Implementing and Improving Electronic Reporting and Monitoring in New England Fisheries

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Executive Summary

This document reports on an independent examination of the work done, and that remains to be done, to implement Electronic Reporting (ER) and Electronic Monitoring (EM) technologies into the commercial fisheries of New England. This project was led by Prof Steve Kennelly from IC Independent Consulting as an independent expert from outside the region, with Mark Hager, who leads the Gulf of Maine Research Institute's EM efforts, providing regional expertise. This project examined a host of documents and interviewed over 80 people throughout the New England region, including fisheries managers, scientists, fishermen (here we use the region's convention of a masculine gender for this term) and their representatives, staff and members of the New England Fisheries Management Council, state fisheries staff and an academic. We also assembled a Project Oversight Group of key stakeholders to liaise with during the project.

Electronic Reporting means the reporting of information about fishing activities (locations, times, catches, bycatches including discards, interactions with protected species, etc.) by fishermen using some sort of electronic means – as compared to paper-based reporting using logbooks (or, as they are known in New England, Vessel Trip Reports – VTRs). In New England, ER mostly refers to the submission of VTRs by electronic means (eVTRs). There are 6 approved eVTR applications used in the region with over 85% of data collected by them coming from the NEFSC's Fisheries Logbook and Data Recording Software (FLDRS) system. This system was designed to capture data to complement observer data and to enhance the use of fishermen's data in management, assessments and other studies. But, by default, because of its history and advanced level of use, it has become the main tool used for ER in the region.

Electronic Monitoring refers to the use of cameras and other sensors onboard vessels to record similar types of information about fishing activities as mentioned above for ER. It is commonly used as a means to validate self-reported data from fishermen. Two models for its implementation are currently being examined for regulated groundfish species in New England: an audit model which involves viewing a random subset of video to validate (ie make more accountable) the data reported by fishermen using logbooks, and a maximum retention model which involves having vessels retain all fish of certain species which is recorded by a dockside monitor when landed, with cameras used on the vessel to verify that no discards occurred at sea.

In synthesizing all the information gathered during the project, we firstly categorized the various issues identified as those that are facilitating or impeding the implementation of ER and EM, respectively. From these many positive and negative issues, several consistent themes emerged which form the basis of this report and the associated recommendations.

Firstly we noted that, in New England, like elsewhere, most stakeholders were quite accepting of the eVTR system as a replacement for paper-based VTRs. The obvious advantages of such a system, in addition to society's general trend towards paperless processes, mean that most fishermen, managers and scientists have few negative concerns with this form of reporting – the main exception being those few fishermen who are uncomfortable with computers in general.

But we concluded that what is required is a simpler, easier-to-use system than those currently available - whose software can accommodate all fishing methods but be able to be used on a variety of platforms - such as tablets, smartphones and laptop computers. This would allow for New England's diverse fisheries to choose what works best for them and to use current equipment already aboard if they wish. Such a system should use WIFI technology (at the dock), cellular networks (when in range) and/or even satellite uploading (when not in range) to transmit data in close to real time. This should allow quick calculations of quotas and feedback to fishermen, so they can adjust their holdings and operations accordingly.

Ideally, the development, implementation and routine use by fishermen and government agencies of such a system would have been the first step in a strategic, longer-term and staged approach to achieve the ultimate goal of a modern way to monitor fisheries in New England: **one that incorporates eVTRs, VMSs and EM cameras (the latter used as a validation tool for compliance) into one paperless, close-to-real time reporting system**. That is, it would have been more effective if efforts in New England concentrated on firstly developing a simple ER system and allowing a period of time for not only debugging and to get fishermen familiar with the system, but also for fisheries management agencies, scientists and government-based data handling systems to adjust their processes to be able to deal with the information. Then, after such a period, when all stakeholders are comfortable with the system, should have come the next (more difficult and controversial) step involving the validation of the data collected using EM cameras. But we cannot turn back time and there have been sufficient advances in recent years in EM to warrant its continued development and use in the region. Indeed, the many issues regarding EM implementation that have arisen out of the numerous projects done and/or underway provides significant momentum and an excellent platform on which to build a good EM system that eventually will be able to validate the data coming from a full ER system and so achieve the ultimate goal mentioned above in **bold**.

To achieve this end, we considered the various issues we identified regarding EM in the following categories: Technology, Leadership and Planning, Program Design, Incentives and Costs, Privacy Concerns, Education and Outreach, and Choke Species Reporting. From this analysis, we identified a series of steps that should, if adopted, eventually lead to a modern, technologically-based monitoring and reporting system for the region's fisheries within the next 5 years (noting that projecting a longer time-frame in such a rapidly advancing technological field is inappropriate).

1. The first step should be to identify and establish (as soon as possible) a lead group to strategically plan and implement ER and EM in the region, run by the federal government (NOAA) and their main end-users of the information - fisheries managers, stock assessment scientists, protected species scientists and compliance officers. The group should also include fishing industry representatives, sector managers, state governments, technical experts and NGOs.
2. Next, this group should facilitate, within the next year or so, the development of a simplified, easy-to-use, ER system.

3. While this system is being built, GARFO and NEFSC should try to adjust their data-handling and analytical processes to accommodate the data streams provided from such a system.
4. Implement this ER system throughout the region, noting that some exceptions using paper-based VTRs will be required for those fishermen uncomfortable with the technology.
5. While Steps 2, 3 and 4 are occurring (i.e., over the next 1-3 years), continue the development of both the audit-based and maximum retention-based EM systems currently being pursued where: the audit system should focus on requiring a modest amount of video review and be fine-tuned for use on as many gear types as possible; and the maximum retention system should become more of an "optimal retention" system for use in those situations where EM has particular difficulty in validating ER data.
6. Continue to resolve other key issues with EM implementation, especially those concerned with privacy and choke species.
7. Continue to encourage the development of other, more longer-term improvements in EM systems (i.e., at a 3-4 year horizon) - including the automation of video review and the streamlining of data transmission and storage – while engaging with other regions and countries who are doing the same.
8. Once the work under Step 4 (ER implementation) has become routine for fishermen and government agencies, begin the rollout of the EM systems developed under Step 5, incorporating solutions from Step 6 and, if available, those developed in Step 7.
9. Link the ER and EM systems that should now be occurring into one ongoing system that should be flexible enough to incorporate additional technological innovations as they occur.
10. While all the above is occurring, a dedicated outreach and education program about ER and EM is required to gain support and ownership of the system by all stakeholders in the region.

Background and Conduct of this Project

This document reports on an independent examination of the work done, and that remains to be done, to implement state-of-the-art Electronic Reporting (commonly abbreviated as "ER") and Electronic Monitoring (using cameras – commonly abbreviated as "EM") into the commercial fisheries of New England - in particular the groundfish fisheries of the region. It is the main deliverable from a project funded by the National Fish and Wildlife Foundation (NFWF) who has funded a significant number of projects concerning ER and EM in the region and is looking for a way forward for future investment in this area.

The main objectives of this project were to deliver: (i) an independent review and synthesis of past and present work in this field, (ii) current and future stakeholder needs for such data in New England, and so provide (iii) a roadmap to achieve a technologically-based fisheries data collection system for the fisheries of the region.

It should be noted that this project differs (in its funding source, scope and objectives) from the current Fishery Dependent Data Modernization effort being led by NOAA in the region. So, whilst our observations and conclusions may prove useful to that larger effort, our project has not been designed to specifically inform that work.

Early in this project we established a Project "Oversight Group" of key stakeholders in the region, with whom we could liaise about the project, its conduct, progress and key findings. This group was comprised of representatives from the New England Fisheries Management Council (NEFMC), the Greater Atlantic Regional Fisheries Office (GARFO), the Northeast Fisheries Science Center (NEFSC), the Maine Coast Fishermen's Association, the Nature Conservancy and the Commercial Fisheries Research Foundation (CFRF).

The first stage of this project involved the collection, examination and preliminary analysis (through desktop review) of all relevant material that could be obtained up-front. In particular, we briefly summarized recent work done in the field of ER and EM throughout the world and the 24 initiatives that have been focused in New England. An Inception Report was prepared in November 2017 that summarized this material, provided preliminary findings and a methodology detailing subsequent stages of the project. This report was shared with the Oversight Group whose feedback was incorporated. Included in this final report in Appendix 1 is our summary of the various ER and EM projects run in New England.

The next stage of this project was the main fact-finding step which involved an intensive period of interviews and meetings in New England with as many relevant stakeholders as possible during November and December 2017. These meetings were held in meeting rooms, offices, people's homes, coffee shops, on boats and docks throughout Maine, New Hampshire, Massachusetts and Rhode Island. Several phone hook-ups with people were also held while in the US and back in Australia.

Over 80 people were personally interviewed for this review, most in person, some in groups and only a few by phone. Some people were interviewed more than once. Some did not care about anonymity, others asked for complete anonymity, and others asked that their comments remain anonymous. So, to respect those latter wishes, and for the sake of uniformity, we do not provide any names in this report. However, the affiliations of those people interviewed were: 21 Fishermen (in this report we use New England's convention of a masculine gender for this term), 10 representatives from Fishermen's Associations, 23 staff from the Northeast Fisheries Science Center (NEFSC), 10 staff from GARFO, 7 Electronic Monitoring providers and technicians, 5 NGO representatives, 4 New England Fisheries Management Council staff and/or members, a Massachusetts state government representative and an academic.

All information collected was then synthesised and drafted into a draft final report, which we shared with the Oversight Group who provided comments which were incorporated as appropriate. We then provided presentations about our findings to the January NEFMC meeting, to GARFO and to the NEFSC. Additional information was provided to us at these meetings and incorporated into this final report.

During the course of this project, several themes emerged that gradually became regular in their occurrence and led us to be quite confident that we were getting a reasonably accurate impression of key issues. These issues form the basis of this report and its recommendations.

Introductory Comments

When introducing a project about fisheries monitoring and reporting, it is useful to first remind ourselves why we monitor the catches, bycatches (including discards) and protected species interactions involved with fishing activities. And the answer is two-fold. Firstly, we monitor these things because the natural resources involved are publicly-owned and managed by governments on behalf of that public. And, as for the proper stewardship of any property, it is appropriate that the owners of that property are provided with reports of its status and sustainability. Secondly, we monitor these things because it is logical that their stewardship and management should rely on information that comes from those who are most familiar with them – ie. the people who engage (at the most intimate level) with fisheries stocks every day - fishermen.

Fisheries management (at its most basic level) involves the interplay between our current generation's need to exploit seafood and humanity's need to do so sustainably or, in other words, forever. And perhaps the most famous (or infamous, depending on one's point of view) example of this interplay concerns the fisheries of the New England region of the USA.

The management of fisheries in New England is, without doubt, one of the world's most complex, having evolved over centuries under a unique array of influences including: a wide variety of fishing vessels and methods; a high diversity of species, some of which have booms and busts; significant public scrutiny and media attention; politics; litigation; and a rich and colourful 400-year history. There are also a host of entities involved in this landscape including commercial and

recreational fishermen, fishing industry associations, government-based federal and state agencies, fisheries managers, scientists, Management Councils, Fishing Sectors, universities, funding bodies, NGOs and politicians.

The monitoring of stocks and fisheries amongst all this complexity has not been without its challenges over a long period of time. Indeed, it is true to say that the New England region in the United States has seen the development and implementation of some of the first and most sophisticated fisheries monitoring programs in the world - its lengthy history of fisheries-independent surveys and observer programs providing among some of the largest and best sets of fisheries-related data anywhere. And of particular relevance to this project, the region is also among the pioneers for developing what many see as the next generation of fisheries monitoring tools – those involving technologies used in ER and EM. Like many other parts of the world, however, the actual implementation of such technologies into mainstream data collection systems has not been as rapid or as complete as many stakeholders (including some in the fishing industry itself) would wish. And this project tries to address this issue and so provide a way forward for its resolution.

The remainder of this report divides the various issues identified during this project into those concerned with the reasons for and against the implementation of ER and EM in New England, followed by a discussion of these issues and the development of a recommended pathway forward in how to proceed.

Electronic Reporting (ER)

In the field of fisheries monitoring and reporting, Electronic Reporting (ER) basically means the reporting of information about fishing activities (locations, times, catches, bycatches including discards, interactions with protected species, etc.) by fishermen using some sort of electronic means – as compared to paper-based reporting using logbooks (or, as they are known in New England, Vessel Trip Reports – VTRs). In New England, ER mostly refers to the submission of VTRs by electronic means (eVTRs). There are 6 approved eVTR applications in use across various fisheries New England (approx. 150 vessels across all fisheries). These are:

1. NOAA's Fisheries Logbook and Data Recording Software (FLDRS)
2. The Standard Atlantic Fisheries Information (SAFIS) eTrips Mobile (soon to be made mandatory in the Mid-Atlantic Charter fishery),
3. Electric Edge's Fishing Activity & Catch Tracking System (FACTS™),
4. Ecotrust Canada's Electronic Logbook (Elog),
5. Olrac's Dynamic Data Logger (DDL), and
6. NOAA's Fish Online.

The vast majority (over 85%) of data up to the present time from these 6 systems has come from the NEFSC's Fisheries Logbook and Data Recording Software (FLDRS) system. This system was originally designed to capture data to complement observer data, as a means of enhancing the use

of fishermen's information in management and assessments, and to support other studies. It involves fishermen recording data onto laptops (mostly supplied by NOAA and kept in their wheelhouses) which is later transmitted to NOAA – mostly via memory sticks (which are posted or collected by NOAA staff) or, more recently in some locations, by WIFI or by VMS. By default, because of its history and advanced level of use, the FLDRS system has become the main tool used for eVTR in the region.

Issues Facilitating Implementation

During this project, we identified several advantages for using ER technology which have assisted in its gradual (though by no means complete) uptake in the region:

- Firstly, the use of eVTRs is seen by many as a naturally-occurring societal trend – where more-and more aspects of day-to-day modern life are becoming paperless due to the speed, costs and environmental savings associated with avoiding paper-based transactions;
- Indeed, that subset of New England fishermen using these systems feel it is just easier than the paper version;
- eVTR systems are more efficient and quicker in data-delivery than the paper-based system by:
    - removing the need for data entry staff,
    - avoiding double-handling of data and associated entry errors; and
    - avoiding ambiguity caused by interpreting a diversity of hand-writing styles.
- ER has the potential to allow automated quality assurance and control capability where obvious errors can be flagged at the point of data entry;
- In New England's Sector-based fisheries management system, the use of eVTR data potentially provides a rapid way to determine quota allocations for fishermen so that they can adjust their quota holdings and/or fishing practices accordingly;
- It also has utility in providing the information required for current and future initiatives concerning the traceability and eco-labelling of seafood; and
- It is consistent with the NEFSC's Strategic Science Plan 2016-2021 which has several themes, foci and targets involving the fishing industry providing scientific information needed to manage fisheries.

Issues Impeding Implementation

With the above advantages of such a system, we were somewhat surprised that, currently, only a minority of fishermen in New England use this system to report their activities. The following is a summary of the issues we identified that seem to be hampering its more widespread adoption:

- Firstly, the eVTR system mostly used in New England (the FLDRS system) is provided by NOAA who supply and install a laptop with FLDRS software on each vessel, provide training in the FLDRS system, retrieve the data and provide ongoing support. This all costs significant resources and, to date, there has only been sufficient funds to provide a relative small subset of fishermen with the technology;

- The FLDRS user platform is considered to be not as easy to use at it could be (at least in comparison, for example, to the tablet-based eTrips mobile App) – especially on smaller boats and for some fishing methods where the need to run back and forth from the wheelhouse to access the laptop is problematic. We do note, however that the NEFSC is in the process of updating FLDRS which may assist in this regard;
- In many locations, the data transmission system is outdated (although we are advised that some new initiatives in this area are currently underway), relying on transfer via memory sticks, staff downloading the data personally, and/or captains taking laptops home to transfer data - rather than using WIFI dockside, cellular transmission when in range or satellite transmission when not;
- The age dynamics of some captains means that they are less comfortable with computers than others and are therefore not willing, or able, to use the technology;
- Many interviewees felt the discard data provided by their eVTRs, and paper VTR's for that matter, are not used in stock assessments as fully as they could be, so fishermen are less accepting of any new technology that purports to provide such information.
- NOAA confirms that there exists a requirement specific to vessels using EM that eVTRs must be completed on a haul-by-haul basis rather than at a subtrip level. This adds to fishermen's workloads and can interfere with fishing practices.

Electronic Monitoring (EM)

Electronic Monitoring is a relatively new term in fisheries and refers to the use of cameras and other sensors onboard vessels to record similar types of information about fishing activities as we mentioned previously for ER (ie. locations, times, catches, bycatches including discards, interactions with protected species, etc.). Throughout the world, a major use of EM is as a method to validate, and make more accountable, the information provided by fishermen in their (paper or electronic) logbooks. Whilst some believe that, eventually, EM systems may be able to do all fisheries monitoring and replace the need for observers and fishermen's self-reported data, the economics associated with video review and the sophistication of the existing technology to achieve this is still some years away.

In New England, two models for its implementation are currently being examined for regulated groundfish species: an audit model and a maximum retention model.

The audit model for EM is the most commonly used application of EM throughout the world and basically involves viewing a random subset of video and/or still photography to validate the data reported by fishermen on logbooks (in New England this would be using VTRs or eVTRs). The experience elsewhere suggests that such an audit system greatly improves the quality (in accuracy and precision) of self-reported data from fishermen.

The maximum retention model for EM involves having vessels retain all fish from certain species no matter their size which is examined and recorded by a dockside monitor when landed. Cameras

are used on the vessel to verify that no groundfish discards occurred at sea. The program being explored mandates retention of all 13 groundfish species allocated under the Multispecies FMP.

Issues Facilitating Implementation

During this project, we identified many advantages associated with using EM in New England's fisheries, many of which are common to any such application throughout the world:

- Firstly, throughout the world, a major reason given for using EM (especially as an audit tool where a fraction of video is examined) is that, intuitively, it should cost less to use cameras than paying human observers to collect similar information - noting that cameras will never replace all functions of an observer such as taking biological samples, interacting with fishermen, etc..
- It also removes other concerns regarding the use of human observers such as:
    - Safety concerns for the observer, crew and vessel where carrying an extra person unfamiliar with a vessel can compromise safe work practices;
    - Crowding onboard; and
    - The need to have additional accommodations, equipment and victualling on board.
- It also has the potential to reduce the need for fishermen (and NOAA staff) to have to deal with the Pre-Trip Notification System (PTNS) (at least for those trips where EM replaces ASM observers) and the various logistics associated with allocating, deploying, meeting, loading and delivering observers.
- Under any fisheries management regime that employs the precautionary principle, lower quotas are usually set when there exists higher uncertainty around the information available for stock assessments. EM has the potential to reduce this uncertainty by being able to cover greater spatial and temporal scales than human-based observer programs.
- Similarly, EM systems, when used throughout an entire fishery, can greatly increase the overall **quantity** of data available about rare events at sea such as interactions with protected species.
- Using EM systems that are run on 100% of trips eliminates any observer bias occurring on the vessels participating. This is when fishermen alter fishing practices when an observer is present and was believed by most people interviewed in this project to be quite commonplace in some parts of New England.
- Camera images can provide (if required) a potentially permanent record of events on a vessel compared to the memory of a human observer.
- EM systems can also provide multiple "sets of eyes" (and angles of view) on a vessel by having multiple cameras positioned as required and operating simultaneously, whilst human observers can only see one part of a vessel at a time. Such systems also permit additional cameras to be installed and monitored by captains – to examine issues such as problems in the engine room, etc.
- Camera images cannot be easily modified or misinterpreted. This is not only important for scientific and compliance purposes but is also important for verifying observations from

fishermen - which have traditionally been viewed as inaccurate, unsubstantiated or anecdotal.

- In some places in New England, a major reason fishermen have taken on EM systems is related to them being permitted access to fish in certain areas that are closed to others during pilot projects.
- Also, in some places in these pilots, fishermen with EM systems gain regulatory flexibility to fish multiple gear types on the same trip that are not permitted to the general fleet.
- In some sectors in New England, the use of EM in various pilot projects also allows fishermen to have individual discards applied to their quotas rather than a sector-wide allocation derived from observer-based monitoring using At Sea Monitors.
- Furthermore, many fishermen involved in EM projects see it as an inarguable way to prove their (previously considered unsubstantiated) claims of higher biomasses of certain species (especially Gulf of Maine cod) than is being estimated in stock assessments. In general, many fishermen noted that they felt more confidence and greater ownership of EM information than observer-collected data.
- The general rate of improvement in technology throughout the world suggests that EM systems will only get better, more efficient, quicker and cheaper, whereas the efficiency of human-based observer programs will likely remain static and probably increase in costs as wages increase.
- Usually the costliest aspect of EM systems involves the human-based review of video. This is why the two above-mentioned approaches, involving either a fraction of video being reviewed or video review occurring at very high speeds to verify fishermen-reported data, is so attractive. But it seems that even this human-based review may soon become obsolete as its automation through machine learning applications is developing rapidly.
- As for ER, EM has significant utility in meeting the transparency requirements of current and future initiatives concerning the traceability and "eco-labelling" of seafood.
- Finally, as for ER, EM is consistent with the NEFSC's Strategic Science Plan 2016-2021 which has several themes, foci and targets that involve the fishing industry providing the scientific information required to manage fisheries.

Issues Impeding Implementation

Whilst the above list of positives is impressive, and suggests that implementing EM should be quite straightforward, we identified a host of issues in New England that are currently hampering such implementation:

- As for any species-specific, quota-management system that involves multi-species fishing methods, it is inevitable that there will be problems associated with the capture, discarding and/or high grading of species with low quotas (so-called "choke" species). And we were told by most people interviewed that a major impediment to the widespread use of EM in certain parts of New England concerns the video recording of the discarding of such "choke" species. That is, it is well known that, when fishing for species for which they have high quota allocations, many fishermen will discard species for which they have relatively low quotas (currently these mainly involve Gulf of Maine cod, but also include yellowtail

flounder and American Plaice) instead of retaining them (as required by regulations) and have them count against their quotas. If they did the latter, these low quotas would quickly become exhausted and therefore stop fishing for the year. When human observers are on board, it is widely believed that fishermen will fish atypically to avoid such stocks, causing significant observer bias and compromising the data from such trips.

If, however, cameras were used throughout the fishery in place of observers, the catch and discard of such choke species would be recorded and could lead to penalties. Or, if fishermen retained such species (as required), their quotas for them would quickly become exhausted, effectively stopping them fishing for the targeted species.

- The second most common problem concerning EM mentioned by the fishing industry involves basic privacy concerns where fishermen are reluctant to have their personally owned vessel (and place of work) constantly under surveillance – whether or not they do anything illegal.
- A third key issue concerns costs. The full costs of human-based observer programs in New England is currently not incurred by the fishing industry because the programs are subsidized by government. This means that any cost incentive to industry in using EM as an alternative (the most common reason for replacing human observers with EM) is not apparent in the region. This situation may change, however, as we were advised by industry and the Council that a greater proportion of the costs of observer programs may be levied from industry.
- The above issue about relative costs is also affected by the fact that it is currently quite difficult to accurately quantify the true comparative costs of the observer programs in New England and a potential EM system. Indeed, the only study currently available to quantify such costs suggests EM is more expensive than human observers – intuitively an opposite result to that expected, and found elsewhere. Related to this issue is a current lack of clarity concerning the eventual structure of such an EM system – especially with respect to the percentage of video review that will be required under an audit-type system (the costliest component of EM).
- Some fishermen, especially those without choke species problems and who have large vessels that can easily accommodate observers, are comfortable with the current system involving only 16% observer coverage rather than the potential 100% monitoring that would occur using EM.
- Currently, both an audit model approach and a maximized retention approach to EM are being pursued in New England. And even with these two options, there remain some sectors of the industry that do not see an option that works for their particular operation(s). This is cited as a reason for not participating in either.
- Another issue concerns a general lack of understanding about EM in the region. Without sufficient information about what EM can and cannot do, it is difficult for fishermen, scientists and managers to form a meaningful opinion about it.
- Another key issue noted by several stakeholders is that there appears to be an inconsistent or unclear message from government regarding the implementation of EM in New England. That is, fisheries managers and compliance staff at GARFO seem very supportive

of the tool as a method to improve the data provided by fishermen on their VTRs or eVTRs and to facilitate quota allocations. But the NEFSC has concerns related to EM as a provider of scientific data for stock assessments, citing issues like:

- Inaccuracies concerning species identifications (eg. red versus white hake), estimated weights and individual length information using cameras;
- Problems with estimating catches and discards using cameras in high volume, mixed species fisheries involving methods like bottom trawling;
- EM's inability to provide biological samples such as otoliths, tissues, etc; and
- A difficulty to incorporate EM data into existing data streams and analyses which have been designed for observer data.

It should be noted that such comments mostly came from people not directly involved in stock assessment work - we were only able to interview one Population Dynamics scientist at NEFSC (who actually seemed quite supportive of the technology when briefed as to its capabilities) despite numerous unsuccessful approaches to other staff in the group.

- An effect of the perceived non-use of EM data by NEFSC is an increase in the frustrations felt by fishermen who use the technology - who hope that their data will be included in stock assessments.
- There also appears to be some lack of collaboration and coordination between the main ER application (run by NOAA) and EM projects (mostly run by non-government agencies). This, like other issues, is symptomatic of the apparent lack of an overall strategy for modernizing fisheries monitoring in the region. We do acknowledge, however, the existence of the Data Visioning Project which is meant to address such issues.
- The most developed EM project in New England (the audit approach) mainly focuses on small boats (it not designed for larger vessels). Larger vessels (that catch the majority of fish) are being examined in the maximum retention project which has a much smaller number of vessels participating, thus hampering a more widespread application of the technology throughout this fleet.
- Currently in the audit model project, weights of discards are not directly measured due to scale sensors not being used and a technical difficulty with cameras recording digital readings from scales. Consequently, fishermen are required to identify, count and lay all discarded groundfish (with some exceptions for subsampling) on a measuring strip in front of a camera so that lengths can later be determined by a technician in the lab. These data are then used with a length-weight key to estimate total weights. This is a very indirect method that is also costly and time-consuming for fishermen – as well as for the technicians onshore. And it probably provides less precise estimates of weights than direct measurements onboard.
- Most EM systems rely on video information being transferred via the physical removal of hard-drives (simply due to the size of the files involved) rather than via WIFI, cellular or satellite.

- There are also some (more minor) concerns regarding the robustness of the equipment used in the various EM projects where occasional breakdowns (in hardware and software) have occurred.
- There are also national issues such as data storage policies, legal custody and/or ownership of video, etc. which are delaying the implementation of EM systems throughout the country.
- With regard to the latter issue concerning video ownership, fishermen are concerned that footage from onboard cameras may be used in media campaigns by environmental groups – especially those concerning protected species interactions - even if the numbers of such interactions fall well below allowable levels.
- Finally, whilst there have been significant steps recently in image recognition work to facilitate video review automation (which should greatly reduce the costs of EM systems), the machine learning software involved requires libraries of tens of thousands of images of fish (currently being collected by the NEFSC's Bigelow and other projects). This means that the development of such automation will involve an initial slow period after which progress should occur quite rapidly as more images are collected.

Discussion

Before discussing the issues regarding ER and EM in New England and suggesting ways to resolve them, it is worth pointing out that the implementation of ER throughout the world has, in general, been much more straightforward than it has been for EM. That is, the acceptance by fishing industries and management agencies of electronic tools has increasingly occurred over the past few decades, such that it is now common to see echo sounders, fax machines, Vessel Monitoring Systems, laptops, tablets, phone apps, etc. used on many of the developed world's commercial fishing vessels. This is similar to (and probably no slower than) the infiltration of rapidly advancing technologies into most aspects of modern society. It is the next step, involving the use of onboard camera technologies instead of human observers that has been comparatively slow to become implemented – not just in New England but in most countries and fisheries where it has been attempted. And the reasons for this are listed above and discussed below.

Electronic Reporting

In New England we found that, like elsewhere, most stakeholders were quite accepting of the eVTR system as a replacement for paper-based VTRs (currently around 150 vessels use the technology across all fisheries). The obvious advantages of such a system (as detailed above), in addition to society's general trend towards paperless processes, mean that most fishermen, managers and scientists have few negative issues with this form of reporting – the main exception being those few fishermen who are uncomfortable with computers in general.

So the question is, why is a fully functioning eVTR system not in place and used by all (or even the majority of) fishermen in the region? We believe (as did many people interviewed) that the answer is a simple matter of resourcing the complete roll-out of an appropriate system. And by "appropriate", we do not necessarily mean the current main one used (FLDRS) which involves

laptops on board, with fisheries-specific software, memory sticks requiring postage and/or pickup and significant training and ongoing support. As mentioned, this system was not specifically designed for eVTR purposes – yet it has become, by default, and because of its excellent record, the main eVTR system used in the region.

Instead, we believe that what is required is a simpler, easier-to-use system whose software can accommodate all fishing methods but be able to be used on a variety of platforms - such as tablets, smartphones and laptop computers. This would allow for New England's diverse fisheries to choose what works best for them and to use current equipment already aboard if they want.

The development of such a system should lead to many more fishermen using the method (ie all those with a smartphone or tablet) instead of the current system where only a small subset of fishermen can be serviced by NEFSC and GARFO staff. And of course such a system should use WIFI technology (at the dock), cellular networks (when in range) and/or even satellite uploading (when not in range) to transmit data in close to real time. This should allow quick calculations of quotas and feedback to fishermen, so they can adjust their holdings and operations accordingly. It is worth noting that similar systems as this are being tested or used. In particular, CFRF is testing such a tool in a relatively small, single species fishery in New England, the charter boat sector is using the eTrip system, and we suggest that a great deal can be learned from those systems and others around the world when developing one for New England.

Ideally, the development, implementation and routine use by all fishermen and government agencies of such a system would have been the first step in a strategic, longer-term and staged approach to achieve the ultimate goal of a modern way to monitor fisheries in New England: **one that incorporates eVTRs, VMSs and EM cameras (the latter used as a validation tool) into one paperless, close-to-real time reporting system**.

That is, with the benefit of hindsight, it would have been more effective if efforts in New England concentrated on firstly developing a simple ER tool and allowing a period of time (a few years) for not only debugging and to get fishermen familiar with the system, but also for fisheries management agencies, scientists and government-based data handling systems to adjust their processes to be able to deal with the information. Then, after such a period, when all stakeholders are comfortable with the system, should have come the next (more difficult and controversial) step involving the validation of the data collected using EM cameras. We believe that such a staged approach would have been a better strategy, particularly in New England, where we know that the trust in, and implementation of, new systems takes a long time – not just for fishermen but also for government - and especially for scientists.

But such a staged (KIS – Keep it Simple) approach did not occur – instead we have the situation where non-government agencies are trying to develop and introduce EM systems on top of a government-run, partially-implemented ER system which, as noted above, requires simplification, modernisation and roll-out.

Electronic Monitoring

But we cannot turn back time, and there have been sufficient advances in recent years in EM development and use in New England to warrant its continued development there. Indeed, we believe that the many issues regarding EM implementation that have arisen out of the projects done and/or underway provides significant momentum and an excellent platform on which to build a good EM system that eventually will be able to validate the data coming from a full ER system and so achieve the ultimate goal mentioned above in **bold**. So, while the above ER system is developed and implemented, one should try to resolve as many of the problems identified for EM as possible, in anticipation of the time when it will be able to meld (hopefully) seamlessly with that ER system.

To achieve this, it is useful to discuss the various issues we identified about EM into the following (rather loose) categories: Technology, Leadership and Planning, Program Design, Incentives and Costs, Privacy Concerns, Education and Outreach, and Choke Species Reporting.

Technology

Technical issues regarding the use and implementation of EM in New England are probably the simplest to resolve and there is a great deal of effort occurring in the region and elsewhere to do just that. The first involves ensuring that the hardware and software installed on vessels are robust and as error-free as possible and we note that this is now mostly the case for the majority of systems used – ie. the usual teething problems associated with installing and running such technologies have mostly been resolved.

One unresolved issue, however, concerns the lack of weight information coming from EM (especially for discards). We believe that a scale-based sensor could be incorporated to provide such data (EM is not just about cameras but all types of electronic sensing) or else place a camera in front of the scale readout – rather the current cumbersome, costly, and probably quite imprecise, length-weight conversion process. Having said that, it is worth noting that individual length measurements of fish can be very useful to stock assessment scientists. Indeed, during our interviews, a population dynamics scientist was very interested in such data. But we think that this sort of data collection would be better achieved via a separate project, specifically designed for that purpose - rather than trying to retrofit the length data currently being obtained for weight estimation purposes into stock assessment modelling.

There are also additional technical issues with EM that we believe will, in time, be improved. These include video transfer using WIFI, cellular or satellite transmission instead of manual hard-drive pickups and/or postage, data storage using cloud technology instead of hard drives and servers, and machine-learned video review automation. And whilst developments in all these things will someday (probably quite soon) occur, when planning ahead, one should not ignore the need to strive for them nor anticipate their eventual availability.

Leadership and Planning

We have seen that the development of EM (and indeed ER) in New England has attracted many one-off projects over quite some time, funded and run by a variety of government and non-government entities. But this does not appear to have occurred according to any over-arching strategic plan - that is, perhaps, one reason for this current project. And one reason for the lack of such a strategy seems to have been a lack of clarity over which entity should lead such developments – possible candidates being the government, the NEFMC, fishing sectors, fishermen's associations and NGOs.

As we noted in the Introduction to this report, governments are accepted as being responsible for the stewardship of a nation's natural resources on behalf of the public and also (therefore) for monitoring and reporting on their status. If we accept that governments should accept such roles, it follows that they should also lead in improving such things – in this case by facilitating and encouraging the use of advances in available technology (noting that such technology is often developed and provided by non-government suppliers). One reason why this has not occurred in New England could be due to the inconsistent support one sees for such technologies from different government departments in the region – with fisheries management and compliance staff at GARFO and the NEFSC's Fisheries Sampling Branch quite supportive while other government staff less so (largely due to the resources available).

That is, as many stakeholders mentioned to us, only by using the technology to the fullest extent possible (and especially in science) can one expect the fishing industry to fully embrace EM and ER technologies. Clearly the two offices of the federal government in the region should be consistent in their approach to the development and use of EM in particular and this would be best facilitated if the NEFSC finds the data from such a system useful for their analytical needs – especially for their all-important stock assessment processes.

It can be argued that this should be relatively straightforward, given the technology's advantages over observer programs in certain areas (eg. its provision of multiple viewpoints on a vessel, its potential for tow-by-tow granularity at greater spatial and temporal scales throughout entire fishing fleets, its lack of observer bias, etc.). And one way to facilitate such use (and one that is usually employed elsewhere when EM programs are initiated) involves the EM provider being given the current observer programs' data forms and protocols as templates for EM data provision. This should greatly assist with fitting EM data into NEFSC's data systems and eventual population models. It is worth noting that this was done in New England during various pilots with many of the personnel involved being quite familiar with the observer program. Nevertheless, we were advised during this current project that problems with the incorporation and use of the data remained.

One area where the NEFSC is currently assisting in the implementation of EM is via their assessment of the accuracy and precision of data coming from EM video. The approach so far has been to firstly compare the accuracy of video review by non-government and government reviewers and then estimate the accuracy levels of EM data at various proportions of review. Yet such work does not address the main purpose of video review in an audit-based EM system: the

proportion of randomly selected video review simply needs to be small enough to realize sufficient cost savings yet large enough to provide a realistic incentive for fishermen to complete their VTRs accurately. That is, in an audit EM system, it is the data from VTRs that is used for scientific and management purposes – not the data from videos. In other parts of the world that use an audit EM system, a standard 10% review of footage tends to be used to verify fishermen-reported data. And at that level, once implemented and running, EM systems usually cost approx. half of the cost of an equivalent human-based observer program. (We note that work is underway in the region to address this issue.)

We note that the audit model project partners are attempting to find ways to increase EM data use by NEFSC through a current project by SMAST. This project is exploring the utility of EM information in stock assessment work. Whilst this initiative is obviously critical, and SMAST are an ideal group to do the work, we were surprised that the involvement of NEFSC population dynamic scientists in the project is, at best, indirect due to a lack of resources. We would have thought that their involvement should be integral to such work as it is this NEFSC group who are the target users of such data.

Program Design

The overall approach/design of an EM program is probably the most critical aspect of any EM system. Indeed, an inappropriate design can prove pivotal in restricting the implementation of EM. The longest standing model examined in New England (using the audit approach) currently has design features that are labor intensive on deck and for video review (eg. placing all discarded groundfish across a measuring strip by fishermen and examining video of this back in the lab). A newer model being pursued for vessels with higher discards (the maximized retention approach) has seen far lower participation by fishermen due to its requirement to land all groundfish and so incur costs of utilizing quota and handling fish that may be worth little, in addition to the complications of its accompanying dockside monitoring program. It is important to note that this latter, maximized retention model, is similar to Europe's Landings Obligation (or Discard Ban) policy and we suggest that there are lessons to be learned in New England from the implementation of that policy which extend far beyond its use as a tool for monitoring fisheries operations (eg. the need to develop new markets and products, handle large quantities of low value fish, ecosystem effects due to non-discarding, etc.).

As both models in new England continue to be developed, significant attention will also need to be paid to balancing expanding data collection needs and practicality. That is, as the scope of EM programs expand to include (for example) the collection of scientific information for stock assessments and protected species interactions, to increase and improve the accountability of the industry, inform traceability initiatives, etc., it is important that all stakeholders closely monitor the operational effects that such increases in scope produce. The lead group that we recommend below should therefore closely monitor any adjustments in the scope and objectives of such programs and their implications for both fishermen and the end users of the data.

Whilst there are issues impeding the implementation of both these programs, there are also significant advantages to each - so continuing to fine-tune both approaches, as they apply in New England, remains worthwhile. It is probable, however, that neither program will be a one-size-fits all solution. Rather, it will require the above-mentioned fine-tuning, in addition to strong leadership and strategic planning (by the lead group we recommend) to implement an appropriate system - which may well be a hybrid of the two.

Incentives and Costs

Earlier we discussed some ways to encourage the scientific use of information from EM. There are also various ways to encourage fishermen to use such technologies. The simplest (and most draconian) is for government to just mandate their use as a requirement on fishing permits. Whilst this may work for EM (ie. requiring vessel owners and/or captains to carry functioning systems), it does not necessarily work in all cases for ER – where some captains are simply not able to use the required technology (ie. currently mostly laptop computers). But whilst EM may one day become mandatory, this should clearly not occur for some time and, in any case, it always better to achieve some form of voluntary acceptance and use of a major change like EM before taking such draconian action.

However, a variety of other incentives have got fishermen using the technology in New England and for the most part these seem to be working quite well. A key one is that vessels using EM systems do not need to take ASM observers, providing them with the many advantages discussed earlier (ie. removing safety concerns regarding the carriage of an extra person unfamiliar with a vessel, crowding, accommodation, equipment and victualling issues, and the simpler logistics associated with turning on cameras instead of coordinating with a human observer). In addition to this, we also see EM as having the potential to reduce the need for vessels to carry observers who are focussed on quantifying marine mammal interactions. A simple EM system should be well-suited to at least quantifying such interactions, at a fraction of the cost, noting that other steps may be needed to ensure that other functions performed by a human observer take place (taking biological samples, some species identifications, etc.).

Other incentives for fishermen may include access to fishing grounds that are closed to non-EM users, being permitted to carry and switch between certain fishing gears on a trip, and the allocation of specific discards to individual boats rather than being given a Sector-wide allocation - the idea with the latter is that more quota may be provided to boats that discard less and are able to prove it via their video footage.

Another incentive for the use of EM mentioned by several fishermen concerns the provision of information to the NEFSC and GARFO by fishermen that has historically been considered unsubstantiated or anecdotal. That is, fishermen believe that significant quantities of bona-fide, location-and-time stamped, video footage of (for example) large quantities of Gulf of Maine cod should be sufficient for scientists to incorporate such information into biomass estimates used in stock assessments. And by doing so, they would expect that the quality of such assessments

should improve, thus incentivising both scientists and fishermen to use such technology. We are particularly pleased to note that the NEFMC is addressing this high priority issue via their establishment of a Fishery Dependent Data Working Group which is due to report by June 2018.

A major incentive behind most EM programs concerns expectations regarding costs – where such programs are supposed to be cheaper than an equivalent human-based observer program. But in New England we have a situation where an accurate and comparable cost estimate of the two systems is not yet available – although we are advised that such calculations are well underway for the Audit Project and will be available soon after the finalisation of this present project. Critical to such calculations will be the inclusion of the proportion of random video review required to validate VTR information (as noted, this is often 10% in other fisheries). If, as expected, similar data quality can be obtained for an audit-type EM system as that obtained from the existing observer program (remembering that the latter has its own problems with observer bias compromising some of its data), at less cost to fishermen and government, then clearly this would provide a significant incentive to implement such a system. If, however, the opposite occurs, or the cost differences are negligible, then the other incentives mentioned here may be the only ones applicable for the use of EM in the region.

Privacy Concerns

The issue of having a vessel under up to 100% surveillance by an external entity was mentioned by many fishermen as a key reason for their non-involvement in EM projects, despite the above-mentioned incentives. Privacy in one's workplace (whether or not one does things in that place that are illegal) is an important issue that requires resolution if a full EM system is ever implemented. But any solution is not straightforward as it relies on fishermen who have privacy concerns being convinced that the advantages for such a system (outlined above) outweigh those concerns. And there are some simple strategies that may assist in this regard including:

(i) Implementing and using a simple, robust, and easy-to-use ER system prior to the introduction of an EM system on such boats – to get such fishermen used to such technologies;
(ii) Start with a simple EM program (with, for example one or a few cameras) first before launching a full-scale, multi-camera system;
(iii) Work with fishermen to identify key locations onboard their vessels that need to be monitored by cameras and those areas that do not; and
(iv) Develop data sharing plans so all parties have clear understanding of who will have access to data and for what use. This should also outline data protections.
(v) Target a strategic communication program about the advantages of EM to those fishermen with privacy concerns and involve fishermen who are more comfortable with their use (ie those that have gotten used to them).

Education and Outreach

Throughout our interviews, it became clear that many stakeholders (managers, scientists and fishermen) did not have a complete understanding of the EM efforts occurring in the region, nor what the technology can and cannot do. In order for all stakeholders to see value in EM data, they require an understanding of the tools involved. Indeed, during the course of our interviews, we often needed to provide such information, after which interviewees became much more engaged, interested and positive towards the technology.

Choke Species Reporting

We have left the most difficult problem with EM implementation in New England to last. That is, how to resolve the issue that if cameras were installed (potentially recording all catches and discards) in place of human observers (where only a fraction of fishing is examined), the catch and discard of choke species (those for which fishermen have low quotas) would be recorded and could lead to penalties. Or, if fishermen retained such species (as required), their quotas would quickly become exhausted, effectively stopping them fishing from for targeted species for which they have large quotas.

Basically, if a simple solution existed for this situation, it would have already been implemented because this issue is not only affecting the trial of EM in some parts of New England, it is also affecting ASM observer trips and therefore compromising the data being used to inform stock assessments and quota allocations. And a few suggestions were provided by stakeholders during this project which may be worth considering.

The main one involves increasing the allowable catches of choke species (mainly Gulf of Maine cod, but also certain stocks of yellowtail flounder and American plaice). Fishermen believe (and some are attempting to show with their videos) that the quotas for such species are low because their stock assessments understate the actual biomasses present - a belief that is further evidenced by their willingness to forgo normal fishing practices to avoid such fish when an ASM observer is present, and to avoid using cameras for fear of being caught discarding them. Paradoxically, one way to obtain the information about the reputed large abundances of such species is from the video recording of fishing operations – which fishermen will not allow for fear of penalty.

A suggested solution (that would need to be developed within current or modified legal frameworks) is to remove such barriers under a so-called “Hallpass” system. Suggestions on how to achieve this included allocating additional quota in a “set-aside” arrangement, using the roll-over of unused quota from one year to another, establishing “risk pools” and/or “permit banks” of quota, and/or allocating additional quota from uncertainty buffers for accountable vessels. Another concept that may prove useful is to use existing data streams (from the Study Fleet, FLDRS and/or Observer programs) to model and estimate discard quantities and allocate them to fishermen in order to dis-incentivize atypical fishing activities and observer bias.

Any of the above arrangements should, however, be designed to allow fishermen (or even just some as a so-called "sentinel" or "study" fleet) to fish normally, without penalty, but record all catches on video (and/or on VTRs validated by video) and provide the data for stock assessments. Such systems may be worth considering to resolve the current paradox where the necessary data to resolve the issue is not being collected in the first place - by cameras nor by ASM observers.

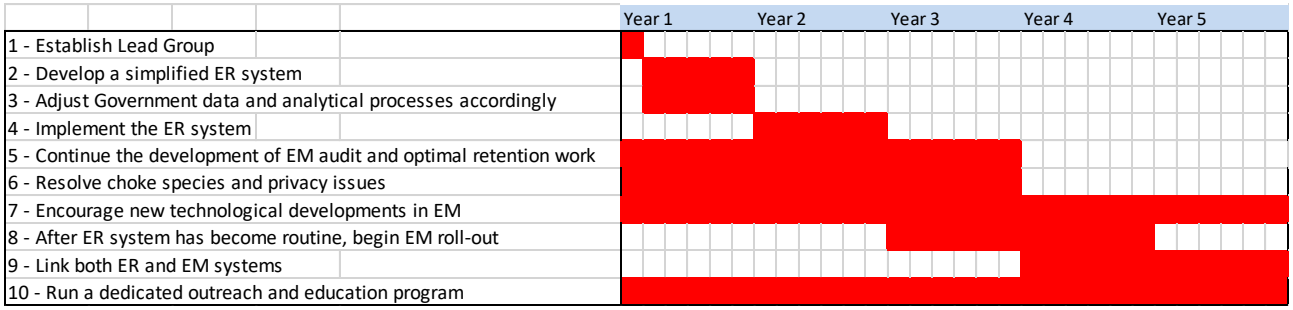
A Way Forward

From the above discussion, we believe that a series of steps emerge that should, if adopted, eventually lead to a modern, technologically-based monitoring and reporting system for New England's fisheries within the next 5 years (noting that projecting a longer time-frame in such a rapidly advancing technological field is inappropriate). See also the Gantt Chart below.

1. The first step should be to identify and establish (as soon as possible) a lead group to strategically plan and implement ER and EM in the region. We believe that this should be run by the federal government and include the main end-users of the information - fisheries managers, stock assessment scientists, protected species scientists and compliance officers – working closely with key fishing industry representatives, state governments, sector managers, technical experts and NGOs.
2. Next, this group should facilitate the development within the next year or so (perhaps through funding agencies like NFWF) of a simplified, easy-to-use, ER system as described earlier.
3. While this system is being built, adjust the data-handling and analytical processes at GARFO and the NEFSC to accommodate the data streams provided from such a system.
4. Implement this ER system throughout the region, noting that some exceptions using paper-based VTRs will be required for those fishermen uncomfortable with the technology (ie. those that cannot use phone or tablet-based apps).
5. While Steps 2, 3 and 4 are occurring (ie over the next 2 years), continue the development of both the audit-based and maximum retention-based EM systems currently being pursued where:
    a. The audit system (whose goal is the validation of ER data), should focus on requiring a modest (possibly around 10%) amount of video review, and be fine-tuned for use on as many gear types as possible - so that it captures the full range of complexities and problems that exist with its implementation in the region; and
    b. The maximum retention system should focus on becoming more of an "optimal retention" system for use in those situations where EM has particular difficulty in validating ER data (eg. on larger vessels with huge catches, for large multi-species catches from bottom trawls, for species whose identification using video is problematic, etc.). Under this approach, vessels will probably also require a level of dockside monitoring and/or human observer coverage.
6. Continue to resolve other key issues with EM implementation, especially those concerned with privacy (using some of the techniques outlined above) and choke species. With regard

to the latter, we encourage the examination of any (legal) options that would allow industry using EM systems to target healthy stocks without exhausting their vessels' allocation of choke quotas - and so provide data to inform science and management.

7. Continue to encourage the development of other, more longer-term improvements in EM systems (ie. at a 3-5 year horizon) whilst being cognizant of work going on elsewhere to do the same. This includes such things as the automation of video review and the streamlining of data transmission and storage.
8. Once the work under Step 4 (ER implementation) has become routine for fishermen and government agencies, begin the rollout of the EM systems developed under Step 5 and incorporating solutions from Step 6 and, if available, those developed in Step 7.
9. Link the ER and EM systems that should now be occurring in the region into one ongoing system that should be flexible enough to incorporate additional technological innovations as they occur.
10. While all the above is occurring, a dedicated outreach and education program about ER and EM is required to gain support and ownership of the system by all stakeholders in the region.



Appendix - Summary of Electronic Technology Efforts in New England

This appendix summarizes electronic reporting and monitoring efforts in New England to date. The studies are separated into three categories: (i) on-the-water efforts, (ii) policy efforts, and (iii) other (non-groundfish) projects.

On-the-Water Electronic Monitoring and Reporting

Cape Cod Commercial Hook Fishermen's Association (CCHFA) Pilot

In 2004 and again in 2006 CCHFA contracted Archipelago Marine Research to examine the utility of EM to monitor cod bycatch in the longline fishery for haddock, and later aboard gillnet vessels as well. These were short studies, lasting only 3-6 weeks but were the beginning of EM in New England. Results were promising for fishing activity recognition and species identification. However, it was many years before EM was more thoroughly tested in the region.

NEFSC EM study

From 2010-2014, the Northeast Fisheries Science Center's (NEFSC) Observer Program conducted a three-stage study to test the applicability of using EM to collect catch and effort data. During the four years, a combination of 13 gillnet, longline and trawl vessels from Maine, Massachusetts and Rhode Island participated. Experiments were done to develop methods for species identification and to obtain weight data. This included developing detailed vessel monitoring plans catered to each vessel. Two EM models, using (i) an audit approach to monitor fisheries that discarded fish and (ii) complete monitoring of catches from vessels that were not permitted to discard any fish (the maximum retention approach), were tested and refined. This set the groundwork for the multi-year EM pilot program described below.

EM - Audit Approach Model

Beginning in 2013, the Gulf of Maine Research Institute (GMRI), The Nature Conservancy (TNC), and Maine Coast Fishermen's Association (MCFA) began testing the capabilities of EM on groundfish vessels ranging from 35-55 ft. The goal was to find a cost-effective alternative to at-sea monitoring using human observers (ASM). Ecotrust Canada was contracted to provide the EM services. Development of technology and protocols continued into 2014 and 2015 with the addition of the Cape Cod Commercial Fishermen's Alliance joining the study. Throughout these years, between 4 and 9 vessels participated. An electronic logbook developed by Ecotrust Canada (elog) was also developed and used for haul-by-haul electronic trip reporting (eVTR). The underlying goal of this work was to develop an audit approach where fishermen reported on eVTRs and the accuracy of their data was incentivized by having a percentage of video reviewed as validation. The eVTR data were then used to inform quota management.

In 2016 and 2017 this program changed and began functioning under an exempted fishing permit (EFP), allowing vessels to use EM in place of ASM observers. Currently 100% of EFP trips where videos are used are being viewed and discard summary reports are being sent to GARFO's database for quota monitoring. This effort is also collecting information to inform how an audit model can run, where only a percentage of EM video would be viewed to validate the eVTR data. Vessels participated in one of two EFPs; one where they turned their cameras on only when they were selected for ASM by NMFS and one where they elected to run their cameras 100% of the time. The latter vessels were allowed access to areas closed to groundfishing and were also granted some gear exemptions. To date there are 17 vessels participating in these two EFPs from 4 states (ME, NH, MA, RI) and using 4 geartypes (trawl, gillnet, longline and jig). Video data are provided to NEFSC, who then conduct a secondary review for quality control and research.

This program is currently are working with the School for Marine Science and Technology at UMASS Dartmouth to advance the use of EM data in stock assessments, and is also pioneering the use of artificial intelligence in video review automation (see below).

Automated EM video review: early progress

The single largest annual cost of EM programs is often video review. Globally the first steps towards automating EM image review to dramatically reduce costs are underway, and due to recent computational advances we expect rapid development in this space. Thanks to a NFWF award, a team led by Kate Wing Consulting, with TNC and CVision Consulting, developed and completed a machine learning competition to automate the extraction of discard data from New England EM video. The competition concluded October 30th and the opensource code from each of the 4 winners will be posted by the end of 2017 .

EM - Maximized Retention Approach

While the above audit approach has been shown to work well for groundfish vessels with modest groundfish discard volume (ie 5-250 lbs/trip), its requirement to measure each discarded groundfish is prohibitive for vessels with high volumes of groundfish discards. As such, GMRI and the Environmental Defense Fund (EDF) teamed up with large offshore groundfishing vessels in 2016 to examine a maximized retention approach. This program will operate under a regulatory exemption that requires vessels to land all allocated groundfish instead of discarding them at sea, thus reducing the burden on the EM program to account for at-sea discards. The EM portion of this project simply verifies that undersized groundfish are not being discarded. Data on the total catch are then collected when landed by a dockside monitor (DSM). This project is still in the final planning and early on-the-water phase, and is currently awaiting EFP approval. There is presently three vessels committed to the project in 2018

New technology that has the potential to lower costs of an EM program is also being explored in this project. Satellite, cellullar and WIFI technologies are being used to remotely transmit video and data, and to provide technical support. Satellite technology allows for system health reports and JPEG images to be sent while the vessel is offshore and data is automatically transferred to cloud-based storage when the vessel returns to cellular range. Pan-and-tilt zoom cameras are used in combination with this technology to allow for camera adjustments to occur remotely. Many additional aspects of the system, like using WIFI at sea, are also being explored through this project.

Fisheries Logbook and Data Recording Software (FLDRS)

FLDRS was originally designed by NOAA in 2006 as a research tool to collect fine scale data on contracted vessels. As interest in eVTR began to grow, industry members took notice of FLDRS as a free and stable tool and began to use it for eVTR reporting. It is now used to replace paper VTRs for commercial and recreational fishing vessels, and can be customized to operate with many different gear types and fishing practices (note that there are other ER packages also being used such as Harborlight and Electronic Edge but not yet in groundfish vessels; and Elog – which we discuss below). The FLDRS program eliminates the need for paper VTRs, expedites data entry, reduces wheelhouse clutter and input errors, and enables faster tracking of catch data. Data can be collected at both the sub-trip and haul-by-haul level and can be provided in five forms: by trip, effort, catch, landing and apportionment. The current version of the system is used by approx. 120 vessels, representing 85% of the total eVTR submissions, accounting for >6,500 electronic trips (eVTR and non eVTR) per year. Currently about 55 vessels report at a haul level, 26 at sub-trip level with GPS, and about 40 groundfish sector vessels report at a sub-trip level. FLDRS has been tested extensively in trawl fisheries, scallop and clam dredge fisheries, longline, gillnet and trap, and hand gears to a lesser extent. Overall, the number of electronic trip reports generated using FLDRS has roughly doubled between 2009 and 2016. Any vessel can choose to submit via FLDRS and there have been programs to help facilitate the use of eVTRs. In 2009 GMRI, with help from NOAA, ran a program that would equip, train and provide support to any vessel that wanted to report electronically. That program has now equipped and trained 65 vessels. Some sectors have also developed support systems and personnel to help transition to, and maintain, this electronic reporting. NEFSC's Cooperative Research Branch runs a Study Fleet program (see also below) that integrates temperature/depth and GPS sensors with FLDRS to help inform NOAA science and management programs. We are advised that FLDRS will continue to make improvements to encourage electronic submission, including being able to submit through the application using WIFI instead of emailing the file or using the web portal. At the time of writing, we have been advised that FLDRS is undergoing a major update which is building on comments and lessons learned using the previous version. A future goal of FLDRS is to use a captain's own recorded data to feed a dynamic data visualization tool that a captain/owner can use to help inform and improve his/her fishing practices.

Northeast Fisheries Science Center Study Fleet

The Study Fleet Project began in 2000 as a result of the joint recognition by industry and NMFS of the need for more fine-scale industry-based data. The primary goals of the study fleet project are to:

1) Provide catch, effort, and environmental data at a high spatial and temporal resolution and
2) Use electronic reporting hardware and software for more accurate and timely data collection.

The initial years of the project focused on recruiting vessels and developing the required hardware and software. After completing the testing of systems and developing the electronic logbooks in 2005, data collection began in earnest in 2006. Approximately 30 vessels participated, recording 759 fishing events and 179 trips at the haul-by-haul level.

Vessel participation has varied over the past decade, ranging from 20-40 vessels during any given year. Vessels are located from Maine to New Jersey with concentrations heaviest around Gloucester and Point Judith. Trips and fishing events recorded have also varied through the years, but have trended upward - 13,546 events and 1,662 trips were recorded in 2015.

Study fleet vessels also collect environmental and biological data, including temperature measurements and samples for age and growth. Study fleet information has been important in contributing data to improve age-length keys for species such as winter, yellowtail and windowpane flounder. Furthermore, study fleet vessels often collect data specific to particular research needs and requests. Notably, temperature data from the study fleet was used to adjust butterfish catchability estimated from the Bigelow, re-stratify butterfish habitats, and ultimately led to increased estimates of biomass.

In addition to the above-mentioned goals, future Study fleet goals include continued efforts to improve age-length keys for commercially important groundfish species and analyze the utility of CPUE data to improve stock assessments. Furthermore, in 2018, plans include increased use of temperature probes and satellite transmissions to inform weather forecasts, possible expansion of weather station deployments and additional testing of WIFI hubs and cellular hotspots at docks.

Policy Efforts

Greater Atlantic Region's Electronic Technologies Implementation Plan

In 2015 GARFO and the NEFSC published an Electronic Technologies Implementation Plan. The plan outlined a strategy and timeline to move modernization efforts forward with the intention to "modernize fishery dependent data collections to ensure collections are timely, correct/validated, optimally automated, vertically and laterally integrated/unified, adaptable to emerging needs, and capable of providing data at a scale that will support anticipatable management". This plan took stock of the current state of data collection and explained modernization efforts focusing on the FDDC (Fishery Dependent Data Collections) and EM efforts, including workplans and timelines. The

report called for a May 2017 implementation of FDDC and EM. As of now (6 months after this deadline), both still require significant work before implementation.

There are certain important items to note from this plan. One is that the plan called for the need for regional performance standards for EM, and explains that pilot studies will inform these standards. Another is a summary of Council engagements with the plan up until the publication of the 2015 report. It would be helpful to build this summary out to the present in order to understand Council's engagement with the plan in full.

Fishery Dependent Data Modernization at NOAA- FDDC and FDDV

In 2013, GARFO and NEFSC began the Fishery Dependent Data Collection Modernization Project. To develop a vision for a new data system, NOAA staff, in collaboration with GMRI, interviewed a wide array of stakeholders to "identify the strengths and weaknesses of the existing data collections and systems, and to elicit the desired characteristics of an ideal fishery dependent data system". The two groups also jointly held a workshop to delve deeper into the issues in June 2014.

Subsequently, a new initiative, the Fishery Dependent Data Visioning Project (FDDV), was started to develop the future of data collection programs. In June 2017, NOAA presented on the FDDV status and progress. The goals of the program are to improve data whilst reducing reporting burdens. Plans include:

- A new Trip Management System (TMS) that will utilize a unique trip identifier;
- Creating region-wide standards and methods for data management;
- Integrating automated QA/QC; and
- Improving accessibility to data through a centralized warehouse.

It is clear from various presentations about this topic that eVTRs could play a major role in this process. A technical team is currently being established to help move this process forward.

Northeast Fisheries Management Council EM working group

Established in 2013, the NEFMC EM working group was tasked with "identifying any existing barriers or necessary steps to NMFS approving sector operations plan(s) that rely on electronic monitoring as a primary mechanism to achieve the Council's identified compliance and catch attribution goals for this program (separate from the biological sampling program)."

This work resulted in the white paper "Toward Implementation of Electronic Monitoring in Groundfish Fishery Sectors" in June 2014. The document contains the following:

- An exploration of barriers to EM;
- Identifies two potential EM models, the maximum retention and audit models; and
- Provides brief recommendations about approaches to EM in New England.

The information in this document is a useful basis for EM implementation in New England but design details and analyses are mostly out-of-date with current efforts in the region. The EM working group has since been dissolved.

NOAA EM Cost Report- A Preliminary Cost Comparison of At Sea Monitoring and Electronic Monitoring for a Hypothetical Groundfish Sector

In 2015 NOAA published a report that examined the cost of an EM program compared to the cost of the existing ASM (Observer) program for a hypothetical sector. This was done in collaboration with EM service providers and NGOs working on EM. The report estimated an ASM cost per trip of $316 compared to a cost for EM of $601. –The report was drafted based on many assumptions and further analysis could be useful.

EM Summary Data Technical Specifications

Through collaboration between EM pilot partners and NOAA, EM Summary Data Technical Specifications have been developed. This document includes details on file formats, security, submission protocols, and file structures for submitting EM data to GARFO. This is an important step towards EM implementation in New England as it allows multiple providers to submit data directly into GARFO's Application Programming Interface (API). Furthermore, these specifications allow data collected by a variety of technologies to be assimilated into NOAA's databases. The groundfish audit project is currently using these specifications. The maximum retention EM program intends to submit data using these specifications as well.

Amendment 23

The NEFMC is currently undergoing an amendment process concerning monitoring in the groundfish fishery. This amendment proposes some alternatives that involve ER and EM. In June 2017 the council passed a motion to "*recommend to the Council that the purpose of Amendment 23 is to implement measures to improve reliability, accountability, accuracy, and precision of catch (landings and discards) information across all segments of the monitoring program toward better achieving the existing goals and objectives as stated in Framework Adjustment 55, while directly taking into account measurable costs and identified benefits to the fishery while meeting requirements in the most cost effective manner possible.*"

Another motion passed in June laid out some alternatives to the current system. This motion *"Recommend(ed) to the Council the development of a range of alternatives for electronic monitoring (EM) that achieve the purpose statement identified by the Committee, such that:*

- *Vessels should have the option to use EM in place of at-sea monitors (ASM)*
- *EM instead of ASM on selected trips, where EM is used to directly estimate discards consistent with current EM exempted fishing permits*
- *Audit based approach for EM where EM runs on 100% of trips and a subset of hauls or trips is reviewed to verify VTR-reported discards*

• Maximum retention approach for EM where EM verifies that all groundfish are landed and uses dockside monitoring (DSM) to sample catch
• Formally approve EM as a monitoring tool"

Many see this ongoing amendment process as a necessary driving force towards ER and EM implementation in New England.

Other Policy Initiatives

There are additional policy-based initiatives that are relevant to this project including:

- Multispecies Amendment 13 (2004) which called for a trip identifier linking dealer, vessel, DAS reporting with ER;
- Amendment 16 which authorized use of EM when a suitable system is designed; and
- Vessel Monitoring Requirements – which is a form of ER

Additional details regarding these (and other initiatives) will be provided as this project progresses.

Other (non-groundfish) projects

Electronic Monitoring in the Western Atlantic Longline Fishery

In 2015 the Highly Migratory Species division of NOAA mandated fleetwide use of EM to monitor Bluefin tuna bycatch in the Western Atlantic Longline fishery. Over 100 vessels were installed with EM systems by Saltwater Inc. and they continue to collect video of pelagic species brought on board and released. This program is very different from others in New England not only because of its scale and objectives, but also because it is actually operational. While many EFPs and other pilot studies are ongoing, this program was the first to be implemented into regulations. Some of the advantages that this program enjoyed were:

- each fish is brought to the vessel individually, in one location and are mostly quite large, and the overall volume of catch is smaller, making identification using EM easier than is the case in other fisheries; and
- the program is coast-wide meaning that no action from the NEFMC was required, simplifying its adoption.

Electronic Monitoring in the Herring Fishery

From August2016 to January 2018, NOAA conducted a study on the utility of EM in the Atlantic herring and mackerel midwater trawl fisheries. They worked with Saltwater Inc. as the EM service provider for 11 large vessels, representing the entire midwater fleet. The purposes of the study were to:

- Deploy and test an EM program in an operational setting, allowing analysis and adjustment

of EM program requirements, and development of business practices to support an EM program.
- Evaluate the utility of EM for monitoring catch retention and identifying discard events in the Atlantic herring and mackerel midwater trawl fisheries.

Additional goals include familiarizing the fishing fleet with EM, gaining industry input on EM operations, and refining industry and NMFS EM cost estimates. In addition, the IFM amendment, currently under final development and agency review, includes alternatives for EM in the herring fishery.

CFRF On Deck Data Program

The Commercial Fisheries Research Foundation (CFRF) in Rhode Island has conducted a study since 2013 that has tested and implemented methods for lobster and Jonah crab fishermen to collect and report biological and environmental data during routine fishing practices. The CFRF's Lobster and Jonah Crab Research Fleet consists of 17 fishing vessels using Android tablets and electronic callipers to collect biological data during three fishing trips per month. Temperature sensors affixed to fishing gear collect continuous data on environmental conditions. Data is transmitted wirelessly to the CFRF's SQL database, where it is monitored for quality before submission/incorporation into the regional lobster and Jonah crab biosamples databases at the Atlantic Coastal Cooperative Statistics Program. Currently, the Research Fleet is still collecting data which continues to be used in the lobster stock assessment and Jonah crab management plan. Documentation describes this approach as highly collaborative, with fishermen very willing to record their data to better manage the fishery. A key to achieving such buy-in is providing fishermen with access to their data as well as regular updates on data application and value.

Since 2015, the CFRF has applied the Research Fleet approach to collect biological data for black sea bass and quahog. Both of these Fleets have been successful in collecting data that is accepted by stock assessment scientists. Different from EM applications in the region, the purpose of the CFRF's Research Fleets is to fill biological data gaps for stock assessments and improve management of the target species, rather than to monitor catches, bycatches and compliance.

Environmental Monitors on Lobster Traps (Emolt)

Emolt is a collaborative electronic data collection program started in 2001 that collects measurements on bottom temperature, salinity and current velocity with sensors deployed in fishing gear. The program has enlisted over 100 lobstermen to contribute to a time-series documenting environmental conditions in the lobster fishery. Target data-users include the lobster fleet itself, lobster scientists and oceanographers. Collecting environmental data purposefully for the use of oceanographers makes this project distinct in New England.

Etrip

eTrips/mobile is a recently approved eVTR application, developed for The Atlantic Coastal Cooperative Statistics Program (ACCSP) by Harbor Light Software, primarily used by charter-for-hire vessels in Massachusetts and Rhode Island but quickly expanding to other fisheries. The use of eTrips has been encouraged primarily through two projects: one in Rhode Island that used captain's data to better understand fishing patterns in the face of ocean planning, and one in Massachusetts (through MADMF and GMRI) to explore the accuracy of customer versus captain's catch estimates.