developing program infrastructure. GMRI selected Integrated Monitoring as the project EM provider through RFP, and together GMRI and Integrated Monitoring determined EM system design, established data transmission protocols, developed EM review software, and installed electronic monitoring systems on 3 vessels.

Following the approval of the program EFP, vessels in the Maximized Retention Electronic Monitoring program began fishing under MREM protocols in August of 2018. In this first fishing year of the project, 3 vessels participated in the program. These vessels have been essential to piloting catch handling and offloading protocols and testing MREM systems and data transmission practices.

Partners:
Electronic Monitoring Provider: Integrated Monitoring, INC
Automatic Analysis Technology Provider: CVision AI

Program Goals:
The Maximized Retention program is intended to advance the objectives and tasks identified in Section 4.2 of the Greater Atlantic Office of Fisheries and Northeast Fisheries Science Center Electronic Implementation Plan by 1) creating incentives for fishermen to adopt Electronic Monitoring (EM), 2) developing the rules, standards, handling procedures, and vessel monitoring plans necessary to effectively implement a maximized retention EM model, 3) working with the government, service providers and sectors to create the infrastructure needed to implement and utilize program data, 4) identifying the cost structures and other operational impacts of this program, and 5) developing recommendations to inform management and policy for an operationalized maximized retention-based EM program in the region.

Year 1 Objectives:
1. Develop program infrastructure and protocols, including:
    a. Develop and submit an application for an Exempted Fishing Permit (EFP) to the NOAA Fisheries Regional Administrator
    b. Work with state agency partners to secure state permissions
    c. Select EM service provider(s)
    d. Work with participants, EM service providers, and NOAA Fisheries to create individual vessel monitoring plans (VMPs) tailored to each participating vessel
2. With EM provider, design Maximized Retention electronic monitoring systems and evaluate system performance for consistent and complete data capture in a Maximized Retention program.
3. With EM provider and Agency partners, design data transmission and video review platforms and protocols and implement the pipeline for electronic monitoring data submission to the Greater Atlantic Regional Fisheries Office.
4. 150-200 Maximized Retention trips monitored
5. Conduct video review of 1 year of Maximized Retention trips.

Results: Year 1

Objective 1: Develop program infrastructure and protocols

A. Develop and apply for an Exempted Fishing Permit

Following a series of engagement meetings with industry and NOAA to identify reasonable and achievable incentives for participation in a Maximized Retention EM program, GRMI submitted an EFP application in June of 2017 which, after a collaborative process of iterations, was approved in August 2018. The EFP requires the use of electronic monitoring on all groundfish trips and all 9 allocated groundfish stocks to be landed. It exempts vessels from minimum size requirements for allocated species, allows undersized groundfish to be landed and grants certain gear exemptions for Haddock and Redfish. Vessels fishing in the Maximized Retention program are not subject to NEFOP observer coverage but are required to carry ASM observers at an equivalent rate to the rest of the fleet.

B. Secure state permissions

GRMI also worked with state agencies on the authorization of participating vessels and dealers to land, possess, transport and sell sub-legal sized fish. Through this process, GMRI, NMFS and state agencies identified a need to trace the origin of sub-legal sized fish back to the Maximized Retention program following landing. Therefore, all containers of undersized groundfish are tagged with the program name, vessel name, EFP number and EVTR number prior to landing and these tags stay with landed fish through sale and processing. Participating vessels and dealers are permitted in MA, RI, and ME. New vessel or dealer participants joining the Maximized Retention program are issued necessary state permits once they have been approved for addition to the EFP.

C. Select EM service provider(s)

In June of 2017, GMRI solicited bids via RFP for an EM service provider and received 5 bids. After carefully reviewing the applications, GMRI selected Integrated Monitoring, based out of Boston, MA, which focuses on 'next generation' EM technology, including: broadband VMS, wireless 4G data transmission, cloud-based storage and data retrieval, and smart cameras. Among the capabilities of Integrated Monitoring's technology are remote wireless data transmission, remote hardware and software adjustments, communication abilities for the captain and crew, and at-sea updates of system performance and camera views.

D. Create individual vessel monitoring plans (VMPs)

In collaboration with participants, Integrated Monitoring, and NOAA Fisheries, vessel monitoring plans (VMPs) tailored to individual vessels' deck layout, electrical and physical specifications, and crew configuration were drafted and approved to enable successful MREM execution. Each VMP details program goals, general Maximized Retention program rules, vessel operator

responsibilities, EM system maintenance, vessel-specific catch handling rules, dockside monitoring protocols, and the vessel-specific EM system design and camera views. VMPs are carried by the vessel on all trips and are approved by NOAA prior to adding the vessel to the Maximized Retention EFP.

Objective 2: Design and Evaluate MREM systems

EM systems in the Maximized Retention program have been designed to include: 4 cameras, a secure communications server, a FleetOne satellite antennae and corresponding below deck unit, a cellular antennae, secondary GPS sensors, a tablet and, if preferred by a the captain, a monitor to view cameras. Data capture and utility goals for this system are as follows.

Cameras are located to provide complete coverage of fishing operations and discard locations. This includes: an overhead view for tracking fish as they move around the deck, close-up views of fish-sorting areas for species identification, and views of the regulated discard point(s) designated in the VMP. Video in the Maximized Retention program is intended to provide a complete picture of any species discarded at-sea and determine any deviations made from the VMP, so that a compliance with MREM program rules can be determined.

For the purposes of MREM data-collection, satellite connection provides a GPS location throughout the trip, allowing each video review annotation to be associated with a location, time and vessel speed. Every system is also equipped with a redundancy GPS sensor to protect against the event of satellite outages during a trip. Satellite and cellular connection additionally allow for remote technician access via VPN to the secure communications server, and thus system diagnostics and camera streams. All data in the Maximized Retention program is transmitted wirelessly through these connections (See Objective 3 below).

The secure communications server logs system function and stores trip data (sensor and video) until it is able to be uploaded to cloud-based storage. While trip data is transmitted following each trip, servers are equipped with sufficient storage capacity to store multiple months of Maximized Retention data. Finally, through satellite and cellular connection, a wifi-signal is generated on board, so captains are able use certain communications applications, such as Gmail or WhatsApp. This connection provides a vehicle for communication with the NEFSC Dockside Monitoring team to facilitate offload monitoring.

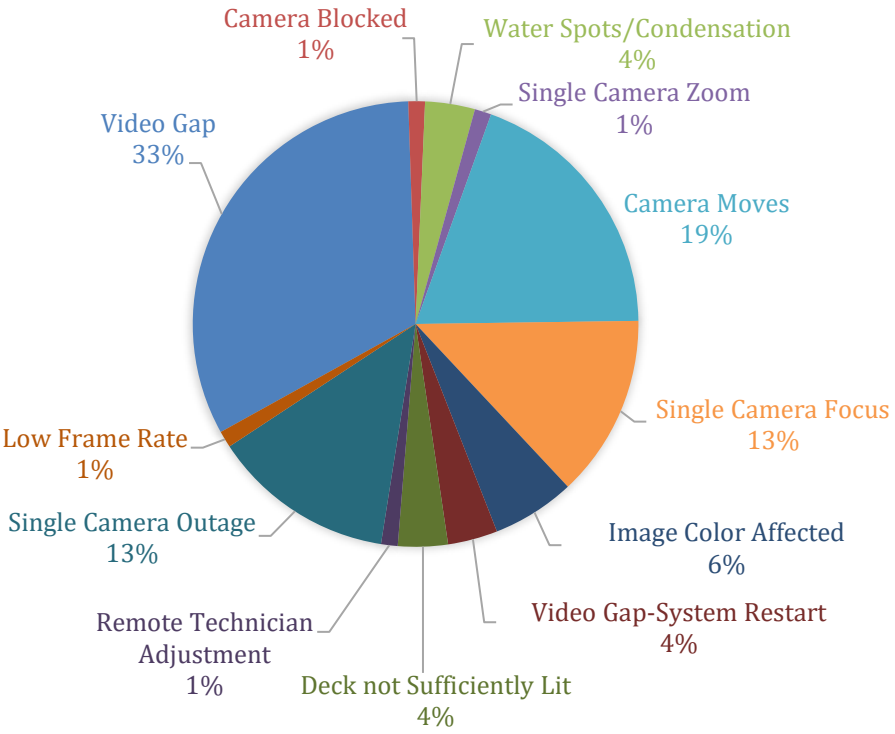
Tablets and monitors provide a system-interface to the captain from which they are able to confirm camera function, GPS location, data storage, and satellite or cellular connectivity.

Equipment installation began on a trial vessel in August of 2017. This early installation provided an opportunity to test installation procedures as well as to begin collecting test data prior to EFP approval. EM systems were subsequently installed on 2 additional vessels. Once the program was approved under EFP, video analysts in the Maximized Retention program tracked video quality, EM system malfunctions and trip failures due to EM system malfunctions as part of their review of each Maximized Retention trip. Malfunctions are broadly categorized as any instance in which the EM system or video quality behaves differently than is expected from installation, and may include instances of system adjustment by a remote technician, minor deviations in image color or camera angle, or major system outages. During fishing, captains are required to report any system malfunctions to Integrated Monitoring or GMRI at the time they are noticed, using the communication capabilities of their EM system. In most instances, this communication allows a remote technician to access the vessel's EM system to resolve the issue during the trip.

During the period of August 1, 2018 to July 31, 2019 reviewers annotated 80 instances of EM system malfunctions during review of 167 MREM trips. Of these events, 35 malfunction events were resolved in under 5 minutes, 17 were resolved in between 5 minutes and 1 hour, and 28 lasted over one hour or persisted for the duration of the trip. Further, only 1 malfunction prevented review of a haul, 9 malfunctions allowed a partial review of a haul and, only 1 trip of 167 failed the review process due to an EM system malfunction.

Figure 1 below shows categories of EM malfunctions identified by video reviewers. 46% of EM malfunctions occurred in a single camera and did not affect the EM system function as a whole. Single camera malfunctions were most often caused by vibration from the vessel or water damage to a camera connection. During trips, single camera focus or position changes could be resolved by remote technician access or a system restart, and in many of these instances video review was not affected due to overlapping coverage of the area by other cameras. For cameras mounted in high-vibration areas, the effects of vibration have been mitigated through the addition of anti-vibration padding and by deploying fixed, rather than pan-tilt, cameras in these

locations. Camera outages due to saltwater infiltration are addressed through adjustments to mounting position and installation of water-resistant connection couplers. Finally, video gaps comprised 37% of EM malfunctions identified, with 4% resulting from an EM system restart. Video gaps not caused by a system restart were most often caused by fluctuations in power to the EM system, and could usually be resolved following a trip by switching the system power source or improving connections between the EM system and the vessel power.



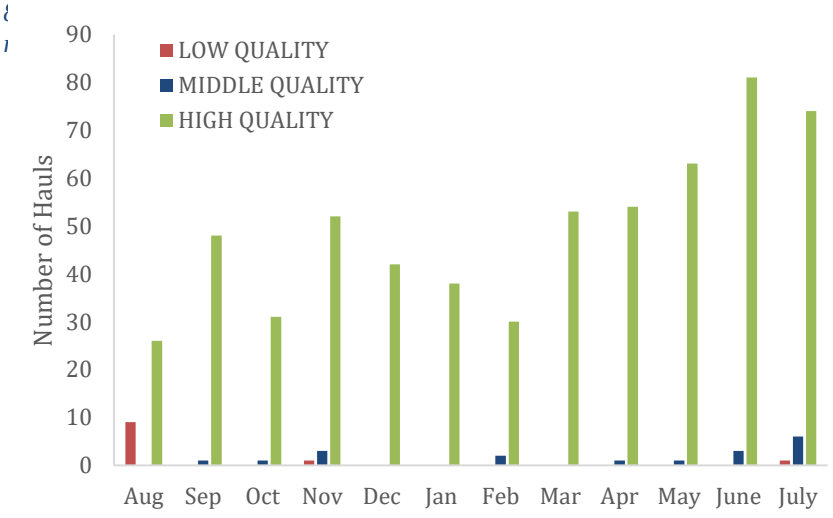


Figure 2: EM image quality ratings for MREM hauls for the period of August 1,2018 to July 31, 2019

In addition to evaluating EM malfunctions, reviewers also annotate video quality for every Maximized Retention haul. Per the guidance in the "EM Video Review Protocols for Multispecies Sector Trips" issued by NOAA Fisheries, video quality ratings are an assessment of the entire camera system during fishing activity, not individual cameras. Of the 622 hauls made, image quality during video review was assessed by primary reviewers as high on 592 hauls, medium on 18 hauls and low on 11 hauls. Hauls assessed as low quality most often occurred in the first month of the program as newly

installed systems were adjusted and were related to either camera movement or video gaps observed in the footage.

Objective 3: Develop data transmission and video review platforms and protocols.

With our partner, Integrated Monitoring, we have designed the Maximized Retention program around cellular transmission and cloud-based storage of EM data. All raw EM data in the Maximized Retention program is transmitted wirelessly and stored using Amazon Web Services. While the vessel is at sea and outside of cellular coverage, video and sensor data are stored to the secure communications server on board. Remote MREM program technicians are able to access this server via VPN over satellite or cellular connection to run system diagnostics, access and troubleshoot cameras, and confirm system function. Once the vessel enters cellular range, video and sensor data transmits via cellular connection to cloud-based storage, and upon complete transmission the vessel data is generated into a trip package for primary review. Video review is conducted using open-source software developed by Chordata LLC and modified in partnership with Integrated Monitoring to accommodate Maximized Retention program requirements. Following primary review, review data is stored via Amazon Web Services and a video review summary file is submitted to GARFO's API.

GMRI began tracking the time from the end of Maximized Retention trips to the time that a trip is available for review by a primary reviewer at the start of the 2019 fishing year (05/01/2019), and has tracked the time from trip end to complete video review and submission to GARFO since MREM trips were first monitored in August 2018. In collaboration with NOAA, GMRI has identified a goal to review all MREM trips within 7 business days of a trip landing, or a maximum of 11 days for the 2019 fishing year.

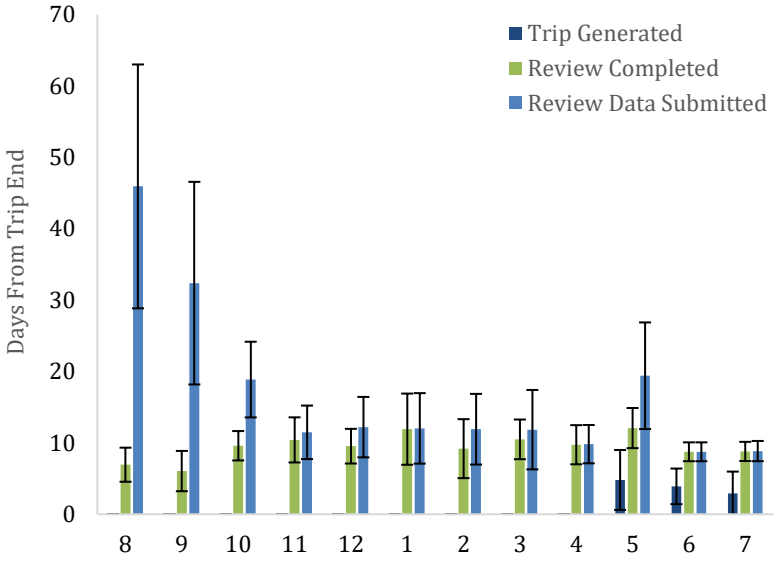


Figure 3: Time from trip end until (1)the trip is available for review (Trip Generated), (2) a primary review of the trip is completed (Review Completed), and (3) review data is submitted to GARFO's API (Review Data Submitted)

During the first year, the MREM program video review and submission process has been iteratively enhanced and streamlined. Although MREM trips began in August of 2018, MREM review data was not submitted to GARFO until October 26, 2018 as the pipeline for submission to GARFO's API was developed and implemented. In May of 2019, the Greater Atlantic Regional Fisheries Office updated its API to accommodate changes and advances to EM programs in the NE multispecies groundfish fishery. New trips from the 2019 fishing year were reviewed under the updated specifications and could not be submitted until June 6, 2019 when the API update was complete. Removing this initial development phase and the wait time for GARFO's API update, review summary files from MREM trips were submitted to GARFO on average 10.7 ±4 days after trip end. Primary review rates were not affected by the start-up phase or the API update and primary review was completed on average 9.4 ±3.2 days after the trip end during the period of 08/01/18 to 07/31/19.

Beginning in May 2019, MREM trips were available for primary review 3.8 ±3.3 days after trip end, with 14 trips out of 59 available for review within 24 hours of trip end. Time to trip generation for primary review steadily decreased between May 2019 (4.8 ±4.2 days) and July 2019 (2.9 ±3 days) due to software updates which enhanced the speed of data transmission and enabled a "soft" power down of the EM system which allows the server to remain on and transmit data for up to 2 hours following the system power-down. All other components of the EM system are powered down during this time so as not to draw significant power from the vessel. Time to complete review and time to submission are also reduced during this time period as a result of video becoming available to reviewers sooner.

To evaluate efficiency of video review, a review ratio comparing the time needed to complete a full trip review to the total length (dock to dock) of the reviewed trip is

calculated for every trip in the Maximized Retention program. The review ratio is represented as a percentage, calculated:

$$Review\ Ratio = 100 * (\frac{time\ to\ complete\ review}{duration\ of\ trip})$$

Overall, the mean review ratio from MREM trips in the period of 08/01/2018 to 07/31/2019 was 20.88 ±8.11%. Therefore, a 16 hour Maximized Retention trip would necessitate 2.04-4.6 hours to conduct a complete review. Vessels participating in the Maximized Retention program fish for both single-day and multi-day trips and review ratios vary between these two categories. For multiday trips, review ratios average 12.59 ±3.77% (e.g. 10.5 to 19.6 hours of review for a 5-day trip). For day trips the review ratio averages 22.28 ±7.81% (e.g. 2.3 to 4.9 hours of review for a 16-hour trip).

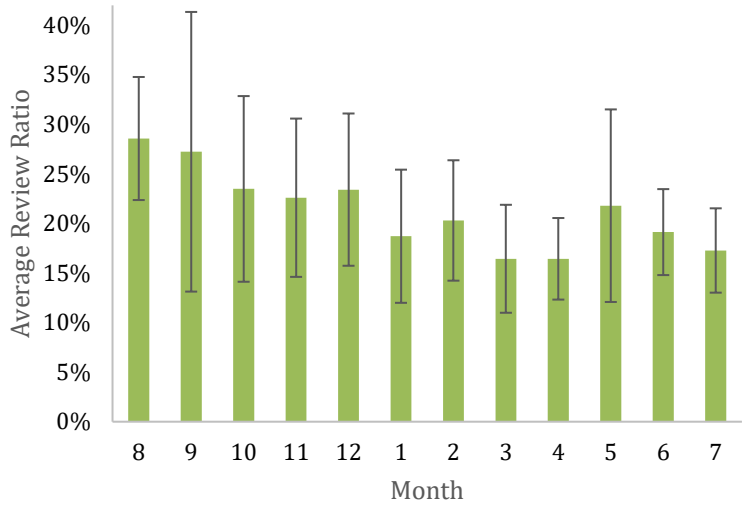


Figure 4: Mean monthly review ratios

Generally, video review rates are affected by catch handling practices, catch composition, duration of catch sorting periods, adherence to VMP protocols by crew, and video quality. Review times are lower for trips in which there are low-diversity catches, catch is sorted quickly, the crew follow VMP rules, and cameras function properly. Review rates are higher for trips in which diversity of catch composition is high, catch is sorted slowly, the crew deviates from VMP protocols or cameras malfunction.

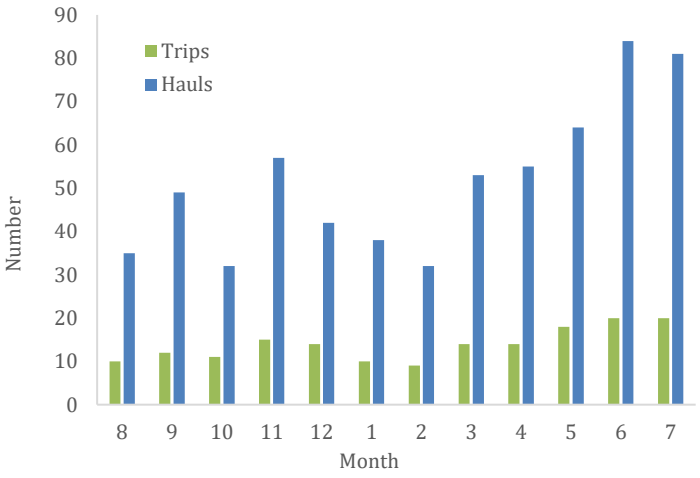
Because the Maximized Retention program is targeted for high-volume vessels which typically fish for longer multi-day trips, GMRI, in collaboration with automatic analysis technology provider, CVision AI, is working to develop activity recognition algorithms that will reduce the cost of data collection, streamline data transmission, minimize storage costs and incorporate automation into video review. We have begun the development, training and implementation of activity recognition algorithms on vessels in the Maximized Retention program. Algorithms focus on identifying important fishing activities including net handling, catch sorting, loading the fish hold, offloading, and discarding.

Activity recognition algorithms have the potential to substantially reduce data collection and processing costs for existing and future EM programs. Machine learning algorithms developed using video images and sensor data, and trained via operational

data sets of reviewer annotations, are capable of automatically determining video containing fishing activity, therefore assisting the video review processes by indicating important video for analysis. While current algorithms are in the development and training stage, future applications could reduce review time by reducing or removing the initial review process in which reviewers break up the trip into important periods of activity. Additionally, because there is a direct relationship between the amount of video collected on-board and total program costs, if activity recognition algorithms are applied prior to data transmission from the vessel, they have the potential to significantly impact costs by reducing the amount or quality of non-critical EM video transmitted and stored.

Objective 3: Monitor 150-200 NE Multispecies trips

To date, 3 vessels are participating in the MREM program. Although the Maximized Retention program is targeted for high-volume vessels, current participants land in the order of 10,000 lbs or fewer per trip, rather than the targeted 50,000 lbs or more. Despite this, these vessels have been active participants and provided critical data to demonstrate the feasibility of the maximized retention theory, test wireless data transmission and trial next-generation EM technology.



by MREM vessels each month

Between August 1, 2018 and July 31, 2019 a total of 167 trips were conducted by 3 vessels participating in the Maximized Retention program. Of these, 166 of were able to be reviewed. Vessels made a total of 622 hauls, with effort peaking in June 2019. On average, vessels conducted 4 hauls per trip and 14 trips per month.

Figure 5: Maximized Retention effort, shown as total number of trips and hauls

Objective 5: Results of primary EM Review

Vessels participating in the Maximized Retention program are subject to the following catch-handling and EM rules.

Catch Handling Rules:

1. The following species must be retained: American plaice flounder, Atlantic Cod, Haddock, Pollock, Redfish, Red Hake, White Hake, Winter flounder, Witch flounder, Yellowtail flounder.
2. All discarded species must be discarded within view of a camera
3. Vessels are required to retain and land all allocated groundfish species, including undersized fish.
4. All discards of non-allocated groundfish species must occur at discard control points
5. One Halibut of legal size may be kept per trip. All other Halibut must be discarded in camera view.

EM rules:

1. Cameras must run on 100% of groundfish trips for 100% of the trip. The EM system must be fully functioning before the vessel leaves the dock.
2. Captains should maintain their EM system as they would other on-board electronics. In addition:
    a. Cameras must be kept clean
    b. Camera views may not be obstructed by any person, gear, equipment or other items aboard the vessel
3. Captains are expected to monitor their EM system while at sea and report any system malfunctions at the time of notice.

Maximized Retention video analysts review video for deviations from these rules and annotate all instances of allocated species discards or EM system malfunctions on a haul-by-haul basis. EM systems malfunction annotation results are described under Objective 3. The following results detail allocated species discards annotated by primary video review during the period of August 1, 2018 to July 31, 2019.

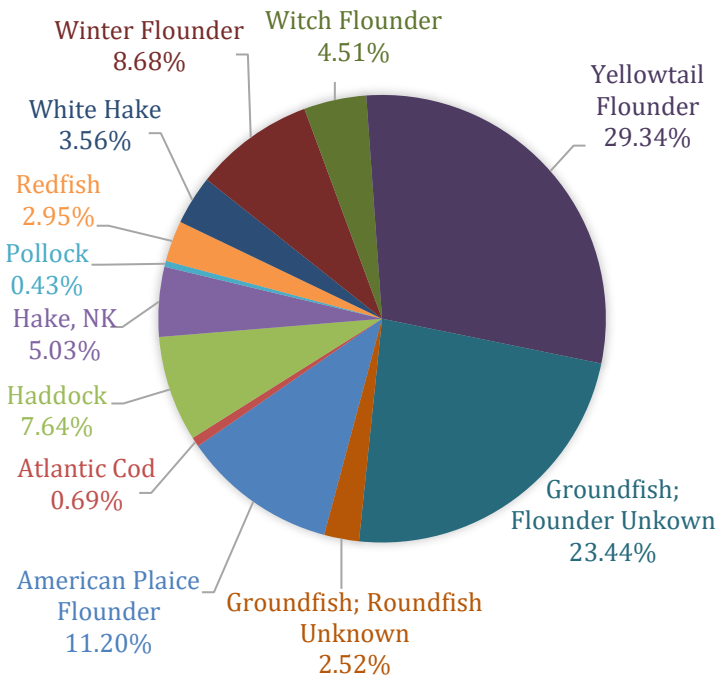


Figure 6: Composition of allocated species discards for all MREM trips 08/01/18-07/31/19

Because discarding of allocated species is not allowed under Maximized Retention protocols, few species discards are annotated by reviewers. Most often, discards that are recorded are accidental discards of single fish or fish that wash overboard singly or in aggregate during catch sorting practices. Maximized Retention reviewers adhere to the species identification standards in the NOAA Fisheries Electronic Monitoring Video Review Protocols for Multispecies Sector Trips and

use 2 or more identification characteristics to determine the species of each discard. No lengths or weights are taken in the MREM program. Discards are therefore accounted for as fish counts.

In the 166 reviewed MREM trips between 08/01/18 and 07/31/19, 1,152 individual allocated groundfish were discarded. Flounder species were most commonly discarded, constituting 77% of annotated discards (Figure 6). Of these, Yellowtail flounder was the most frequently discarded at 29.34% of allocated species discards. Discards in the "Groundfish; Flounder Unknown" category could be identified as a right-eyed flounder but could not be identified to species based on identification standards. Round groundfish species are more distinctive from each other and are less commonly discarded during MREM trips. Therefore "Groundfish; Roundfish Unknown"

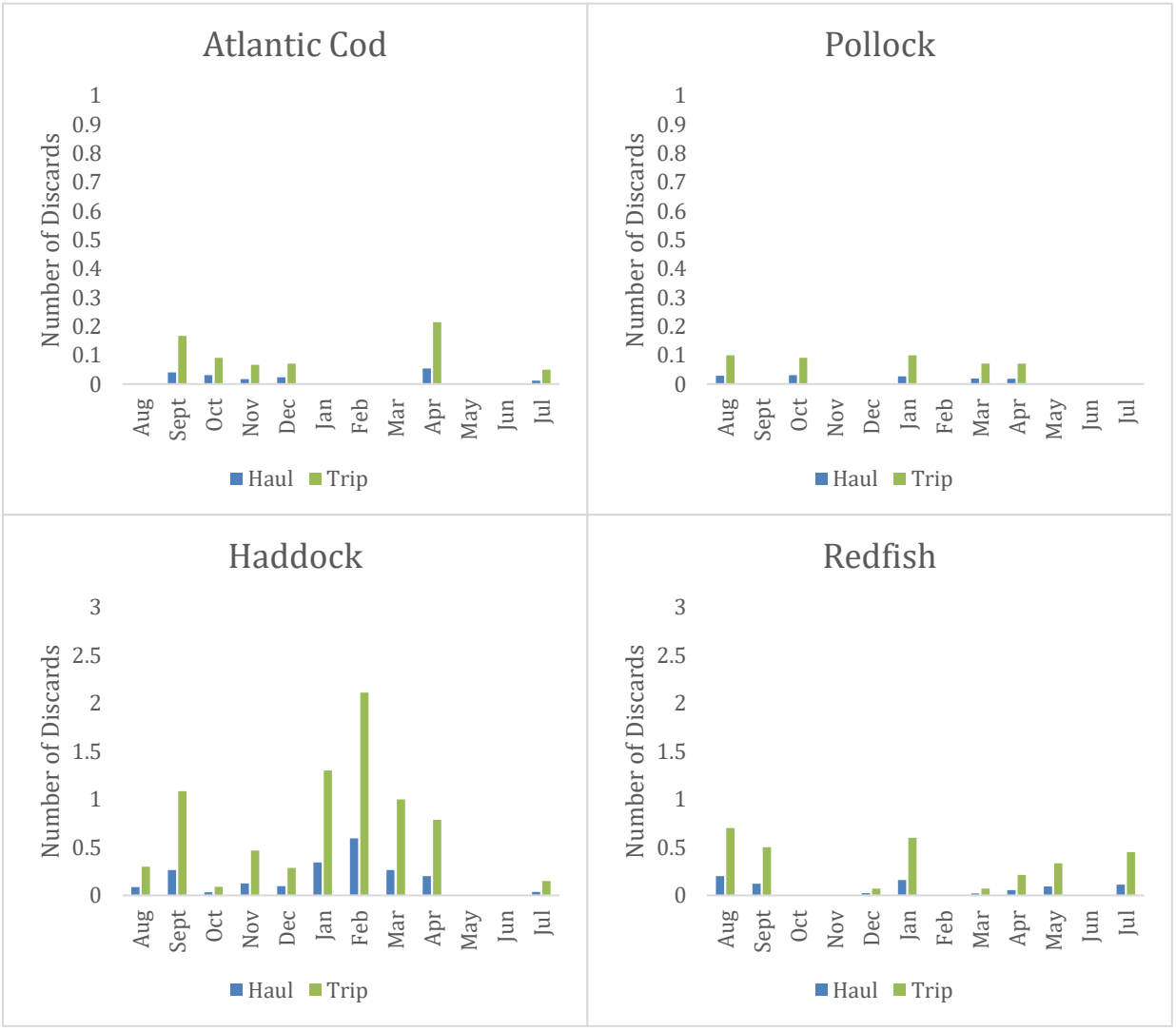


Figure 7: Monthly discard rates of Atlantic Cod, Pollock, Haddock, and Redfish

only constitute 2.5% of annotated discards. Haddock was the most frequently discarded roundfish species at 7.6% of all annotated discards.

On a per-trip level, discard rates of allocated species are low. For all allocated species, the mean discard rate per trip for the period of 08/01/18-07/31/19 was 6.3 ±7.3 fish.

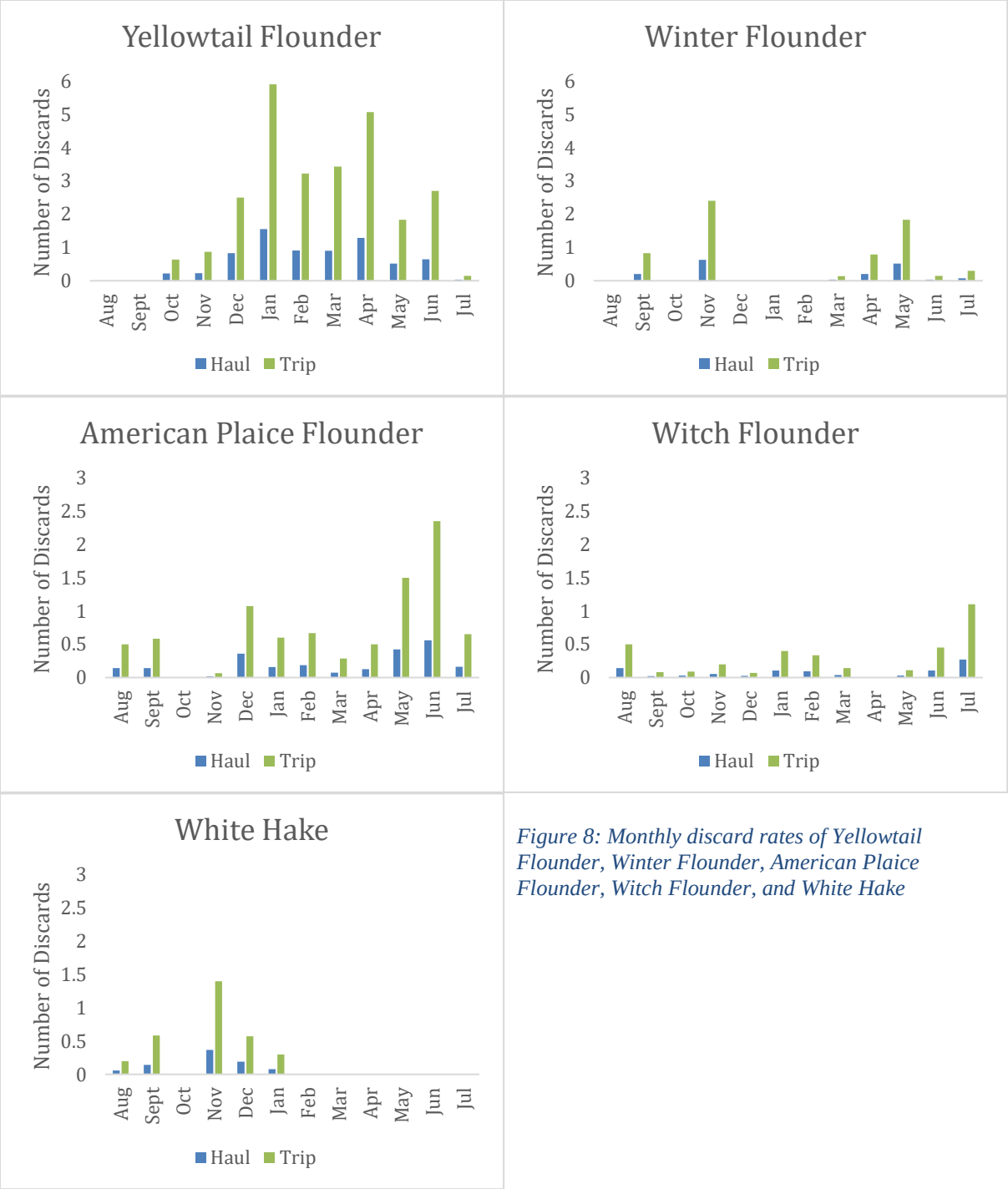


Figure 8: Monthly discard rates of Yellowtail Flounder, Winter Flounder, American Plaice Flounder, Witch Flounder, and White Hake

Per species, monthly discard rates did not exceed 6 fish per trip or 2 fish per haul for any single allocated groundfish species (Figures 7 and 8).

Summary:

In the past year of MREM program execution, we have developed catch handling and review protocols, resolved initial challenges to program execution, and established data management infrastructure and protocols. We have demonstrated the feasibility of the Maximized Retention theory on 3 vessels that have conducted over 160 Maximized Retention trips, which has allowed GMRI, GARFO, the NEFSC and EM providers to begin to develop and evaluate program standards and the framework within which to operate a Maximized Retention Electronic Monitoring program. We have created and implemented vessel monitoring plans, protocols for video analysis, attained all necessary state and federal permits, and collaborated with the NEFSC in the formation of their complimentary dockside monitoring protocol. With our current EM provider, Integrated Monitoring, we have optimized EM system design for participating vessels, developed cellular data transmission, created open source video review software, and successfully implemented the pipeline for EM data submission to the Greater Atlantic Regional Fisheries Office. MREM program reviewers have successfully reviewed 166 trips. Finally, in collaboration with EM and automation providers we have begun the development, training and implementation of activity recognition algorithms that could reduce the cost of data collection, streamline data transmission, minimize storage costs and incorporate automation into video review.

However, due the landing profiles of participating vessels (under 10,000 lbs per trip), and the small number of participating vessels, we are left with additional questions that must be answered in order to fully understand and identify solutions to the challenges of operating a Maximized Retention program on offshore vessels landing upwards of 50,000 lbs per trip. These questions include; “How must on-board catch handling and dockside monitoring protocols be adjusted to accommodate fishing operations on high-volume vessels?”, “What constitutes compliance in a Maximized Retention EM program?” and “What additional structure and policies are needed by the Agency, industry and EM providers to support implementation of a Maximized Retention program?”. Therefore, going forward, this program is focused on scaling to include a greater number of participating vessels, targeting the addition of offshore, high-volume vessels to the program, and the continued development of the appropriate performance standards, regulations and infrastructure to support a Maximized Retention electronic monitoring program in the NE Multispecies fishery.

Specifically, goals for the next program year are listed below.

Year 2 Goals:

1. Scale the MREM program to include 4-8 vessels, focusing on the recruitment of high-volume vessels.

2. Develop and test MREM protocols for high volume vessels that allow for required data collection and are acceptable to all stakeholders
3. Addressing the specific questions identified in the NOAA Regional Electronic Implementation Plan as they relate to a maximized retention-based EM model including:
    a. *What are the detailed roles and responsibilities of the various parties involved?*
    b. *How much will it cost the government and the industry*
4. Working with partners to develop and package consensus recommendations for implementing maximized retention-based EM
5. Develop, test and evaluate activity recognition algorithms, trained via operational data sets.
6. Explore the ability for EM to assist in the collection of non-biological in the current DSM program