

WORKING GROUP ON TECHNOLOGY INTEGRATION FOR FISHERY-DEPENDENT DATA (WGTIFD; outputs from 2020 meeting)

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i Executive summary

The Working Group on Technology Integration for Fishery-Dependent Data (WGTIFD) examines electronic technologies and applications developed to support fisheries-dependent data collection, both on shore and at sea, including electronic reporting (ER), electronic monitoring (EM), positional data systems, and observer data collection. The primary objective of this report is to inventory and review the various hardware, software applications, and approaches to fisheries-dependent data collection. The report identifies the challenges and successes of electronic technology programmes worldwide; reviews the technical, policy, and analytical considerations for utilizing data from electronic technologies; and reports on the developments in machine learning and computer vision technologies and their applications in fisheries dependent data collection. WGTIFD also started to examine the risks and benefits of different technologies and how to integrate data from technologies; these topics will be examined further by the working group in the next year.

There are a number of tools that are being adopted more widely across a range of fisheries, vessel sizes, etc., including ER systems that allow for self-reporting to meet certain data requirements and positional data systems such as vessel monitoring systems (VMS), which can provide near-real time location of fishing fleets. EM has been gaining interest very rapidly over the last five years, but there are some challenges in terms of inadequate funding, lack of clear policies and standards, and the costs of manual video review and data transmission. In almost every instance of an EM program or project, computer vision (CV) and machine learning (ML) applications are being developed to reduce costs, and improve the timeliness and accuracy of information. While CV/ML alone will not lower the barrier entirely for much wider adoption of EM, these technology developments are advancing in the marine sciences and will help shape fisheries monitoring in the future.

The broad relevance of electronic technologies and the work of WGTIFD has been highlighted both within and beyond the ICES network in recent years. Fisheries and fishers have been greatly impacted by the resulting impacts from the COVID-19 pandemic, but many electronic technology programmes around the world have provided some amount of resiliency to data collection (e.g. observers were removed from vessels, but electronic monitoring was still deployed). Looking ahead, WGTIFD recommends working with data-poor stock assessment scientists and working groups to examine approaches for adding new types of electronic monitoring data into assessments to complement existing analyses that rely on data with a longer time-series.

ii Expert group information

Expert group name	Working Group on Technology Integration for Fishery-Dependent Data (WGTIFD)
Expert group cycle	Multiannual fixed term
Year cycle started	2019
Reporting year in cycle	2/3
Chair(s)	Brett Alger, United States
	Lisa Borges, Portugal
Meeting venue and dates	6-8 October 2020, online meeting, 39 participants

1 Introduction

Fisheries monitoring and reporting are strategies to collect information from a fishery based on a set of goals and objectives, but they also represent a series of tools that can be used to collect data. These tools provide information on vessel location, gear and effort; and on the types and quantities of retained or discarded fishery catch, among many other uses. Fisheries monitoring and reporting programs have historically relied upon independent fishery observers, vessel monitoring systems (VMS, real time vessel position reporting), landings reports, and self-reported paper logbooks for a large majority of fishery-dependent data collection. Constraining budgets and increasing demands for data are driving the need to evaluate and improve existing programs, in particular with respect to cost-effectiveness, economies of scale and sharing of electronic technology (ET)¹ solutions across regions. Fishery managers and scientists are exploring how global position systems (GPS), electronic reporting (ER), video cameras, gear sensors, technologies for human observers, and other tools can improve the timeliness, quality, integration, cost-effectiveness, and accessibility of fishery-dependent data. As more tools are developed and implemented, it is critical to examine how these new data streams can be integrated with traditional fishery-dependent data collection programs to support fishery monitoring and fish stock assessments, but also to explore how data derived for one purpose may have utility to support other interests such as monitoring and control, business development, traceability, and other applications.

WGTIFD is taking a stepwise approach to initially assess the ETs currently available and in development, and better understand the objectives and schemes in which they are currently deployed. There are many choices in designing a data collection program, and it can be challenging to incorporate data from new sources into existing monitoring programs and stock assessments. WGTIFD will provide guidance on how to design a program, and how to examine and integrate new information with data collected through traditional means. Many technologies are being deployed alongside each other (e.g. VMS, electronic logbooks, and observers), and WGTIFD is examining how to integrate the many data collection technologies in a single approach to ease the reporting burdens and costs of data collection and reduce duplication of effort on behalf of fishers. The field of computer vision and machine learning is rapidly advancing in fisheries, and WGTIFD is also examining how these data collection and processing applications intersect with ETs.

The second meeting of the WGTIFD was initially scheduled for 11-15 May 2020 in Galway, Ireland, due to the COVID-19 pandemic the meeting was moved virtually over three days (6-8 October) to cater to the 10 different time zones of the 40 participants. Each day addressed a different topic covering several of the WGTIFD ToRs, plus a discussion on the impact of COVID-19 pandemic on ET programmes around the world. Below is a summary of the discussions and recommendations made by WGTIFD during the three days.

¹ Electronic Technologies are defined as any electronic tool that is used to support fisheries-dependent data collection, both on shore and at sea, including electronic reporting, electronic monitoring, positional data systems, and observer data collection. Please see Year 1 Report for a full list of definitions.

2 ET programs around the world (ToRs A, C)

WGTIFD had planned a discussion during the second meeting to develop a series of matrixes (see Year 1 report as example) that would help provide guidance on to develop a program and select tools based on the fishery types, goals and objectives, and data needs. However, this task needs a more in-depth discussion that may only be possible in an in-person meeting, and thus was delayed until the third WGTIFD meeting. Nevertheless, the WGTIFD discussed the challenges, successes, and recommendations for integrating ET tools from programmes around the world, considering factors such as programmes reporting obligations, costs, compliance, technicalities, data integrity, fishers buy-in and participation, among others.

The main challenges identified were:

- Industry buy-in and participation - associated to low levels of monitoring, compliance programmes, to privacy and data ownership concerns.
- Cost effectiveness - matching objectives and work load to different fisheries realities (vessels sizes, economic realities), scaling pilot studies to fisheries, system details (storage and hardware set-up), and compliance with monitoring levels of ET vs. Human Observers (HO) programmes.
- Lack of interoperability of programmes and products –different standards, requirements, and specifications for service providers, equipment, but also between ET and HO programmes (such as monitoring levels and reporting requirements).
- Coordination between different programme actors - industry, service provider, scientists, management agencies within the same programme.
- Reporting obligations – there can be several reporting and monitoring requirements, at different temporal and spatial scales, across different jurisdiction and governances. It can be difficult for fishers trying to adhere to complex requirements, but also resource-intensive for managers and scientists trying to integrate and analyse data across these systems.
- Logistics – difficulties in transmitting data from where vessels operates to where video is reviewed, in tracking vessels, in providing physical support to systems.
- Disparity in programmes coverage of fishing activity, especially during Covid-19, as EM continues to operate while HO stopped.

The main successes and recommendations identified were:

- Engagement and empowering the fishing industry from the beginning of an ET programme increases transparency and trust, leading also to increased buy-in. Involve industry at the beginning of the process, in the design phase of a programme.
- Adding value makes fishers more willing to incorporate and maintain ETs (e.g. (by)catch reporting, increased observer safety, greater confidence in collected data, deter illegal activity, increased transparency).
- Good communication between stakeholders, for example, reporting any catch handling or data quality issues back to fishers (feedback reports) after EM imagery is reviewed, but also integrating fisher's knowledge (in finding solutions).
- The right balance between reaching programme technical requirements and objectives and building flexibility to adapt to fisheries and fishers realities
- Long term success is difficult but possible, by moving from a pilot programme to an operational program at scale and integrating EM data into the current data streams.
- ET allows fishing regulations to change and adapt, while increases compliance.

- To increase interoperability, one should focus more on common data outputs from ET programmes, and less on common hardware and software, to build the competitiveness of service providers.
- Be mindful of scalability – do not over limit the programmes initial objectives and carry out pilot studies on only a few boats, before scaling up to the entire fishery
- Monitoring programmes (ER, EM, HO) should complement each other, and be used to validate data across tools. This will lead to improved data integrity, improve catch reporting, and ultimately lead to a better understanding of assessing a fisheries stock. Using EM to validate reporting can also improve catch handling practices to improve data quality

Feedback and Communication is Key to Data Quality

The WGTIFD agreed that feedback loops, including communication between hardware installers and video reviewers (i.e. camera placement on a vessel), or data users communicating back to fishers (i.e. ensuring proper catch handling and data quality) are key to the success of a programme. Program managers need to consider the lag between when video is collected and when it is reviewed, a simple error or issue with how the images are being captured on a particular trip may persist again and again until it is identified and communicated back to the vessel. Feedback to the industry of the programme implementation, including access to data and videos, will improve fisher's knowledge of the programmes, will increase transparency, may improve fisher's efficiency, and thus will help with industry buy-in. It is also important to note that providing feedback to fishers can result in identifying weaknesses or deficiencies that could be explored for foul play.

Examples of different types of feedback reports can be found in Annex 3.

Regarding ToR C, in the first WGTIFD meeting an inventory was carried out of the types of data that can be collected from existing electronic tools on a vessel during normal fishing operations, including which data types can be collected autonomously vs. manually. The intention was to create a smaller set of summary tables, to be populated by WGTIFD participants at the second meeting. Given the inability to move forward on this in a large virtual setting, WG members instead provided summaries of their various ET monitoring programmes.

Summaries of ET programmes can be found in Annex 4.

3 Collecting, processing, and analysing data (ToR D)

On the second day of the virtual meeting, WGTIFD discussed the importance of data integration from existing data collection programs, as well as developing future systems that are more integrated on the front-end, focusing on three different aspects: policies and standards; technical considerations; and products and outcomes.

On **policies and standards**, the discussion centred on three different questions:

- a) What are the key issues regarding data ownership, access, and privacy?
- b) How should managers develop standards and regulations for ET systems that may change over time?
- c) What are the best practices for hardware and service acquisition?

WGTIFD discussed that clearer terminology and standards across governance are needed, but that standardized government procurements can end up being too inflexible, compromising competitiveness of service providers. Given the diversity of vessel setups, it can be challenging to define prescriptive (hardware) standards. Alternatively, performance-based standards should be used to provide needed flexibility in system setups that can meet overall program objectives and rules. These 'flexible' rules could provide on-vessel specifications (e.g. image resolution, number of cameras) needed in order to meet different program objectives (e.g. species ID, discards).

Regarding data ownership and privacy, there are several layers to consider, including privacy of crew in their workplace and confidentiality of the data after it leaves the vessel. As discussed in the previous section, if the EM program is designed with the engagement of the full range of relevant stakeholders, particularly when it's geared for compliance purposes, information sharing and auditing may be easier. Programs should develop clear regulations or guidance on who has access to data, how it can be used, and if/how it could be made publicly available.

Regarding **technical considerations**, four questions were examined:

- a) Describe the key requirements for installing and deploying ET systems on vessels
- b) What are important considerations for developing hardware? Software?
- c) Describe the best practices for developing data standards
- d) Describe the best practices for data integration and management

Key requirements for installing and deploying ET systems are: 1) effective communication, 2) knowledge of the requirements of the program, and 3) making sure that materials can withstand harsh conditions (at-sea and transportation). Effective (quick and clear) communication is important in cases of issues with the system operating on-board (e.g. obstructions, dirt, change in regulations, failing system, etc.), as fishers must know there is an issue/change and what to do to act on it. Strict and clear procedures for the maintenance of the system on-board are needed, including training of fishers/crew, if necessary. Knowledge of the requirements of the program is crucial to planning ahead of system installation and operation. For example, do we want an overview of the fishing operation or do we need to be able to identify species? Usually, the time to install the system on-board a vessel is limited, especially for vessels that fish often and are rarely in port, therefore a lot of the planning and work needs to be done prior to installation. Communication between all stakeholders, fishers, NGOs and research, enforcement and management agencies, is a crucial part of system installation planning.

When developing hardware and software, it is important that the providers are flexible and allow for adaptations as EM programmes are a work in progress in many countries, i.e. constant tweaking of the technology (hardware, software and operating supporting systems) may be necessary. However, minimum standards for software and hardware are needed. When changes in data requirements are made, it is important to consider who pays the costs of consequential software adaptations. In many cases, it is the service providers that absorb the costs and they do not want to lose their clients, so it is important to accommodate the necessary resources to adjust the change in data requirements.

To develop data standards and to integrate ET data in management, it is important to identify business needs upfront and provide clear expectations on requirements. Knowing the data and its format (footage, numbers, measurements, units, etc.) would mitigate costs associated in data formatting, conversions between datasets, etc. Service providers could be flexible in how they collect/analyse data (i.e. innovative with software) but data outputs should be standardized. Setting minimal standards will provide the foundation for a multi-provider system, which incentivizes innovation and competitiveness. Regarding the integration of ET data in management, issues of data ownership, confidentiality, access, and privacy need to be considered. Anonymization is not always a solution as data from different sources must often be combined to have a high resolution and provide a base for accurate advice.

Finally, the WG acknowledged that there is an EM provider consortium (funded by The Net Gains Alliance) working to promote data interoperability, and recommendations to improve how EM products and services are tendered.

Finally, on **products and outcomes**, WGTIFD discussed the following questions:

- a) Are there any examples of improvements in data collection and analysis from implementing ET systems?
- b) Has catch or quota monitoring been improved? Have uncertainties in stock assessment been reduced?
- c) Are there any examples of using ETs to gain sustainability certifications, marketing, or increase in landed value?

Across WGTIFD participant's experiences around the world, the main outcome from the implementation of ET programmes is a change in industry behaviour, towards ET itself, changing fishing practices, reporting improvement, and compliance. Many refer to improvement in data quality, namely in the precision of data reported in logbooks and the robustness of the associated quota system, in observers programmes data, and sampling protocols and in the increase of at-sea sampling coverage of fishing activities. There has also been increase in compliance and transparency with a view to environmental sustainability certification.

WGTIFD discussed that the next logical step for ET programmes is for their data to be used in support of stock assessment. ET data can be used to increase spatial coverage of catch data, improve accuracy of reported and observers data, show previously unknown fishing behaviour, and assist in understanding model results, among others. Working with data poor stocks may be the way forward, as they are already data limited so any data that can be provided to these stocks is appreciated; they are likely more receptive to novel data streams. The data limited stocks assessments tend to be length based and lengths can be obtained from EM data. Furthermore, in some instance EM data itself may not be included in a stock assessment, but EM can be used to validate and significantly improve self-reported data quality through reduced bias. Therefore, WGTIFD recommends working with ICES WGs that focus on data limited stocks, presuming that they have experiences with being opportunistic on including new data sources.

Looking at the future, EM scalability is essential. Technologies need to be flexible to be able to work across multiple fisheries. But products scalability is at the moment very dependent on cost, which in many cases cannot be currently support by industry. Ultimately ET development may come down to a societal decision: of whether society wants fisheries to be fully monitored, and if so, providing funding for ET programmes.

Finally, there are many and varied uses of ET data in the future to benefit a multitude of projects and this should not be forgotten. EM collects a wealth data that should and can be used, for biodiversity studies, marine litter, climate change, etc.

4 Machine learning and computer vision (ToR E)

As fisheries continue to implement new ETs for data collection, it is equally important to develop artificial intelligence (AI) applications, such as computer vision (CV) and machine learning (ML) to improve the cost-effectiveness, accuracy, and timeliness of data management associated with new data streams. CV and ML applications exist in almost all of society (e.g. self-driving cars, social media, health care), and more recently these tools are being developed for the marine sciences, such as underwater surveys (e.g. habitat, coral, fish) and aerial surveys (e.g. marine mammals). These applications are well-suited for fisheries-dependent data as well, with the tremendous potential of performing detection, classification, clustering, and prediction for camera-based EM programs. WGTIFD participants were provided the following questions to develop a series of recommendations:

Characterize the data collected from ET systems – Describe the data types (e.g. images, spatial) in their raw form and define challenges in processing the available data. What are the different conditions that affect data quality (e.g. weather, hardware performance, crew negligence)?

List the existing CV and ML applications in fisheries-dependent data programs – Are there applications implemented under regulation? Applications used by data analysts for an entire fishing fleets? Are there new ideas being considered for research and development? Are there existing annotated data libraries? Are those public?

Develop best practices for creating CV/ML-friendly programs and operationalizing – How should systems on the vessel be designed/redesigned on the vessel to improve data quality? What are the key features of an optimal training dataset? What are the necessary policies and standards to scale applications to an entire fleet? Are there applications that may be easier to achieve in the short term?

Data Types and Applications

The vast majority of AI applications are focused on EM imagery in commercial fisheries and still under research and development mostly, but there are limited instances of tools being included in video review software and other points in the EM data flow process. Tools are being developed in a number of different fisheries for species identification, length and weight estimation, and even to count hooks in a longline fishery. There is a lot of interest in using AI to obtain net measurements and other fishing gear characteristics. In addition to catch and gear applications, imagery and gear sensor data are being analysed for the presence/absence of crew on deck to allow video reviewers to quickly process information when no catch is on deck (i.e. no fishing is occurring). Hydraulic sensors can flag bycatch entanglements or other points of interest for video reviewers, and sensor-only data are used for tracking effort and interactions with closed areas and marine protected areas.

There are also several AI applications being developed for research surveys, including camera systems over conveyor belts and measuring boards, and mobile systems for scanning catch. There are also several examples of phone-based image capture to aid in gathering data on rarely encountered species and/or data limited species; these applications greatly expands the number of people/vessels/fisheries that can collect and share data, such as small-scale commercial and recreational fisheries

Participation of the vessel

The data quality from ML and CV application relies on the successful participation and integration of the vessel's crew in the image collection. In some EM programs, there may be incentives for fishers to not operate the EM system properly (e.g. hide fish, block cameras), it is important to ensure there are incentives for working with the EM system, and even consider data quality as measure of compliance. The crew needs to ensure cameras are cleaned and clear, not blocked or moved, and ultimately that the images are high quality. AI onboard the vessel can help with this by processing data in real time, and flagging issues for the captain, such as blocked objects or blurry imagery. Because most data from EM programs is processed days or weeks at the conclusion of a trip, it is important to provide data quality feedback as soon as possible before too many subsequent trips are taken. A single issue may be repeated trip and after trip until it is identified and rectified via communication with the EM service provider or fishing crew. Catch handling (especially on trawlers, where discarded fish are piled up) and camera set up (i.e. settings, lighting, position to discard chute) affect the quality of images that are available for CV and ML applications. A conveyor belt and/or an established process to spread out the fish may be needed in many cases. Any adjustments of catch handling to accommodate CV and ML should be gradual to allow fishers to learn and appreciate how subtle changes can improve data quality. AI can capture overlapping fish, but it is preferable to not have overlapping fish. This is a simply trade-off, ensuring there are few to no overlapping fish requires a lot more attention and catch handling by the crew, which may erode their patience and interest in supporting the development of any associated tools.

Technical Configurations

In addition to on-deck system configuration, the control center in the vessel's wheelhouse must have appropriate computing power to run many AI applications if the intention is to analyse imagery in near-real time and transmit summarized data while the vessel is still at-sea. Different system configurations may be needed based on different gears, and vessel size and characteristics, but consistency is important. Lighting, field of view, and background colours are important to standardize when possible. For example, something as simple as a standard measuring board for all vessels can aid in creating consistency in data quality. It is important to determine the proper image quality to fit the data needs, low-resolution imagery is sufficient in some cases and greatly reduces data transmission and storage costs. Lastly, do not just focus on the system configuration for AI, the entire system needs to ensure that the required fish are being identified and measured by having other cameras monitoring catch handling and discard control points.

Policies and Standards

Clear policies and guidelines are essential to any EM program, but especially when trying to integrate AI applications with the imagery. Policies or regulations should establish expectations on privacy and confidentiality, who will access the imagery and whether or not the information will be made publicly available. Collecting imagery without the vessel crew and/or identifying features of the vessel make it more likely that vessel owners will participate in data collection to support AI, and overall make more data available to AI developers. In some instances, the EM program may need to develop the proper agreements and approvals from fishers for data access and sharing. In terms of data standards, it may be necessary to examine the accuracy/bias of data collected from observers vs. EM (with human review) vs. EM (with AI/ML) to develop 'acceptance' of an AI model. From there, image quality standards can inform feedback to the vessel

crew to improve their catch handling protocols. Lastly, it is important to standardize the metadata associated with imagery, such as the location, time, date, etc.

Additional Considerations and Recommendations

1. Examine the trade-offs of data collection and transmission costs with frequency of data collection and ping rates. Depending on the amount of data, frequent ping rates may be too costly, but too infrequent ping rates may allow fishers to exploit data gaps.
2. Consider AI applications during the development of an EM pilot project, work with the EM service provider(s) to ensure proper camera type and placement, and image quality.
3. Develop a large annotated image library with images of various species to train AI and even train human analysts. Consider gathering imagery from fish auctions, dealers, processors, etc.
4. Test different densities of fish (overlapping fish, volumetric measurements)
5. Consider getting the public involved in annotating training datasets such as identifying key objects or identifying fish
6. When possible, try to limit fishers being on camera (e.g. camera view focused only on measuring board and catch being processed), this helps with privacy issues and improves image clarity for ML and CV application development
7. Feedback among video reviewers, EM service providers, and vessel crew are critical to monitor data quality, ML performance, and how to make system or catch handling adjustments
8. Be prepared to invest in proper data storage and management especially for large volumes of data for training.
9. Test different concepts and system configurations at a small-scale first, try a conveyor belt, a chute or box with lighting inside, stereo cameras, standard EM systems, etc.
10. The use of AI/ML competitions may help drive innovation and interest, but the winning AI products may not be suitable across an entire fishing fleet
11. Annotate and label the imagery while conducting the initial video review, rather than reviewing later for CV/ML development. This may be costlier and time intensive in the short term, but will make the program more cost-effective over the long term.

5 COVID-19 pandemic impacts

The impact that COVID-19 had on ET programmes includes: 1) biased sampling to ET programmes vs. observers programmes as these have been severely impacted (between limited observers availability with quarantine rules or being completely suspended), but vessels under EM programmes have generally continued to be monitored; 2) reduced fishing activities which made maintaining the normal review process or sampling levels challenging; 3) programmes suspended due to legal restrictions (applied across monitoring programmes and not necessarily specific to ET); 4) difficulties in accessing material and vessels due to goods and movement restrictions.

Most participants agreed however that ET programmes were only marginally impacted by the pandemic, and thus that there are substantial advantages of having technologies-based monitoring programmes. The COVID-19 pandemic has already open new opportunities: a) for new or additional ET programme deployments, b) for innovation, for example by the necessity of integrating bio-sampling activities with EM information, and c) service providers, that are technology savvy, adapted rapidly to remote support with no significant disruptions.

6 Conclusion and next steps

WGTIFD addressed mainly ToRs A, C, D and E: the WG provided examples of feedback loops (Annex 3), an inventory of the participants ET programmes (Annex 4); reported on developments in machine learning and computer vision technologies and their applications in fisheries dependent data collection, respectively; and discussed the impact of COVID-19 pandemic on ET programmes around the world. The necessity to meet virtually with almost 40 people across 10 time zones limited WGTIFD ability to make more progress. Nevertheless, work will continue on all ToRs next year, but particularly on ToRs C and D.

WGTIFD participants have documented positive changes in industry behaviour, towards ET itself, improved reporting, and compliance. However, WGTIFD discussed that active and effective communication between all stakeholders, fishers, NGOs and research, enforcement and management agencies are an essential part of developing and implementing an ET monitoring program. In this context, WGTIFD agreed that feedback loops, including communication between hardware in-stallers and video reviewers (i.e. camera placement on a vessel), or data users communicating back to fishers (i.e. ensuring proper catch handling and data quality) are key to the success of a monitoring programme.

The WGTIFD acknowledged the importance of leveraging existing data standards and data collection frameworks and how ET programs data should be integrated in these data flows, considering the dynamic nature of sampling programs with evolving objectives. In this perspective, WGTIFD recognizes the need for minimum data standards between jurisdictions and programmes, but that these need to be flexible to cater to different fisheries and evolving objectives, at-sea conditions, and as technologies evolve. Setting minimum data standards will provide the foundation for a multi-provider system, which incentivizes innovation and cost effectiveness. WGTIFD recommends working with data-limited ICES WGs and stock assessment scientists, to explore how to utilize new data (e.g. data from EM systems) for science advice.

Research and development of ML and CV applications for ET programmes continues to grow, and it is important to continue communication and collaboration in this quickly changing field of data science. Participation on the fishing vessel is critical to collect high data quality, such as operating the EM system properly (e.g. cleaning the camera lens, not blocking the field of view) and following catch handling protocols to ensure standardized collection of imagery for creating training datasets. WGTIFD recommends technical configurations that standardize the lighting, field of view, and background colours, when possible, but also to develop clear policies and guidelines on privacy and confidentiality; anonymizing data or eliminating fishers from the field of view when possible may help to gain participation. Similar to other recommendations, feedback is essential, image quality standards can inform the vessel's crew to improve their catch handling protocols.

Finally, regarding the theme session at the 2020 ICES Annual Science Conference (ASC; Annex 5), participants were informed that the approved theme session was postponed to the 2021 ICES ASC, and that all papers submitted were rejected. However, new or amended abstracts will be considered, and a new evaluation will be carried out at the beginning of 2021 for the ASC.

Annex 1: List of participants

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Annex 2: Resolutions

2018/MA2/EOSG08 The **Working Group on Technology Integration for Fishery-Dependent Data (WGTIFD)**, co-chaired by Brett Alger*, United States and Lisa Borges*, Portugal will work on Terms of Reference (ToRs) and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2019	7-9 May	ICES HQ, Denmark	Interim report by 21 June to ACOM/SCICOM	
Year 2020	6-8 October	Online meeting	Interim report by 20 November to ACOM/SCICOM	
Year 2021	TBD	TBD, EU	Final report by Date Month to ACOM/SCICOM	

ToR descriptors

ToR	Description	Background	Science Plan Codes	Duration	Expected Deliverables
a	Inventory and review the various national fisheries dependent hardware and software applications and approaches highlighting synergies and similarities with an aim to improve cooperation and collaboration. Indicate readiness states, availability and development plan including scientific training dataset availability.	As a new WG, it is imperative to initially assess the technologies currently available and in development, the objectives of the schemes under which they are deployed in fisheries and scientific research, what data is being collected and by whom. This TOR will build upon a forthcoming paper examining REM use around the globe, to include other technologies currently deployed in fisheries	4.1, 4.5	Year 1	Draft a review paper for publication in a peer-reviewed journal.
b	Define consistent vocabulary across approaches and develop communication strategies for attracting participation in voluntary programs, and deploying and implementing electronic technologies for fisheries dependent observation.	There are a range of terms and perspectives on monitoring technologies, and a perception by some that cameras are on vessels for purely enforcement purposes. While we do not need to standardize terms, this TOR will help us better understand one another's terms, appreciate challenges for gaining participants, and collectively communicate that the primary goal of monitoring technologies is fisheries data collection.	4.1, 4.5	Ongoing	Incorporate general terms and communication strategies for writing regulations, technical documents, and various forms media. Include section in first working group report documenting use of terminology
c	Evaluate risks and benefits of technologies across different fisheries and data requirements	There are many choices in designing a monitoring program, including hardware, software, data transmission,	3.5, 4.4	Year 3	ICES Cooperative Research Report on best practices

	to establish methodological acceptance for science and management.	and other technical aspects. Additionally, it can be challenging to incorporate data from new sources into existing monitoring programs and stock assessments. This TOR is a handbook for those designing/redesigning their programs that illustrates how to integrate new information of comparable accuracy/precision and quality with data collected through traditional means.			
d	Develop tools and innovative strategies for collecting, handling, processing and analysing fishery-dependent data from electronic technologies	Many technologies are being deployed alongside one another (e.g., VMS, electronic logbooks, and REM). This TOR will examine how to integrate the many data collection technologies in a single approach to ease the reporting burdens and costs of data collection, reduce duplication of effort.	4.2, 4.3	Year 3	Section of working group report providing technical guidelines on integration of fishery-dependent data from various sources in a consistent manner.
e	Report on developments in machine learning and computer vision technologies and their applications in fisheries dependent data collection and cooperate with WGMLEARN on methodological advances and communicate with WGMLEARN on the topic.	The field of computer vision and machine learning is rapidly advancing in fisheries. This TOR will be examined at each working group meeting and other opportunities of engagement to ensure our working group products reflect current applications	4.3, 4.4	Ongoing	Produce a peer-reviewed paper summarising the state of the art in year 3.
f	Organize a session at ICES ASC			Year 2	Topic session in 2020

Summary of the Work Plan

Year 1	Produce an annual overview of the working group's progress
Year 2	Produce an annual overview of the working group's progress
Year 3	Produce a final report on the working group's progress and completed TORs

Supporting information

Priority	Fisheries stakeholders and managers are looking to improve the timeliness, quality, cost effectiveness, and accessibility of fishery-dependent data by integrating innovative technology into monitoring programs. Remote electronic monitoring (REM) has clear potential to meet these challenges by incorporating cameras, gear sensors, and electronic reporting (ER) into fishing operations. We believe that ICES can provide a forum for exchanging information to share relevant technical applications and policy development to harmonize how data is collected and used for fisheries management and science.
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Resource re- quirements	None to ICES, nationally the programs that will provide input to this group are established, there is no need for additional resources.
Participants	Electronic monitoring is a growing topic of interest, with programs in every Region in the United States and the EU. We expect an initial working group to consist of 20-30 people, with expansion into other parts of the globe growing the group to more than 50.
Secretariat facil- ities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	
Linkages to other commit- tees or groups	WGMLEARN, WGCATCH, WGFAST, PGDATA WGSFD, WKSEATEC ICES Data Centre, DIG
Linkages to other organiza- tions	

Annex 3: Examples of feedback reports in ET programmes

Example 1: Alaska – EM hard drive report for sensor and video review

Drive Report for Sensor and Video Review			
This document summarizes EM data review for the following drive(s). This report may not be inclusive of all EM issues. This report may contain sensitive or confidential information and is intended only for the vessel owner(s), vessel operator(s), or authorized representative(s). If you are not the intended recipient, you may not access this report or share the information with any other unauthorized person, and must immediately destroy all copies. By downloading this document, you acknowledge notification of any potential violations of the terms and conditions of the exempted fishing permit.			
Report ID:	Vessel Name / Date	Date of Dataset Begin:	10/xx/2020
Vessel Name:		Date of Dataset End:	10/xx/2020
Date of Report:		Date Drive Received:	10/xx/2020
Completed By:		Number of Fishing Trips on Drive:	3
Trip Number:	Return Date:	Fish Ticket Number	
1	10/xx/2020	E20xxxxxx	
2	10/xx/2020	E20xxxxxx	
3	10/xx/2020	E20xxxxxx	

Note this is a sample. The data presented here is not real. It is very rare for multiple events to be reported on a drive report. Most drive reports have at most one category with a note.

Event	Present?	Comments
Hard drive submitted in the required time period	Yes	
Hard drive submitted with a complete dataset	Yes	
Logbooks submitted in the required time period	Partial	Sample Text Trip 2 logbooks submitted late due to Internet issues.
Logbooks submitted complete	Partial	Sample Text Trip 2, Haul 2: Rockfish kept for personal use not recorded in the logbook Please record all personal use in logbook
Number of trips on hard drive does not exceed maximum trips allowed under vessel's EFP	No	Sample Text Drive submitted after 4th trip (3 trips are allowed per hard drive)
Vessel recording continued through offload	Yes	
Pre-Trip Function Test Completed	Yes	
If a critical malfunction occurred, the vessel stopped fishing until it was resolved or downgraded (Note: they are allowed to complete the haul if gear is already deployed)	N/A	
Data Quality		Sample Text Trip 1, Haul 6: 3 sensor/video gaps during the beginning of the tow,

	Sensor and Video Data Complete (No Time Gaps)	Partial	~1.5 minutes each. These did not impact review. Trip 2, Haul 4: During the middle of the tow, the system rebooted itself and lost the forward deck camera. This did not impact review as the other views covered what we needed to see. These issues did not occur again for the remaining trips on the drive. There was a note in the logbook that recorded the system reboot and forward deck camera issue.
	All catch handled inside of camera view and consistent with VMP. Camera views are unobstructed, lighting adequate, etc. Ability to identify the species of fish caught and/or discarded or the fate of the catch is uncompromised by image quality	Yes	
	All discarding occurred at VMP designated control point	Yes	
Catch	All fish retained other than operational discards, animals larger than 6-ft, unavoidable discards	Yes	<u>Sample Text</u> Trip 2 Haul 2: Had a 25,000 lb. net bleed/overfull net. Recorded in logbook.
Other Notes: Reviewers will report weight/count for fish discards			

Example 2: Northeast Groundfish – Feedback on discard reporting in EM-ER audit program

**NOAA**
FISHERIES

Groundfish Electronic Monitoring Summary Report

Fishing Year: 2019Report Run on: 2019-06-19

Trip Information

Sector: NotReel Sector
Vessel: FakeFischer
Permit: 123456
Trip ID: 123456190819
DOCID: 9876543
Message ID: 7777
Gear: GNS
Date Sail: 2019-06-01 01:30:00
Date Land: 2019-06-02 17:59:00
EM Data Received: 2019-06-01

Trip Status

EM Program: 100% EM
EM Trip Submission: **VALID: 100% EM hauls observed**
VTR Resolution (HAUL or TRIP): HAUL
Percent Hauls EM Observed: 100%
Delayed Catch Processing: YES
Audit Eligible: YES
Audit Rate: 50%
Audit Selected: YES
EM-VTR Discard Comparison Audit: **FAIL**
Discard Source: **EM**

EM and VTR Groundfish Species VTR - EM Discard Differences (lbs)

Species	Audit Threshold	EM	VTR	Difference (VTR minus EM)
CAT	50	0	0	0
COO	25	50	80	30
FLBB	50	0	0	0
FLDAB	100	0	0	0
FLGB	50	0	0	0
FLSD	100	0	0	0
FLYT	50	0	12	12
HACO	100	25	125	100
HAL	50	27	21	-6
POLL	100	75	100	30
POUT	50	0	0	0
RED	50	20	20	0
WHAC	50	50	55	5

Rows highlighted in red indicate species exceeding the audit threshold lbs

Download (CSV)

Example 3: Gulf of Mexico snapper-grouper – Example of feedback provided to a captain on effort and species distribution of catch for 2 years participation

Report Provided by Mote Marine Laboratory, Center for Fisheries Electronic Monitoring

1. Trips Recorded per Year

Retrieval_Year	Number_of_Trips	Cumulative_Trip_Sum
2019	5	5
2020	2	7

2. Hauls Reviewed per Year (25% of total recorded)

Retrieval_Year	Number_of_Hauls_Reviewed	Cumulative_Haul_Sum
2019	27	27
2020	11	38

3. Sea Days with Video Data Recorded per Year

Retrieval_Year	Days_Fished	Cumulative_Days_Fished
2019	64	64
2020	30	94

4. Most Frequently Caught Species (Top 20)

Common Name	Number Caught	% of All Catch
Red Grouper	988	52.75
Red Snapper	274	14.63
Yellowedge Grouper	146	7.79
Blueline Tilefish	103	5.50
Tilefish, Golden	84	4.48
Dogfish, Spiny (Cuban)	31	1.66
Atlantic Sharpnose Shark	28	1.49
Gag Grouper	27	1.44
Scamp	19	1.01
Tiger Shark	19	1.01
Red Porgy	16	0.85
Blacknose Shark	14	0.75
Snowy Grouper	11	0.59
Eel, Unidentified	10	0.53
Sandbar Shark	9	0.48
Moray Eel, Unidentified	7	0.37
Nurse Shark	6	0.32
Gray Triggerfish	5	0.27
Hake, Unidentified	5	0.27
Little Tunny	5	0.27

Note: Based on our 25% review of your complete recorded set haul events, there have been 1,873 fish caught from 50 different species/species groupings.

5. All Sharks Caught

Common Name	Number Caught	% of All Catch	% of All Sharks
Dogfish, Spiny (Cuban)	31	1.66	26.72
Atlantic Sharpnose Shark	28	1.49	24.14
Tiger Shark	19	1.01	16.38
Blacknose Shark	14	0.75	12.07
Sandbar Shark	9	0.48	7.76
Nurse Shark	6	0.32	5.17
Silky Shark	5	0.27	4.31
Dogfish, Smooth (Florida)	3	0.16	2.59
Scalloped Hammerhead	1	0.05	0.86

Note: 97% of all sharks arrived alive.

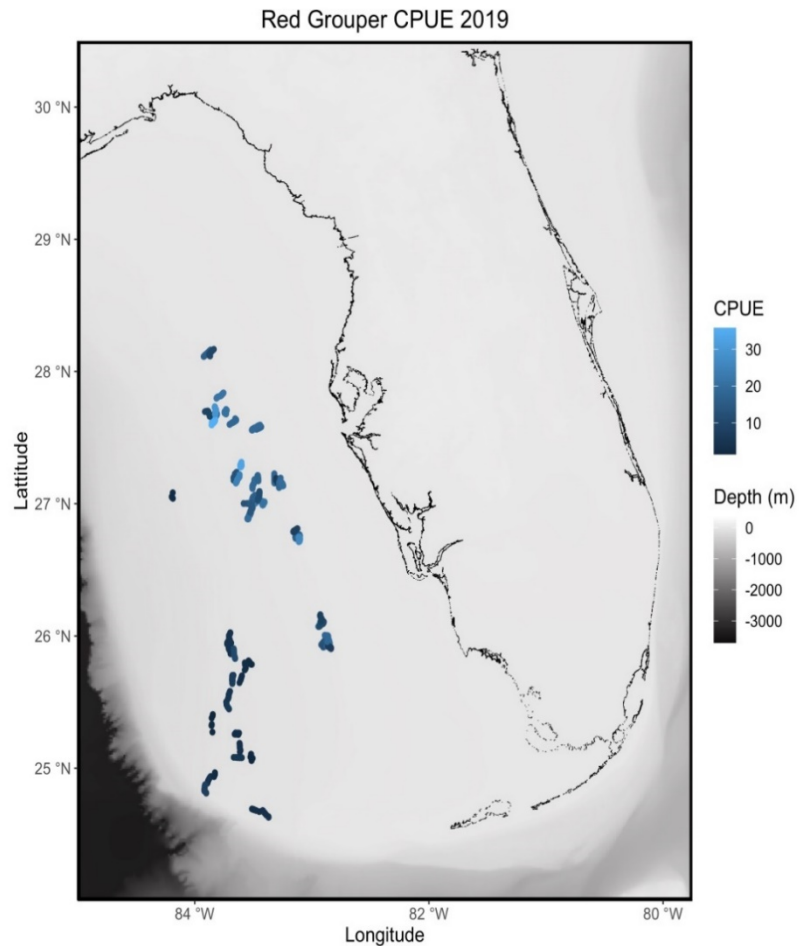
6. Fate of Target Species

Catch Fate	% of Red Grouper	% of Red Snapper	% of Other Bony Fishes
Discarded - Dead	1.72	9.12	2.44
Discarded - Live and Damaged (Not Vented)	0.20	0.73	0.41
Discarded - Live and Healthy (Not Vented)	17.81	33.21	2.44
Discarded - Live and Healthy (Vented)	25.71	11.31	0.20
Discarded - Unknown	0.30		0.61
Retained	53.95	44.89	85.74
Unknown Fate	0.30	0.36	0.41

7. All Catch (Top 25)

Common Name	Number Caught	Relative Frequency (%)
Red Grouper	988	52.75
Red Snapper	274	14.63
Yellowedge Grouper	146	7.79
Blueline Tilefish	103	5.50
Tilefish, Golden	84	4.48
Dogfish, Spiny (Cuban)	31	1.66
Atlantic Sharpnose Shark	28	1.49
Gag Grouper	27	1.44
Scamp	19	1.01
Tiger Shark	19	1.01
Red Porgy	16	0.85
Blacknose Shark	14	0.75
Snowy Grouper	11	0.59
Eel, Unidentified	10	0.53
Sandbar Shark	9	0.48
Moray Eel, Unidentified	7	0.37
Nurse Shark	6	0.32
Gray Triggerfish	5	0.27
Hake, Unidentified	5	0.27
Little Tunny	5	0.27
Silky Shark	5	0.27
Snakefish	5	0.27
Speckled Hind	5	0.27
Flatfish (all)	4	0.21
Jolthead Porgy	4	0.21

8. Example of a species/specific map that can be automatically generated using R, provided to vessel captains and owners, and tailored to specific requests. A 10 x10 minute grid can be placed over this map to help guide fishing effort (note: not included here to maintain confidentiality).



Annex 4: Case studies of ET monitoring programmes solutions

ET Program 1: Scotland - Cod Catch Quota Trial

Organizations: Marine Scotland

Fishery Description: Demersal trawl fleet (~150 vessels) fishing seine nets or and otter trawls for mixed whitefish

ET Fleet Description (as a proportion of the total fishery fleet): 14-24 vessels (10-15% of fleet annually)

ET Systems and Requirements: Electronic monitoring, electronic reporting, observers (<1% coverage), and vessel monitoring systems (VMS), ML (onshore and still in development). Sensors: hydraulic (net drums).

Monitoring and Reporting Regulations:

Required: 100% ER: submit e-log entries on a daily basis, 100% VMS (2-hour ping rates).

Voluntary: 100% EM: submit e-log entries on a haul by haul basis, 20% video review, < 1% observer coverage (no requirement).

Purpose and Program Evolution: catch-management scheme for cod – reduce stock mortality for cod by incentivizing increased selectivity by imposing a cod discard ban to participants. EM used to ensure compliance with scheme conditions.

Data Collection: Fishing Operations; Timestamp, positional data, vessel activity, vessel identifier, Gear sensor data, Crew catch handling. **Catch;** bycatch, length, aggregate weight, weight individual, species ID, disposition, size-class, protected species interaction/sightings.

Applications of Artificial Intelligence (AI) and Machine Learning (ML): Counting number of discarded fish by species.

Components and description of the AI/ML system: Annotated training data, instance segmentations, image classifier, object tracker.

The system consists of four components: a dataset of training images with corresponding manual annotations; an instance segmentation system that detects and outlines individual fish, based on the Mask R-CNN algorithm; an image classifier that identifies species of individual fish; and finally an object tracker that tracks individuals across frames, allowing an individual appearing in a video to be counted once. The first step involves selecting frames for the dataset for annotation. Large portions of videos feature a static conveyor belt with little to no changes. Images should be chosen such that they differ from one another; as images with repeated content are not useful from a machine learning perspective. This can be done manually, or by automatically tracking the belt and grabbing a frame when a large enough portion of the belt (we use 50%) has scrolled out of view. Selected frames are uploaded to a web-based annotation system, where domain experts annotate them by outlining individual fish and identifying their species. Once this is done, annotations are downloaded and used to train the Mask R-CNN instance segmentation system. Mask R-CNN detects individual fish and predicts an outline for each one. Each detected fish is then 'cut out' from the image and passed to the species classifier (a standard ResNet image classifier) that predicts the species. Finally, an object tracker associates detections

between adjacent frames, allowing fish to be tracked in each frame throughout a video. This also allows species predictions to be averages over a range of frames, improving accuracy.

Challenges:

- Integration of data into stock assessment
- Voluntary participation only (Incentives no longer feasible under EU landing obligation)
- EM imagery review and data management is resource hungry

Successes:

- Activity mapping
- Cost analysis vs. at-sea observer programme
- Post-hoc ML project in development using historic footage from scheme
- Analysis of observations of marine litter

Best Practices:

- EM vessels treated as separate fleet in Scottish catch estimation procedure.

Resources and Publications:

1. The Scottish Conservation Credits Scheme – WWF Report 2015 http://assets.wwf.org.uk/downloads/scottish_conservation_credits_scheme.pdf
2. Coby L. Needle, Rosanne Dinsdale, Tanja B. Buch, Rui M. D. Catarino, Jim Drewery, Nico Butler, Scottish science applications of Remote Electronic Monitoring, ICES Journal of Marine Science, Volume 72, Issue 4, May 2015, Pages 1214–1229, <https://doi.org/10.1093/icesjms/fsu225>
3. Catch Quota Management Scheme August 2011 Report – Marine Scotland <https://www2.gov.scot/Topics/marine/Sea-Fisheries/management/17681/CQMS082011>
4. French, G., Fisher, M., Mackiewicz, M. & Needle, C. T. In Amaral S. Matthews, T. P. S. M. & Fisher, R. (Eds.) [Convolutional Neural Networks for Counting Fish in Fisheries Surveillance Video](#), Proceedings of the Machine Vision of Animals and their Behaviour (MVAB), BMVA Press, 2015, 7.1-7.10. Note: Best paper Award.

ET Program 2: Scotland - Modernisation of the Scottish Inshore Fishing Fleet (Phase 1 – Scallop dredge fleet)

Organizations: Marine Scotland

Fishery Description: Two species of scallop are commercially exploited in Scottish waters; primarily the larger king scallop (*Pecten Maximus*) but also the smaller queen scallop (*Aequipecten opercularis*). Fishing with Newhaven dredges; heavy-duty metal framed nets mounted to tow bars, pulled over the seabed with a row of spring-loaded metal teeth mounted on the front edge to rake the seabed. No limits on landings in the form of TACs or quotas.

ET Fleet Description (100% of fleet to be fitted, started roll-out March 2020): Currently ~120 vessels (90 >12 meters) in the fleet, 17 (20%) of which are equipped with EM systems.

ET Systems and Requirements: EM (GPS, winch sensors + 2 cameras positioned to monitor the tow bars deployment and retrieval allowing the number of dredges on the tow bars to be observed), ER, VMS (> 12 m).

Monitoring and Reporting Regulations:

Required: 100% ER, 100% VMS (2-hour ping rates). For compliance purposes EM review is on a risk based approach, dependent on fishing location, size of vessel and the number of dredges.

Purpose and Program Evolution: To promote sustainable and responsible fishing whilst facilitating a level playing field for Scotland's scallop sector:

- If EM systems are installed, that allow Marine Scotland Compliance to inspect the number of dredges being used in real time, vessels are able to fish with an additional 2 dredges per side in the 6-12 nautical mile area (10 per side total). Without EM systems vessels can fish up to 8 dredges per side in the 0-12 nautical mile area.

The main objectives of the programme are to use EM to;

- Ensure that Scallop dredging is compliant with all relevant regulations.
- Build an evidence base of the spatial distribution of dredging activity in Scottish waters to embed inshore fisheries management into wider marine planning.
- Promote transparency and accountability within the fleet and if required have non-circumstantial evidence to support investigating alleged infringement of fishing regulation.

Data Collection: Fishing Operations; Timestamp, Positional data, Vessel activity, Vessel identifier, Gear sensor data, Gear configuration.

Applications of Artificial Intelligence (AI) and Machine Learning (ML): N/A

Components and description of the AI/ML system: N/A

Challenges:

- Current camera set up does not include suitable view points for collecting information on catches. WP8 of SMARTFISH H2020 project is conducting sea trials to determine what biological data could be collected (counts, length measurements, ages) and developing recommendations for additional cameras for scientific data collection.

Successes: TBC - programme is in its early stages of implementation.

Best Practices: TBC - programme is in its early stages of implementation.

Resources and Publications:

1. [Scottish Inshore Fisheries Strategy 2015²](#)
2. [Modernisation of Scotland's Inshore Fleet \(2020\)³](#)
3. News article: [Scottish gov't under pressure to impose real-time tracking on all inshore fishing vessels⁴](#)

² <https://www2.gov.scot/Topics/marine/Sea-Fisheries/InshoreFisheries/InshoreFisheriesStrategy>

³ <https://www.gov.scot/binaries/content/documents/govscot/publications/minutes/2020/02/inshore-fisheries-management-and-conservation-group-meeting-may-2019/documents/ifmac-meeting-may-2019-presentation---inshore-fleet-modernisation-programme/ifmac-meeting-may-2019-presentation---inshore-fleet-modernisation-programme/govscot%3Adocument/IFMAC%2Bmeeting%2BMay%2B2019%2B-%2Bpresentation%2B-%2Binshore%2Bfleet%2Bmodernisation%2Bprogramme.pdf>

⁴ <https://www.undercurrentnews.com/2019/02/27/scottish-govt-under-pressure-to-impose-real-time-tracking-on-all-inshore-fishing-vessels/>

ET Program 3: Scotland - Trial Electrofishery for Razor Clams

Organizations: Marine Scotland

Fishery Description: Razor clams (*Ensis siliqua*, *E. magnus* - previously known as *E. arcuatus*)

ET Fleet Description (as a proportion of the total fishery fleet): 26 vessels (2 currently inactive; 100% of fleet) hand diving (scuba) for clams exposed on the seabed surface behind towed electrodes.

ET Systems and Requirements: Electronic monitoring – GPS and sensor only, weekly paper reporting to port of administration.

Monitoring and Reporting Regulations:

Required: 100% trip coverage, EM validation of pre-trip notification information and electrofishing activity conducted only within specified 'production areas'. Vessels are responsible for the provision of accurate scientific data to Marine Scotland Science (MSS): electronically submitting a length frequency of one sample each month and sending a live sample (on rotation) per trial area per month.

Purpose and Program Evolution:

Prior to the 2018 scheme razor clams could only be legally harvested in Scotland by hand, by divers or by dredge however there was evidence of an unmonitored illegal electrofishery expanding to meet burgeoning demand from overseas. Since the trial started electrofishing is the sole method permitted to catch razor clams commercially. Objectives include:

- Management goals: to ensure that trial participants are compliant with its terms and conditions at all times and that shellfish harvesting is safe and compliant with all relevant regulations and to encourage good stewardship among trial participants.
- Biological goals: to gather 'baseline' local level information on razor clam populations and stocks and to obtain further information about the impacts of the electrofishing method on target and non-target species.
- Economic goals: to support the Scottish inshore fishing sector, in particular diversification opportunities for the sector.

Data Collection: Fishing operations data only: Vessel identifier, Timestamp, Positional data, gear sensor data.

Applications of Artificial Intelligence (AI) and Machine Learning (ML): N/A

Components and description of the AI/ML system: N/A

Challenges:

- EM system issues and occasional 'tampering' or manipulation of equipment. Data transmission depends on the 3G network and can take time to reach the server – live data would be preferable.
- Effective communication with stakeholders and gov. divisions regarding data collection and quality – written logbooks contain limited and often poor quality information.
- Integrating data from different sources and gov. divisions at differing temporal and spatial resolutions.

Successes:

- Large quantities of 'first look' biological and EM sensor data to determine the fishing footprint.
- Stakeholder buy in to regulating the fishery.

Best Practices:

- Application of ICES WGSFD benthic indicators developed for VMS to EM sensor data.

Resources and Publications:

1. Breen, M., Howell, T., and Copland, P (2011). A report on electrical fishing for razor clams (ensis sp.) and its likely effects on the marine environment. Marine Scotland Science Report Volume 2 No 3.
2. Marine Scotland (2019). [Update: Electrofishing for razor clams trial⁵](https://www.marinescotland.gov.scot/topics/marine/sea-fisheries/management/razors/trial) (1 February 2018 – 31 January 2019).

ET Program 4: Chile - Electronic Monitoring Program for Bycatch and Discards

Organizations: SERNAPESCA Servicio Nacional de Pesca y Acuicultura, Chile (compliance agency), SUBPESCA Subsecretaría de Pesca y Acuicultura, Chile (regulatory agency)

Fishery Description: Mixed groundfish species, pelagic fisheries

ET Fleet Description (as a proportion of the total fishery fleet): 140 industrial vessels using bottom trawl, mid water trawl purse seine, and longline, this represents the entire industrial fleet

In Chile Industrial fleet is composed of any vessel longer than 18 meters total length. Smaller than 18 m are considered artisanal for administrative and regulatory purposes

ET Systems and Requirements: Electronic monitoring, electronic logbooks, and vessel monitoring systems (VMS) are required for all the industrial fleets. Artisanal fleets (12-15 m) are required only VMS, smaller than 12 m does not have ET requirements. Observers are mandatory and embarked in artisanal and industrial fleets but only for scientific purposes and with lower coverage compared to EMS

Monitoring and Reporting Regulations:

Required in industrial fleet: 100% EMS coverage, 100% ER (electronic logbooks), 100% VMS. However observers are deployed in a random scheme covering from 5% to 100% depending on the fishery

Voluntary: There is currently not a voluntary program

Required in artisanal fleets: As of 2024, 100% EMS coverage will be mandatory in artisanal vessels from 15 to 18m. Currently 100% VMS in vessel from 12 to 18 m. No mandatory electronic logbook for artisanal fleets, it may be used in a voluntary basis. Observers are deployed in a random scheme covering from 1% to 5% depending on the fishery.

Purpose and Program Evolution: Use of EM is to monitor compliance with discard and bycatch regulation. Recently was added the role to EMS of monitoring compliance with other fishery regulation in general. VMS used for effort and compliance with area restriction of operation for certain fleets. In Chile there are marine parks, prohibition to operate on seamounts and also areas of exclusive operation for artisanal fleets.

⁵ <https://www.webarchive.org.uk/wayback/archive/20180129173825/http://www.gov.scot/Topics/marine/Sea-Fisheries/management/razors/trial>

Data Collection: data collection is performed by Sernapesca according to local regulation and requirements.

Applications of Artificial Intelligence (AI) and Machine Learning (ML): In phase of study for future implementation. Is expected for 2021 or later

Components and description of the AI/ML system: Not implemented yet

Challenges: Not implemented

Successes: Reduced video review rates, better reporting,

Best Practices: Develop a robust data standard and a process for adjusting video review rates over time.

1) Chilean Industrial fleet

Purpose: Control compliance with discard and bycatch reduction measures established in 2019 through mandatory reduction plans, including handling protocols, species authorized or banned to discard, use of mitigation devices and good fishing practices. From 2019 industrial fleets have to sort and report all catches (including discards) in a set by set basis and are mandated to retain or are allowed to discard some species.

1. Control of compliance with fishing regulation at sea
2. Individual accountability for discard of species managed with quota
3. Control of compliance with discard ban for some species
4. Control of compliance with bycatch handling protocols
5. Reduce burden associated with humans inspectors, solve logistical constraints
6. Gather data that may be used for multiple purposes (compliance and science)
7. Improve fisheries sustainability, improve access to more demanding markets

Requirements:

1. EMS required in the entire industrial fleet as of January 2020, Electronic Logbooks also required in the entire industrial fleet as of 2020. VMS has been required for many years. Electronic reporting must be performed through electronic logbooks in a set by set basis.
2. EMS is required from 2024 in all the artisanal fleet ranging from 15 to 18 m. Electronic logbook is voluntary however paper logbook is mandatory. VMS is required for vessels longer than 12 m in pelagic fisheries and longer than 15 m in other fisheries.
3. Observers are mandatory for both industrial and artisanal fleets but in coverage ranging from 1% to 100% depending on the fishery. Their role and jurisdiction is only for science, they don't monitor compliance

Regulations: EMS (cameras onboard), Electronic Logbooks, VMS and Observers

Program Evolution

- 2012: Discard and Bycatch Law was enacted initiating a process that included diagnosis, reduction and monitoring compliance
- 2013-2018 Discard and Bycatch Research programs are performed in all the industrial fleets through observers onboard. (Sanctions are exempted conditional to participation in research programs). The objective is identify magnitude and causes of the problem
- New Regulations on observers are enacted
- New Regulations on provision of information by fishermen are enacted
- 2015 Regulation on EMS is enacted
- 2015 Regulation on Electronic Logbooks is enacted
- 2018-2019 mandatory reduction plans for discard and bycatch are elaborated along the fishing users in different fisheries management committees involved.

- Reduction plans are enacted becoming mandatory
- 2019 -2020 All the fishing regulation is reviewed against new evidence collected by research programs in order to reduce regulatory discards
- 2019 voluntary implementation of EMS
- 2020 EMS is implemented and operating in the entire industrial fleet
- 2020 Feedback meeting with fishing users to discuss findings
- 2021 Pilot projects to implement EMS in artisanal fleets

Sensors: speed/GPS, frame by seconds depending of the operation, 2-7 video cameras

Number of vessels height of scheme: ~140 (the entire industrial fleet)

Current # of vessels: ~110 (all the operative vessels in 2020)

Data collected:

- ER: caught and discarded weights for all species, with emphasis in quota species
- GPS: Time, date, position for each set
- Quota managed discard species ID of each discard (group for certain groups of species) .
- Record interactions with sharks, rays, marine mammal and seabird

Challenges: Video review costs, storage, integrating data from different sources (VMS; EMS, logbooks), use of EMS information for science and management, incorporating a vast artisanal fleet (over 500 vessels) in a cost-effective way, cultural challenge to involve fishermen, lack of incentives to adopt EMS

Publications:

1. Discard Law
<https://www.bcn.cl/leychile/navegar?idNorma=1044210>
2. Observer's regulation
<https://www.diariooficial.interior.gob.cl/media/2014/09/02/do-20140902.pdf>
3. EMS Regulation
<https://www.diariooficial.interior.gob.cl/publicaciones/2017/03/18/41712/01/1194730.pdf>

ET Program 5: France - EMS tuna purse seine fishery

Organizations: ORTHONGEL-CFTO-IRD-OD

Fishery Description: Tuna purse seine fisheries

ET Fleet Description (as a proportion of the total fishery fleet):

- 8 (over 11) EMS equipped purse seine vessels in the Indian Ocean
- 2 (over 9) EMS equipped purse seine vessels in the Atlantic Ocean
- All vessels equipped with ERS (electronic logbooks) and VMS

ET Systems and Requirements:

- Electronic reporting (ERS) + vessel monitoring systems (VMS)
- EM monitoring (cameras, GPS, sensors):
 - a. 10 vessels equipped with cameras to monitor bycatch and discards catch composition as well as safe handling and releasing techniques for sensitive species (sharks, whale sharks, mobulids, sea turtles).
 - b. GPS positioning of fishing sets

- Hard drives transported from the Western Indian Ocean fishing grounds to France at the end of each fishing trip
- 2 Electronic observers are needed to review recordings

Monitoring and Reporting Regulations:

Required

- 20% onboard observer coverage,
- 100% ER
- 100% VMS (60-minute ping rates)

Voluntary

- Complementary onboard or electronic observation to reach 100 % coverage
- In the Indian Ocean:
 - 63% (7/11) purse seiners with a routine EMS scientific observation of discards (the rest of the vessels are covered by onboard observers)
 - 92% of video with sufficient quality to be reviewed
- In the Atlantic Ocean: EMS installed onboard 2 vessels but only onboard observers used

Data Collection: Date and position of fishing operations, Type of fishing sets (Floating Objects - FOBs, free swimming schools), Estimates of discards (including bycatch and tuna) per species (when the identification at the species level is possible), Description of catch sorting operations (counts per minutes of discarded fish), Application of safe handling and releasing techniques for sensitive species, Other recent EM project (in trial), Description of catch brailing operations (number of brailers, brailer fullness) and total catch evaluation, Test of stereoscopic cameras to measure discarded individuals

Purpose and Program Evolution:

2013-2018: Pilot project ("Electronic Eye Optimization" project)

- Increase observer coverage to reach 100% (voluntary program from the Producer Organization ORTHONGEL and its member fishing company CFTO), by using EM as a solution for vessels that cannot board an observer
- Validate EM as a scientific observation tool for French and Italian tropical tuna purse seiners, in particular to estimate discards (in number and volume)
- Evaluate the pros and cons of EM compared to onboard observation
- Monitor the application of safe and fast releasing techniques for sensitive species

Since 2018: EM and onboard observation optimization

- Evaluate the possibility to use EM to improve/ onboard observation protocols (for scientific purposes)
- Evaluate the possibility to use EM to validate total catch declared in logbooks and location of fishing sets (for control purposes)
- Evaluate the possibility to use EM in real-time by onboard observers to improve data collection on sensitive species (for scientific purposes and as part of sustainability programs of the fleet)
- Further improvement of EM configuration before full validation of the tool: dead angles, water projections, storage devices, etc
- Further tests of EM tools: stereoscopic cameras, etc

Challenges:

Data collection:

- Need for further improvement in EMS configuration: lack of lighting, too high discard belt speed in the lower deck, dead angles on the upper and lower decks, etc
- Lack of discard identification at the species level on the upper deck (cameras too far from catch handling areas)
- Lack on information on the use of Floating OBjects (except for FAD deployment operations, other operations occurring too far to be observable)

EMS record reviewing and data storage:

- Fragility of hard drives during transport
- Delayed analyses (hard drives transported from Indian Ocean to France, effect of the COVID-19 pandemic in 2019)
- Lack of software tools (webservice) for direct EMS data entry in the up to date version of the ObServe database (delay in data validation)

EMS and fishing crews:

- Need of EMS maintenance by fishing crews (camera cleaning)
- Need constant monitoring and feedback on-board and on-land to ensure recording quality (decrease of EMS record quality noticeable in 2019)
- Lack of positive incentives (compared to onboard observer physical presence) for fishing crews to apply safe and fast releasing techniques for sensitive species

Successes:

- Simultaneous coverage of the upper and lower decks (impossible for onboard observers)
- Relatively good monitoring of discards at the species level in the lower deck (82% of the total individuals)
- Complementary information provided by the EMS to describe fishing and sorting operations in space and time in details
- Complementary information provided by the EMS to improve onboard observer protocols.
- Standardization of EMS information to integrate the collected data in the common onboard/EM database (ObServe)

Best Practices:

- Fix problems of deficient hard drives, lightning, discards belt speed, dead angles to improve the current percentage of video exploitation
- Reconfigure EMS in concordance with the evolution of management and scientific needs.
- Develop a robust data monitoring and EMS best practices advices to ensure EMS video quality (recording failure alert, camera cleaning by fishing crews)
- Improve feedback and communication between all stakeholders
- Develop a user friendly software to improve EMS reviewing

Resources and Publications:

Website Thalos

<https://www.thalos.fr/en/solutions-en/superviser-en/oceanlive-en.html>

Publications:

1. Briand, K., Bonnieux, A., Dantec, W.L., Couls, S.L., Bach, P., Maufroy, A., Relot-Stirnermann, A., Sabarros, P., 2018a. Comparing electronic monitoring system with observer data for estimating non-target species and discards on French tropical tuna purse

seine vessels - ICCAT presentation | Bycatch Management Information System (BMIS), p.14. https://www.iccat.int/en/pubs_CVSP.html

2. Briand, K., Sabarros, P., Maufroy, A., Relot-Stirnermann, A., Le Couls, S., Goujon, M., Bach, P., 2018b. Improving the sampling protocol of electronic and human observations of the tropical tuna purse seine fishery discards | IOTC. Presented at the Working Party on Ecosystems and Bycatch 14-18, p. 19. <https://www.iotc.org/documents/improving-sampling-protocol-electronic-and-human-observations-tropical-tuna-purse-seine>

ET Program 6: South Georgia – Toothfish-Archipelago Electronic Monitoring Program

Organizations: Argos Ltd., Sanford Ltd., Polar Ltd., Government of South Georgia and South Sandwich Islands, Archipelago

Fishery Description: Toothfish (demersal longline)

ET Fleet Description (as a proportion of the total fishery fleet): 6 bottom longline vessels (100% of the fleet)

ET Systems and Requirements: Electronic monitoring, daily electronic reporting, 100% observers, AIS, and vessel monitoring systems (VMS)

Monitoring and Reporting Regulations:

Required: 100% human observer coverage, 100% EM, 100% daily ER, 100% VMS (60-minute ping rates), 100% AIS, electronic Catch Documentation Scheme

Voluntary: initially 33% EM coverage with Trip Reports done covering data collected, regulatory requirements and 5% catch accounting

Data Collection: Fishing Operations (Timestamp, Positional Data, Vessel Activity, Vessel Identifier, Crew Behaviour and Practices, Event Unique Identifiers, Crew Catch Handling), Catch (Bycatch, Length, Species ID, Disposition, Protected Species Interaction) plus not on our list last year, Regulatory (Use of Bird Mitigation Devices, Tagged Fish Recovery).

Purpose and Program Evolution Initially a compliance only, industry led project. The goal was to show progressiveness in the fleet and offset observer workloads to allow greater biological data collection. The regulator liked the approach enough they made 100% EM a requirement in the next licencing round. Now all boats carry EM and observers on 100% of the trips as required, plus are each looking to use EM to their own advantage (either collecting data of company significance or by enabling scientific/regulatory data collection to enhance their licence applications in the next round).

Challenges: Extreme environment for the technology. One trip per season (make or break). Global fleet, six vessels and four flags so challenging logistics. Regulator not prepared to take in EM data.

Successes: Streamlined data review. Standardized reporting. Regulator engaged in proper EM program design process.

Best Practices: Vessels 100% committed to delivering top quality data. Expanded vessel role in system performance (all vessels voluntarily carry extensive spare parts list). Collaboration on data reported.

ET Program 7: Netherlands - Fully Documented Fisheries

Organizations: Wageningen Marine Research

Fishery Description: beam trawlers

ET Fleet Description (as a proportion of the total fishery fleet): 6 – 8 vessels

ET Systems and Requirements: Electronic monitoring, computer vision device

Monitoring and Reporting Regulations:

Voluntary: scientific project

Purpose and Program Evolution Investigate the possibilities of complete catch registration of target species (“Fully Documented Fisheries”) under the European Landing Obligation in the Dutch beam trawl fishery based on EM and computer vision technology.

- Develop EM review methods to complete document catch (fully documented). (No audit model to check a random selection of catch registration form logbooks).

Data Collection: 6 hauls for each trip for 6-8 vessels.

Applications of Artificial Intelligence and Machine Learning:

Develop Machine Learning technology to automatically record target species during catch processing on board the vessels, without interfering in the current procedures on board. As a consequence of the later requirement, ML methods need to be able to recognize fish which is possible only partially visible, due to debris or overlapping fish on sorting belts.

Challenges: Deal with the fear of fishers, that EM will be used for control purposes.

Successes: Promising results in experimental set up of automated catch registration.

Best Practices: An operational automated catch sorting system from which the industry will benefit, e.g. data ownership, increased transparency, reduce administrative burden of logbook registrations, insight in fishing practices, etc.

Resources and Publications:

edwin.vanhelmond@wur.nl

ET Program 8: USA West Coast Region - Multispecies Groundfish Catch Share Electronic Monitoring Program

Organizations: NOAA Fisheries

Fishery Description: Mixed groundfish species, Pacific whiting, sablefish

ET Fleet Description (as a proportion of the total fishery fleet): Catcher vessels: 58 vessels using midwater trawl, bottom trawl, trap/pot gear. Majority of midwater Pacific Whiting vessel using EM.

ET Systems and Requirements: Electronic monitoring, observers, and vessel monitoring systems (VMS)

Monitoring and Reporting Regulations:

Required: 100% at-sea observer coverage for discard catch accounting, 100% shorebased landings monitoring, 100% VMS (15-minute ping rates)

Voluntary: 100% EM (replaces 100% observer coverage), 100% of video reviewed, 100% discards reported in logbook when using EM.

Purpose and Program Evolution Use of EM to validate paper logbook at-sea discard reporting in lieu of catch share observers. Under the catch share program, participants delivering to shore-based processing plants are required to obtain monitoring both at-sea and shorebased. Mother-ship catcher vessels (catcher boats delivering Pacific whiting to an at-sea processor) are also required to have at-sea observer coverage. To ease the transition costs of monitoring, the National Marine Fisheries Service (NMFS) paid for initial monitoring coverage in early years which then gradually shifted to full cost responsibility to industry. With increased industry costs for human observers, the possibility of using EM as a potential cost-savings alternative was considered. The EM program has been operating under Exempted Fishing Permits (EFP) since 2015. Under the EFP, NMFS pays for EM data services (hard drives, data review and storage) through grant funding to PSMFC. Vessel owners pay for their own EM system hardware and technical support services.

Full program implementation under regulations is expected January 1, 2022, with costs for data review and data storage shifting from federal government to industry responsibility.

In order to augment the EM data with additional biological sampling, bottom trawl, optimized retention midwater trawl, and fixed gear trap/pot vessels using EM enter a selection pool for scientific observer coverage (about 30% of EM trips). The West Coast Groundfish Observer Program (WCGOP) deploys observers to EM catch share vessels, in addition to non-catch share groundfish fisheries throughout the west coast.

VMS is used for compliance across all fisheries, with recent changes to ping rate of once every 15 minutes.

Data Collection: Electronic Monitoring (imagery, sensor, GPS), logbook

Challenges:

- Multispecies bottom trawl catch handling (crew handling discards in ways that allows for sufficient EM data capture but still allows for cost-effective vessel operations).
- Longline catch handling protocols
- Costs
- Industry data storage requirements
- Reduced video review rates

Successes:

- Successfully integrated EM reported discards into NMFS catch accounting programs and the West Coast Fishery Observer Bycatch and Mortality Reports
- Increased EM participation over the progression of the EFPs, particularly in the Pacific whiting shorebased and at-sea sectors
- Development of database infrastructure in support of NMFS assessment of service providers and data submission.

Best Practices:

Developed service plan guidelines for EM service providers: <https://www.fisheries.noaa.gov/permit/electronic-monitoring-service-provider-permit-and-em-service-plan>

ET Program 9: Alaska - Electronic Monitoring Program for Small Fixed Gear Vessels

Organizations: NOAA Fisheries, Pacific States Marine Fisheries Commission, Saltwater Inc., Archipelago Marine Research Ltd., Alaska Longline Fishermen's Association

Fishery Description: Mixed groundfish species using nontrawl (fixed) gear

ET Fleet Description (as a proportion of the total fishery fleet): 173 vessels out of 929 using pot and longline gear.

ET Systems and Requirements: Electronic monitoring, electronic reporting, observers, and vessel monitoring systems (VMS)

Monitoring and Reporting Regulations:

Vessels are monitored on selected trips through EM systems or at-sea fishery observers. Vessels may annually opt into the EM program for monitoring with EM systems in lieu of at-sea fishery observers.

Required: 17% observer coverage or 30% EM coverage, 100% VMS (pot gear only)

Voluntary: 100% of video reviewed

Purpose and Program Evolution: Use EM for catch accounting, including species ID, counts, discard monitoring, and compliance with regulations.

Applications of Artificial Intelligence (AI) and Machine Learning (ML): AI/ML not currently deployed, but there is ongoing research for length measurement and species identification.

Components and description of the AI/ML system: N/A

Challenges: Time between fishing and video review, addressing vessel non-compliance in a timely manner

Successes: Industry support, participation from vessels in remote locations and on smaller vessels.

Best Practices: Iterative development over several years in partnership with vessel operators before putting into regulation.

Resources and Publications:

1. NOAA Alaska Region's EM programs: <https://www.fisheries.noaa.gov/alaska/resources-fishing/electronic-monitoring-alaska>
2. Ongoing research by the Alaska Fisheries Science Center on AI/ML for the EM program on small fixed gear vessels;
3. <https://www.fisheries.noaa.gov/feature-story/advancing-innovative-technologies-modernize-fishery-monitoring>
4. <https://www.fisheries.noaa.gov/feature-story/developing-machine-vision-collect-more-timely-fisheries-data>
5. Cahalan, J.A., B.M. Leaman, G.H. Williams, B.H. Mason, and W.A. Karp. 2010. Bycatch characterization in the Pacific halibut fishery: A field test of electronic monitoring technology. NOAA Tech Memo NMFS-AFSC-213. 66 pp.
6. Huang, T., J. Hwang, S. Romain and F. Wallace. 2019. Fish Tracking and Segmentation from Stereo Videos on the Wild Sea Surface for Electronic Monitoring of Rail Fishing. *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 29, no. 10, pp. 3146-3158, Oct. 2019, doi: 10.1109/TCSVT.2018.2872575.

7. Huang, T., J. Hwang, S. Romain and F. Wallace. 2019. Recognizing Fish Species Captured Live on Wild Sea Surface in Videos by Deep Metric Learning with a Temporal Constraint, *IEEE International Conference on Image Processing (ICIP)*, Taipei, Taiwan, 2019. pp. 3407-3411, doi: 10.1109/ICIP.2019.8803592.
8. Wallace, F., K. Williams, R. Towler, and K. McGauley. 2015. Innovative Camera Applications for Electronic Monitoring. In: G.H. Kruse, H.C. An, J. DiCosimo, C.A. Eischens, G.S. Gislason, D.N. McBride, C.S. Rose, and C.E. Siddon (eds.), *Fisheries Bycatch: Global Issues and Creative Solutions*. Alaska Sea Grant, University of Alaska Fairbanks. <http://doi.org/10.4027/fbgics.2015.06>

ET Program 10: Alaska - Electronic Monitoring Pilot Program in the Pollock Pelagic Trawl Catcher Vessel Fisheries

Organizations: NOAA Fisheries, Pacific States Marine Fisheries Commission, Saltwater Inc., Archipelago Marine Research Ltd., United Catcher Boats, Alaska Groundfish Data Bank, Inc., Aleutians East Borough, 9 processors.

Fishery Description: Pollock Pelagic Trawl Catcher Vessels in the eastern Bering Sea and Gulf of Alaska.

ET Fleet Description (as a proportion of the total fishery fleet): 47 out of 116 catcher vessels.

ET Systems and Requirements: Electronic monitoring on the vessel combined with shoreside fishery observers.

Monitoring and Reporting Regulations:

Vessels are required to take at-sea fishery observers, but may volunteer for a pilot program testing EM coverage in lieu of at-sea fishery observers

Required: Bering Sea 100% observer coverage, Gulf of Alaska 24% observer coverage

Voluntary: 100% of video reviewed

Purpose and Program Evolution: EM for compliance monitoring, shoreside observers for catch sampling including monitoring salmon bycatch and collecting biological information.

Data Collection:

Applications of Artificial Intelligence (AI) and Machine Learning (ML): N/A

Components and description of the AI/ML system: N/A

Challenges: Meeting sampling goals of the shoreside observers and enhancing logistical communication.

Successes: Industry support, weekly meetings between project team, support from Regional Fishery Management Council.

Best Practices: Frequent and transparent communication with stakeholders during testing phase

Resources and Publications: N/A

ET Program 11: Alaska - Electronic Monitoring on Catcher/Processors and Motherships

Organizations: NOAA Fisheries

Fishery Description: Each of the following programs were implemented with specific compliance monitoring goals:

- Video monitoring of at-sea scales evaluates tampering on scales that weigh all/most catch at-sea.
- Video monitoring of salmon bins ensures no pre-sorting prior to observer sampling
- Video monitoring of salmon ensure fishery observers can sample salmon for prohibited species catch limits
- Video monitoring on vessels participating in halibut deck sorting ensure fishery observers are present and can sample Pacific halibut for prohibited species catch limits

The monitoring programs above are used in the following fisheries:

- Bering Sea and Aleutian Island (BSAI) Non-Pollock Trawl Catcher/Processor
- Bering Sea Pollock Trawl Catcher/Processors and Motherships
- Central Gulf of Alaska Rockfish Trawl Catcher/Processor
- BSAI Pacific Cod Longline Catcher/Processor

ET Fleet Description (as a proportion of the total fishery fleet): 67 out of 67 vessels

ET Systems and Requirements: Electronic monitoring on the vessel combined with at-sea fishery observers.

Monitoring and Reporting Regulations:

Required

200% observer coverage (these vessels carry two observers on all fishing days)

- Bering Sea and Aleutian Island (BSAI) Non-Pollock Trawl Catcher/Processor (C/P)
- Bering Sea Pollock trawl Catcher/Processors and motherships

100% observer coverage

- Central Gulf of Alaska Rockfish Trawl C/P
- BSAI Pacific Cod Longline C/P (some vessels have 200% observer coverage)

Voluntary: video is reviewed when requested by NOAA Fisheries

Purpose and Program Evolution: EM for compliance monitoring

ET Program 12: Gulf of Mexico (GoM) US - Electronic Monitoring in the Gulf of Mexico Commercial Reef Fish Fishery

Organizations: Mote Marine Laboratory's Center for Fisheries Electronic Monitoring at Mote (CFEMM). **Collaborators** - WaterInterface LLC., Saltwater Inc., GoM Reef Fish Shareholders' Alliance, GoM reef fish fishery vessel owners, captains, crew (members of Shareholders Alliance, Southern Offshore Fishing Association, and Independent), Fish Houses, dealers, and industry businesses. Collaborations and scientific advisors at state and federal management agencies: Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute,

NOAA AFSC, Seattle, WA, NOAA NMFS SERO, St. Petersburg, FL, NOAA NMFS SEFSC, Miami, FL, and NOAA NMFS SEFSC, Galveston, TX.

Fishery Description: Gulf Reef Fish Species, primarily groupers, snappers, and tilefish.

ET Fleet Description: Commercial bottom longline and vertical line vessels; up to 20, current 15, target of 20-21 in 2021, (currently 27% of active permitted GoM vessels).

ET Systems and Requirements: Electronic monitoring (voluntary) and vessel monitoring systems (VMS). Observers (~2% / yr. coverage), trip intercept program, discard reporting (voluntary).

Monitoring and Reporting Regulations:

Required: ~2% / year observer coverage, 100% VMS, trip intercept program (TIP) as available

Voluntary: CFEMM EM 25% of complete set haul events reviewed/trip; captain logbooks for discard reporting (NOAA voluntary program).

Purpose and Program Evolution: Advance regional capacity of EM in the GoM reef fish fishery towards implementation; bycatch accounting; discard condition; document shark depredation and interactions with species of concern.

Data Collection: >200 metadata variables; fishing operations - date, time, gear, location (sets and hauls), soak time; catch, discards – disposition, fate, vented or not vented, entanglement, length measurements (in trials); document shark and marine mammal depredation; document seabirds and sea turtles; shark bycatch species, sex, size range for maturity. Gulf-wide dataset (as of 11/2020) includes: Species Annotations = 98,155, Species/species groupings = 129, Trips = 265, Reviewed Hauls = 1,661, Sea Days = 2,318.

Applications of Artificial Intelligence (AI) and Machine Learning (ML): Identifying shark interactions on unreviewed set-haul events; Catch and bycatch identification and length measurements.

Components and description of the AI/ML system: Currently labelling annotated images as training sets for AI development.

Challenges: Voluntary fleet, aging vessels, captain and crew turnover; fishers concerns - privacy, possible non-beneficial regulation changes, EM does not negate taking on-board observer.

Successes: Addressing industry requests – provide data to improve fishing efforts and sustainability, document shark and marine mammal depredation. Fishers positive feedback –useful trip species bycatch and discard data, corresponding hot spot maps, catch video compilations, catch and gear depredation documentation. In-House - reduced video review rates; trained professional “citizen scientists” volunteer assistance team – provide video review and other tasks (reduce overall program costs); implemented >50 QA/QC checks; application of R for timely industry and management data outputs; developed precise location and temporal data for spatio-temporal identification of undesirable events (shark depredation, choke species, heavy discard areas); integrated an underwater camera and deployment device integrated with the SI EM system for documentation of large sharks cut off at rail, improved identification of species, sex, and maturity; expanded vessel coverage Gulf-Wide; contributing EM data for consideration into management data streams; networking – including SEDAR 68, 70, and 72 as panelist, ACCSP EM Working Group, ICES Technology Integration for Fishery-Dependent Data Working Group; increased collaborations with federal and state agencies, industry, researchers, and businesses; involvement of multiple NOAA scientific advisors.

Best Practices: Collaborate with stakeholders to establish best methods for timely and efficient integration of EM data with other fishery dependent data sources for management and industry applications.

EM Contributions:

1. CFEMM website:
<https://mote.org/research/program/fisheries-ecology-and-enhancement/electronic-monitoring-project>.
2. Neidig, C., M. Lee, R. Schloesser, D. Roberts, and R. Schloesser. 2020. EM-Gulf of Mexico Commercial Reef Fish Fishery. International Exploration of the Sea (ICES) - Working Group on Technology Integration. Presentation. 6-8 October 2020
3. Neidig, C., M. Lee, R. Schloesser, D. Roberts. 2020. D. Preliminary Non-Technical Fishery Profile and Limited Data Summary for Scamp, *Mycteroperca phenax*, with Focus on the West Florida Shelf: Application of Electronic Monitoring on Commercial Snapper Grouper Bottom Longline Vessels. SEDAR68-DW-22. Pp. 15.
4. Neidig, C., M. Lee, R. Schloesser, D. Roberts. 2020. Bottom Longline Discard Summary for Greater Amberjack, *Seriola dumerili*, with Focus on the West Florida Shelf: Application of Electronic Monitoring. SEDAR70-WP-08. Pp. 8.
5. Neidig, C., D. Roberts, M. Lee, and R. Schloesser. Eye on the Gulf - Electronic Monitoring: An Emerging Technology and Platform for Science in the Gulf of Mexico Snapper-Grouper Fishery. SEDAR 68 Scamp and Yellowmouth Grouper. Discards Working Group. Presentation. 1 May 2020.
6. Neidig, C., D. Roberts, M. Lee, and R. Schloesser. Eye on the Gulf: Electronic Monitoring in the Gulf of Mexico Snapper-Grouper Fishery. SEDAR68 – Commercial Working Group. Presentation. 13 April 2020.
7. Neidig, C., D. Roberts, and M. Lee. Gulf of Mexico Snapper Grouper Fishery - Linking EM Data with Other Fishery-Dependent Data. Atlantic Coastal Cooperative Statistical Program (ACCSP). Presentation. 18 August 2020.
8. Neidig, C. 2020. Projects in the Field: Eyes on the Gulf. EM4Fish.
<https://em4.fish/projects-in-the-field-eyes-on-the-gulf/>
9. Neidig, C., D. Roberts, M. Lee. 2019. Eye on the Snapper Grouper Fishery - Preliminary Assessment: Factors, Decisions, and Tradeoffs EM Pilot Work in the Gulf of Mexico. National EM Workshop. New Castle, NH. Presentation. 13-14 November 2019.
<https://s3.amazonaws.com/media.fisheries.noaa.gov/2020-09/2020-EM-National-Workshop-Report-FINAL-4-webready.pdf?ci7Mq1XPdpkHw2yzVtxGTtWXXObKWlPr>
10. Roberts, D., C. Neidig, M. Lee, R. Schloesser. 2019. Electronic Monitoring Program Design: Video Review and Data Processing Cost Considerations in a Pilot Reef Fish Monitoring Program in the Gulf of Mexico. National EM Workshop. New Castle, NH. Presentation. 13-14 November 2019. <https://s3.amazonaws.com/media.fisheries.noaa.gov/2020-09/2020-EM-National-Workshop-Report-FINAL-4-webready.pdf?ci7Mq1XPdpkHw2yzVtxGTtWXXObKWlPr>
11. Neidig, C. L., D. Roberts, M. Lee. 2019. Eye on the Gulf - Electronic Monitoring: An Emerging Technology and Platform for Science in the Gulf of Mexico Snapper Grouper Fishery. Gulf of Mexico Fishery Management Council, Galveston, TX. Presentation. 21-24 October 2019. Tab E, No. 7. <https://gulfcouncil.org/meetings/council/october-council-meeting-2019/>
12. Roberts, D. and C. Neidig. Exploratory Use of Electronic Fishery Monitoring to Spatially Characterize Distribution and Catch of Targeted Reef Fish and Bycatch along the West Florida Shelf. AFS FL Chapter. Presentation. 3-5 April 2019.
13. Neidig, C., D. Roberts, M. Lee, J. Steinwachs, T. Taccardi, R. Ryterman, D. Law, B. Hilbrunner, and S. Hayes. Electronic Monitoring – Emerging Technology and Platform for

- Science in the Gulf of Mexico Commercial Reef Fish Fishery. AFS FL Chapter. Presentation. 3-5 April 2019.
14. Neidig, C., M. Lee, J. Gill, W. Derr, W. Wolf, M. Hickey, G. Cudihy, G. Sato, D. Roberts, N. Williams. Electronic Monitoring – Emerging Technology and Platform for Science in the Gulf of Mexico Commercial Reef Fish Fishery: Pilot Investigations - Underwater Camera and Digital Ruler. AFS FL Chapter. Poster. 3-5 April 2019.
 15. Neidig, C., T. King, B. Hueter, and K. Leber. Electronic Monitoring in the Gulf of Mexico Snapper Grouper Fishery. AFS, EM Technologies Special Session, Tampa, FL. Presentation. August 2017.

ET Program 13: Northeast US - Vessel Monitoring System Program

Organizations: NOAA Fisheries, United States Coast Guard, State Law Enforcement.

Fishery Description: Limited Access Scallop, NE Multispecies, Monkfish, Herring, Surf Clam/Ocean Quahog, Mackerel/Squid, and any other fishery a vessel participates in if they hold any of the above VMS required permits.

ET Fleet Description (as a proportion of the total fishery fleet): Approximately 1000 vessels out of 4301 vessels permitted in the Northeast, about 23% of the region.

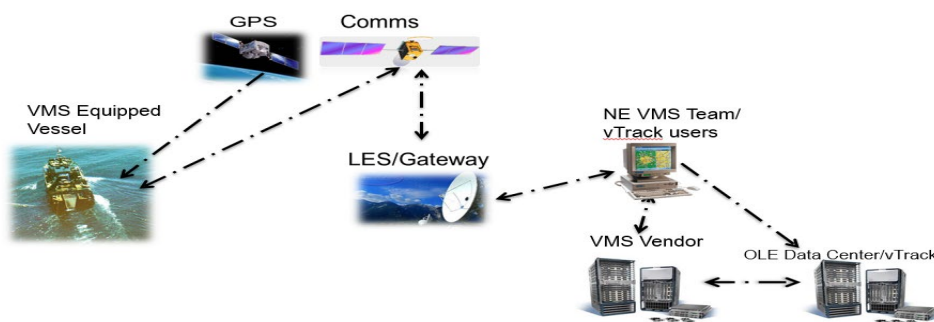
ET Systems and Requirements: VMS requires the ability to send GPS position reports, send required fisheries forms (ex: daily catch and pre-land reports), and receive and send messages. The VMS should not be interfered with.

Monitoring and Reporting Regulations: Specific VMS regs can be found at 50 CFR 648.9, 50 CFR 648.10 and throughout the NE regulations and notices.

Required: VMS is required by any vessel that holds a VMS required permit in the fisheries listed above.

Voluntary: A vessel can voluntarily use VMS if it is not required. We see this sometimes if a vessel wants VMS for safety reasons and the ability to send e-mails while at sea. The VMS team will let an owner know if they are not required to use VMS and leaves it up the owners if they voluntarily want to share their data with NOAA Fisheries.

Data Collection:



Purpose and Program Evolution: VMS is a satellite surveillance system primarily used to monitor the location and movement of commercial fishing vessels in the U.S. Exclusive Economic Zone and treaty areas. The system uses satellite-based communications from on-board transceiver units, which certain vessels are required to carry. The transceiver units send position

reports that include vessel identification, time, date, and location, and are mapped and displayed on the end-user's computer screen. Other uses for VMS include

- Managing sensitive and protected areas, like marine sanctuaries.
- Monitoring activity and arrivals in port to plan for sampling.
- Supporting catch share programs.
- Tracking, monitoring, and predicting fishing effort, activity, and location.
- Managing observer programs.
- Verifying/validating data from other sources.
- Identifying fishing vessels.

Challenges: **1,** Vendor/Satellite outages (rare, but happens) and latency. **2,** Yearly software updates to account for changes with fishery reporting requirements. For example, scallop areas change yearly so the vessel needs to be able to choose from the correct list of areas to send an activity declaration for the area to be fished. Challenges occur with the software testing and release to the fleet. **3,** Making sure the fleet is aware of their VMS requirements (ie: send a declaration on every trip, even if taking the same type of trip every day). **4,** High cost (satellite communications).

Successes: VMS is used to support law enforcement initiatives and to prevent violations of laws and regulations. VMS also helps enforcement personnel focus their patrol time on areas with the highest potential for significant violations. The system operates 24 hours a day, 7 days a week with near-perfect accuracy, which is why the program is of interest to other users, including the U.S. Coast Guard, academia, and the coastal states. VMS data are, by law, subject to strict confidentiality requirements.

Best Practices: Continued monitoring of the program by technicians and help desk staff to make sure the best quality data are received and reports are accurate.

Resources and Publications: VMS data are used in many NEFSC, NFMFC, MAFMC, and USCG reports/publications.

1. <https://www.fisheries.noaa.gov/national/enforcement/regional-vessel-monitoring-information>
2. <https://www.northeastoceancouncil.org/>
3. <http://portal.midatlanticocean.org/>

ET Program 14: Northeast U.S. – Electronic Reporting Program

Organizations: NOAA Fisheries - Greater Atlantic Regional Fisheries Office (GARFO)

Fishery Description: Vessel Trip Reporting (VTR) logbook program for GARFO-permitted vessels active in fisheries managed by the New England Fishery Management Council (NEFMC) and Mid-Atlantic Fishery Management Council (MAFMC).

ET Fleet Description (as a proportion of the total fishery fleet): The current electronic vessel trip reporting (eVTR) fleet is approximately 750 vessels, or 33% of the active fleet of 2000 vessels that have a VTR requirement. The existing eVTR fleet consists of users who are either required to report electronically or who volunteer to report electronically. At present, only those vessels permitted in for-hire fisheries (party and charter) managed by the MAFMC are required to report electronically.

ET Systems and Requirements: eVTR users are required to use applications and programs that are reviewed and approved by GARFO. All existing applications are iOS, Android, and

Windows 10 operating systems compatible and function on both smartphones and tablets. One of the approved programs is PC-based and requires installation on a personal computer.

Monitoring and Reporting Regulations: All GARFO-permitted fishing vessels with permits for species managed by the MAFMC and NEFMC are required to submit VTRs documenting all fishing activity and catch. The use of eVTR has been available as an option for all GARFO-permitted fisheries since 2013. In 2018, regulations were put in place to require the use of eVTR in the for-hire fisheries managed by the MAFMC. More recently, GARFO approved a joint action of the MAFMC and NEFMC, in effect, requiring all Federally-permitted vessels (>4,000+) to use ER beginning November 2021.

Required: 800 vessels permitted in MAFMC for-hire fisheries

Voluntary: 3200 vessels permitted in MAFMC commercial and NEFMC for-hire and commercial fisheries.

Data Collection: vessel-based vessel trip reports/logbooks

Purpose and Program Evolution: collection of catch and effort data used to augment landings data reported by seafood dealers.

Challenges: adoption of eVTR on a voluntary basis proved to be challenging and we encountered different forms of resistance including resistance to change in reporting habits, resistance to adopting technology, and resistance to reporting in general. As the regulatory environment gradually moved to mandating electronic reporting, adoption became easier and industry started becoming supportive of electronic reporting.

Successes: eVTR applications have proven to be efficient and easy to use on devices that most industry members already own. Gaining industry support and buy-in has proved successful once industry is introduced to the applications.

Best Practices: Develop technical and data standards that all approved eVTR applications must meet. The presence of support services including help desk, outreach, and training are critical to achieving industry support.

Resources and Publications:

1. [GARFO VTR/eVTR webpage⁶](#)
2. [Vessel Trip Report instructions⁷](#)
3. [eVTR Technical Requirements guide⁸](#)
4. [eVTR Software Application Approval Process⁹](#)

⁶ <https://www.fisheries.noaa.gov/new-england-mid-atlantic/resources-fishing/vessel-trip-reporting-greater-atlantic-region>

⁷ <https://www.fisheries.noaa.gov/webdam/download/108803805>

⁸ <https://www.fisheries.noaa.gov/webdam/download/108889469>

⁹ <https://www.fisheries.noaa.gov/webdam/download/108684572>

ET Program 15: Atlantic Highly Migratory Species Electronic Monitoring Program

Organizations: NOAA/NMFS Atlantic Highly Migratory Species Management Division, Saltwater Inc., ERT Inc.

Fishery Description: U.S. Pelagic longline fishery for Atlantic tunas and swordfish. Fishery is limited access and has a catch share requirement for bycatch of Atlantic bluefin tuna.

ET Fleet Description (as a proportion of the total fishery fleet): ~100 active pelagic longline vessels ranging geographically from Maine through the Gulf of Mexico and the Caribbean

ET Systems and Requirements: All U.S. Atlantic pelagic longline vessels are required to have certified operational EM and VMS systems to embark on trip. These vessels are also subject to being selected to take an at sea observer.

Monitoring and Reporting Regulations:

Required: 100% of longline trips must have the EM and VMS systems powered on prior to departure and the systems must remain on for the entire duration of the trip. The EM systems record haulback of the gear and stores the video and all relevant metadata. Harddrives must be submitted to NOAA/NMFS upon the completion of the trip. The footage is reviewed with a target of 10% trips reviewed with each vessel being reviewed at least once. If bluefin tuna are interacted with on a set, a report must be submitted via the VMS unit no more than 12 hours after completion of haulback.

Voluntary: N/A

Data Collection: Fishery dependent vessel-based video of haulback, review of subsample of the footage/meta data, vessel set reports submitted via the VMS, vessel trip reports/logbooks, at-sea observer reports (if selected).

Purpose and Program Evolution: The purpose of the EM program in the U.S. Atlantic Pelagic longline fishery is to monitor landings and discards to support a catch share program implemented concurrently to address accounting of an Individual bluefin tuna bycatch allocations. The program has undergone one evolution to date to incorporate a binding ICCAT recommendation which requires live release of mako sharks, yet those that are dead at haulback can be retained if disposition can be verified via at-sea observers or EM monitoring.

Challenges: 1, Scope of the Program - currently a narrow compliance purpose, however may not be fully capitalizing on systems data collection/monitoring capabilities and influence on potential management options. 2, Funding - currently the systems are funded with NOAA/NMFS financial support, however these costs may need a different funding model as the scope/longevity of the program evolves. 3, Fishery benefits - it has yet to be fully realized what benefits the fleet derives/can derive by being required to use EM system.

Successes: NOAA/NMFS' ability to implement an EM program to an entire fishery across a broad geographic scope and diverse fleet. Seeing the presence of and use of EM systems/data being weighed more in both domestic and international management evolution. Seeing the fleet gravitate to how the system can be used to provide more fishing opportunities while preserving conservation gains achieved by the system's presence.

Best Practices: With mandated full fleet implementation, robust data are informing the technical and operational standards that accompany this technology. The presence of support services including remote, in person, and regulatory are critical to achieving industry support. Clear lines

of communication between agency, providers, and the fleet allow for programmatic flexibility to address both fishery and technological changes not foreseen upon initial implementation.

Resources and Publications:

1. [Amendment 7 to the HMS Fishery Management Plan¹⁰](#)
2. [3-Year Review of the Bluefin Tuna IBQ¹¹](#)
3. [Amendment 13 Scoping to the HMS Fishery Management Plan¹²](#)

ET Program 16: Northeast US - Groundfish Electronic Monitoring Program-Audit

Organizations: Cape Cod Commercial Fishermen's Alliance, The Nature Conservancy, TEEM Fish Monitoring, NOAA Fisheries (NEFSC and GARFO)

Fishery Description: ~200 active vessels in multispecies groundfish fishery. Roughly 25% larger offshore trip boats (land >25,000# per trip) and remaining 75% smaller day boat fleet. Use Trawl, Gillnet, Longline and Jig.

ET Fleet Description (as a proportion of the total fishery fleet): 21 active vessels, 10% active fleet. Day boat vessels that use all 4 gear types (bottom trawl, bottom longline, rod and reel, and gillnet) and geographically representative (from Maine, New Hampshire, Massachusetts and Rhode Island)

ET Systems and Requirements: Electronic monitoring, electronic reporting, observers, and vessel monitoring systems (VMS)

Monitoring and Reporting Regulations:

Required: Commercial groundfish fishermen in the region may choose to enroll in sectors, which is a catch share management system with annual quota allocations and an industry funded monitoring requirement. Sector vessels must carry human at-sea monitors or EM on a subset of trips to collect data on catch.

Voluntary: N/A

Data Collection: EM system, eVTR (ER), imagery, sensor, transmitted positional data systems, machine learning, fishery-dependent data, monitoring.

Applications of Artificial Intelligence (AI) and Machine Learning (ML): Data [competition¹³](#) in 2017 developed [OpenEM¹⁴](#) tools. Count, measure and ID discarded fish. No AI tools currently used in daily workflow, some in development. Have created annotated training data.

Components and description of the AI/ML system: In Development: Activity recognition, sensor data, still working to integrate Open EM

¹⁰ <https://www.fisheries.noaa.gov/action/amendment-7-2006-consolidated-hms-fishery-management-plan-bluefin-tuna-management>

¹¹ https://media.fisheries.noaa.gov/dam-migration/ibq_program_draft_three-year_review.pdf

¹² <https://www.fisheries.noaa.gov/action/amendment-13-2006-consolidated-hms-fishery-management-plan-bluefin-management-measures>

¹³ <https://www.drivendata.org/competitions/48/identify-fish-challenge/>

¹⁴ <https://github.com/openem-team/openem>

Purpose and Program Evolution: Validate eVTR groundfish discards with EM audit at manageable cost to industry

Challenges: Scalability of program, testing EM for high discard volume vessels in the fishery, camera performance during nighttime, incorporation into existing scientific programs, high program costs related to human video review, and low industry participation.

Successes: Use of EM data in management, approval of EM as a suitable monitoring tool.

Best Practices: Invest in collaborative approach among agency and stakeholders, active communication, understanding data needs prior to program implementation.

Resources and Publications:

1. [FMRD Electronic Monitoring API¹⁵](#)
2. [Electronic Monitoring for Sectors Fact Sheet¹⁶](#)
3. <https://em4.fish/projects-in-the-field-the-new-england-third-party-audit-model-pilot/>
4. Video of conference panel presentation: <https://bcove.video/3g2L3Zv>

ET Program 17: Northeast US - Mid-Water Trawl Herring Electronic Monitoring Program

Organizations: NOAA Fisheries, Northeast Fisheries Science Center, Greater Atlantic Regional Fisheries Office, Saltwater Inc.

Fishery Description: Mid-water trawl vessels, Category A or B herring permits.

ET Fleet Description (as a proportion of the total fishery fleet): Six mid-water trawl vessels (roughly half of the active fleet) have selected EM as their IFM monitoring option.

ET Systems and Requirements: Electronic monitoring, portside sampling, NEFOP observers, at-sea monitors, and vessel monitoring systems (VMS).

Monitoring and Reporting Regulations:

Required: The Industry Funded Monitoring (IFM) Amendment specifies a 50% IFM coverage target for vessels on declared herring trips. Standardized Bycatch Reporting Methodology (SBRM) agency coverage + IFM industry coverage = 50% IFM total target.

Voluntary: N/A

Data Collection: ET, EM, imagery, sensor, transmitted positional data systems, archival positional data systems, fishery-dependent data, monitoring, and control.

Purpose and Program Evolution: EM used to validate catch retention and portside samplers provide biological sampling information on landed catch. Observers used for monitoring and sampling discards at-sea, and VMS used for effort and compliance.

Challenges: Due to COVID-19, there have been delays to observer coverage for all fisheries in the northeast. Given NEFOP includes coverage in the herring fishery, the start of the IFM will likely be delayed until April 1, 2021. Coverage will now align with the SBRM year which will allow the agency to better track and meet IFM coverage needs.

¹⁵ <https://apps-nefsc.fisheries.noaa.gov/FSBEM/index.php>

¹⁶ <https://drive.google.com/file/d/1FoRpxsu2IkUMNj212zguWEwj7baBAMF/view?usp=sharing>

Successes: The northeast region has been awarded internal funds to support both at-sea industry and shoreside agency EM costs in the second year of the IFM (2022).

Best Practices: Not applicable at this time.

Resources and Publications:

1. [GARFO staff presentation¹⁷](#)
2. [Final report of the Herring and Mackerel Fishery Electronic Monitoring Report¹⁸](#)
3. [Memo from Electronic Monitoring review panel members to Dr. Hare and Mr. Pentony, dated March 19, 2018¹⁹](#)
4. [IFM Infographic²⁰](#)
5. [FMRD Electronic Monitoring API²¹](#)

ET Program 18: Northeast US - Groundfish For-Hire Electronic Monitoring Pilot Project

Organizations: The Nature Conservancy, Saltwater Inc

Fishery Description: ~900 federally permitted charter/for-hire vessels in the Northeast. Two general types: Charter=6 passenger limit; Party=>6 passengers (often 25-50 passengers)

ET Fleet Description (as a proportion of the total fishery fleet): First generation pilot completed with 2 vessels, one Charter, one Party

ET Systems and Requirements:

Monitoring and Reporting Regulations:

Required: All MAFMC permitted For Hire vessels required to report catch and effort electronically (see above)

Voluntary: N/A

Data Collection: Recorded EM video on all trips in summer 2019, reviewed 50 charter and 25 Party

Purpose and Program Evolution: Can EM validate eVTR reports from For-Hire vessels? Two vessels ran EM for one season to verify effort (# passengers, time fishing) and catch (# fish caught by species and retained or discarded). EM also collected discard lengths

Challenges: Party boat: numerous passengers make accurate eVTR reporting difficult, and EM review expensive. Avg 3.6 minutes review/one minute of fishing time.

¹⁷ https://s3.amazonaws.com/nefmc.org/1_180419-IFM-Amendment-and-EM-Presentation.pdf

¹⁸ https://s3.amazonaws.com/nefmc.org/2_Herring-and-Mackerel-Fishery-Electronic-Monitoring-Project_Final-Report.pdf

¹⁹ https://s3.amazonaws.com/nefmc.org/3_Memo-from-EM-review-panel.pdf

²⁰ <https://drive.google.com/file/d/1xLhx0qEoZ66cODu0akhKDM9umfitNXrs/view?usp=sharing>

²¹ <https://apps-nefsc.fisheries.noaa.gov/FSBEM/index.php>

Successes: Charter boat: easy for captain to report all effort and catch, and EM review relatively simple (0.8 min video review time/ one minute fishing time). Discard length data statistically matched in person measurements. Passengers indifferent to video cameras.

Best Practices:

Resources and Publications: Coming soon

ET Program 19: Northeast US - Northern Gulf of Maine Scallop Pilot Project

Organizations: Maine Coast Fishermen's Association, New England Marine Monitoring, Teem Fish Monitoring, NOAA fisheries (consulted) and North East Fisheries Management Council (consulted)

Fishery Description: 35-50 ft scallop vessels that participate in 1 month derby style fishery using scallop dredges in the Gulf of Maine. Mostly day trips.

ET Fleet Description (as a proportion of the total fishery fleet): 3 vessels of 40 vessel fleet

ET Systems and Requirements:

Monitoring and Reporting Regulations:

Required: None to date

Voluntary: EM coverage is the only coverage

Data Collection: N/A

Purpose and Program Evolution: N/A

Challenges: N/A

Successes: N/A

Best Practices: N/A

Resources and Publications: N/A

ET Program 20 – Northeast US - Observer At-Sea Information System (OASIS)

Organizations: NOAA Fisheries, Northeast Fisheries Science Center (NEFSC)

Fishery Description: All Northeast fisheries observer and at-sea monitoring programs.

ET Fleet Description (as a proportion of the total fishery fleet): Average trips per year; 106 Industry Funded Scallop, 261 At-sea monitoring (groundfish), and 520 NEFOP, with 117 active observers.

ET Systems and Requirements: Samsung Galaxy Tab Active 8-inch tablet with Android OS

Monitoring and Reporting Regulations:

Required: Groundfish currently has full trip, haul, catch, and biological sampling data entered electronically. Scallop, squid, and high volume fisheries have some catch data entered electronically; other fisheries have only basic information collected electronically. Portside sampling for herring trips is in development and will be completely electronic. Dockside monitoring is operational and completely electronic.

Voluntary: N/A

Data Collection: ET, ER, fishery-dependent data, monitoring, control.

Purpose and Program Evolution: To provide near-real-time reporting for quota-monitored fisheries and tracking of trips for all other fisheries. Electronic data collection began in 2006 and has been progressing steadily since. Slow transition in the groundfish program from paper logs as primary source to paper logs as backup to nearly paperless data collection. Based on the success in moving to paperless in groundfish, the portside sampling program is being developed as a paperless program from the onset.

Challenges: Different needs by fishery and sampling program; development time dictated by management actions. Full requirements not always available before development.

Successes: Transition to paperless nearly complete in groundfish fishery. Responsive development team can incorporate feedback from observers and staff. In-house programmers allow for improved integration between systems (e.g. at-sea collection with data processing and quality control systems).

Best Practices: Collaborate with regions to avoid duplication, share code examples. Understand full scope of fishery upfront (expected number of vessels and trips). Obtain detailed requirements from project lead as early as possible.

Resources and Publications: N/A

ET Program 21: Northeast US - Artificial Intelligence and Machine Learning Research and Development

Organizations: NOAA Fisheries, Northeast Fisheries Science Center (NEFSC)

Fishery Description: Bottom trawl fall and spring NOAA surveys.

ET Fleet Description (as a proportion of the total fishery fleet): Henry B. Bigelow is the first NOAA white ship vessel to carry an EM system.

ET Systems and Requirements: Electronic Monitoring and Fisheries Scientific Computer System (FSCS) reporting.

Monitoring and Reporting Regulations:

Required: N/A

Voluntary: Piloted project to develop a groundfish image library in support of algorithm development in support of Electronic Monitoring programs in the northeast.

Data Collection: ET, EM, imagery, sensor, machine learning, computer vision, fishery-independent data

Purpose and Program Evolution: One salient point found in each application of EM has been that human video review is labor intensive and thus expensive. As a result, there is a need to develop technologies to automate the processing of video data. Automated-image classification via machine learning is an emerging technology that has the potential to enhance the efficiency of video review.

Challenges: Successful algorithm development requires a large training dataset with a consistent legacy. Resulting algorithm development is not a “plug and play” application and requires some level of software development to incorporate into EM service provider annotation software applications.

Successes: Resulting data were collected and correlated to 99% of Fisheries Scientific Computer System (FSCS) trawl survey data. After correlation, the video data were used to create a curated groundfish image library to serve as a launchpad for EM machine learning applications.

Best Practices: The system allows for continuous, high definition, video recording of activities at three sampling locations and a conveyor belt. An object detector network was also successfully trained to validate the utility of the image library for future machine learning applications.

Resources and Publications: N/A

ET Program 22: Gulf of Mexico US – Gulf of Mexico Shrimp Fishery (Multiple projects since 2014)

Organizations: NMFS Southeast Fisheries Science Center (Galveston and Panama City) and Saltwater Inc.

Fishery Description: ~1,420 federally permitted vessels in the Gulf of Mexico; the South Atlantic has 481 federally permitted vessels and 215 rock shrimp vessels.

ET Fleet Description (as a proportion of the total fishery fleet): Currently in third pre-implementation project underway starting August 2020. Initial pilot project involved only one vessel (two were installed on but one volunteer backed out prior to first trip), second project had 2 vessels and current project is hoping to get 12 vessels (combined efforts of a NFWF funded project (5 vessels) and NMFS funded project (7 vessels)).

ET Systems and Requirements: EM system comprises 3 or more cameras to capture full deck view and along both rails, GPS, reel sensor(s), Monitor, keyboard and a main control box. Vessel operators asked to run the EM system for the entirety of every trip.

Monitoring and Reporting Regulations:

Required: 2% observer coverage.

Voluntary: EM coverage for selected volunteer vessels.

Data Collection: Volunteer vessels asked to run EM system on 100% of trips and 100% of processing video will be reviewed.

Purpose and Program Evolution: The initial pilot project was focused on capturing data on fisheries take and mortality smalltooth sawfish. Due to the rarity of sawfish captures and low observer coverage, the level of uncertainty in the estimates of these events is high.

The second pre-implementation project was used to determine if EM could collect imagery of high enough quality for EM reviewers to identify fish above a certain size.

The current project in this fishery is looking at using a modified catch handling protocol to collect basket samples from the nets that is replicating how observers sample on these vessels that will allow the EM reviewer and eventually CV to be able to annotate the catch in these samples.

Challenges: Catch handling, deck space.

Successes: While there were no sawtooth interactions recorded in the first project, EM reviewers were able to identify small sharks, guitarfish and some ray species, all of which were in the same size range that the sawfish would be, leading us to believe that EM could be used to capture sawfish interactions. We also collected footage of a loggerhead turtle caught in the small try-nets the captain uses to determine catch composition when towing the net. These nets are not monitored by observers and are not required to have turtle excluder devices on them which means

protected species could be more easily caught in these nets and less likely to be discovered by observers.

Best Practices: In order for an EM program to be implemented in this fishery, it's likely EM will need to be able to provide a full characterization of catch similar to that which the current onboard observer program can provide. This will require catch handling changes on these vessels by either implementing a conveyor or chute system where all catch can be sorted, or asking crew to take basket or tote samples from each haul and display them in a way that an EM reviewer and eventually CV, will be able to perform species ID for all bycatch.

Resources and Publications: Manuscript for publication in Marine Fisheries Review has been accepted and set to be published in the first quarter of 2021.

Annex 5: ICES 2020/2021 ASC Theme Session proposal

Can technology monitoring programmes deliver timely, cost-effective and quality fishery-dependent data?

Fisheries stakeholders and managers continue to develop and implement electronic technologies (ETs) to improve the timeliness, quality, cost-effectiveness, and accessibility of fisheries-dependent data collection. Electronic monitoring (EM; cameras, gear sensors, and GPS), electronic reporting (ER), and other ETs, together with advancements in computer vision and machine learning, will provide innovative and integrated data collection for monitoring programs to address the increasing scientific and management information needs. As technology advances, it is important to pause and review what is available, share lessons learned, highlight best practice and be sure that programs are selecting the ETs that fit their data collection needs. The process of incorporating ETs into a new monitoring approach has significant challenges including modernizing back-end data infrastructure, validation, optimizing for automation and integration, adapting to emerging needs, and providing data at a scale that will support future management and scientific needs.

The objectives of the theme session are thus to promote and share the ongoing progress made on technology-based, at-sea fishery monitoring, the implementation practicalities and challenges, opportunities for further integration of data collection, extensions of data applications, and analytical approaches and innovation.

Contributions regarding the following three main topics are welcome in this session:

- Understanding the design needs of technology-based, at-sea monitoring from different stakeholders' viewpoints. Can a monitoring enforcement-based programme be used for science and vice versa? Can fishers improve operational efficiency based on information from ET programmes? Will ET programmes address the needs for more industry transparency?
- Understanding the different uses of technology-based, at-sea monitoring information. How can ET information be integrated into the advisory and decision-making process? How have existing ET programmes evolved to benefit additional stakeholders' needs? What have been the applications of ET programmes in conservation? Business planning? Traceability and marketing? What improvements are needed?
- Sharing best practice of effective ET programme implementation. How can we encourage research and development of electronic technology and its applications to improve data quality, drive innovation and cross-sectorial collaboration, and promote best practice? How can we encourage industry participation? What are the lessons learned on integrating EM with machine learning applications?