WORKING GROUP ON TECHNOLOGY INTEGRATION FOR FISHERY-DEPENDENT DATA (WGTIFD; outputs from 2021 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. This report provides a summary over the 3-year period of the discussions and recommendations by technology service providers, academic and governmental marine institutions, and non-profit environmental organizations.

A number of tools 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, which is the use of imagery, sensors, and global positioning systems (GPS) to independently monitor fishing operations, effort, and/or catch, 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 future monitoring programs.

WGTIFD has agreed to pursue the ongoing work from the last three years as well as a number of new initiatives to further advance the implementation of electronic technologies (ETs). WGTIFD will continue to develop ET vocabulary, communication strategies, inventory the various applications of ETs, and evaluate the risks and benefits of developing tools for specific types of fisheries. The new initiatives, focus on standardizing data collected from EM systems and integrating that information into science advice, providing recommendations on interoperability of ET systems, and examining how EM could be used for monitoring bycatch of protected, endangered, and threatened species.

ii Expert group information

Expert group name	Working Group on Technology Integration for Fishery-Dependent Data (WGTIFD)
Expert group cycle	Multi Annual Fixed Term
Year cycle started	2019
Reporting year in cycle	3/3
Chair(s)	Brett Alger, United States
	Lisa Borges, Portugal
Meeting venue(s) and dates	7-9 May 2019, Copenhagen, Denmark, 30+ participants
	6-8 October 2020, online meeting, 40+ participants
	30 November-2 December 2021, online meeting, 40+ 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) 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 addresses goal number 4 of the ICES Strategic Plan: Emerging techniques and Technologies: develop, evaluate, and harness new techniques and technologies — to advance knowledge of marine systems, inform management and increase the scope and efficiency of monitoring.

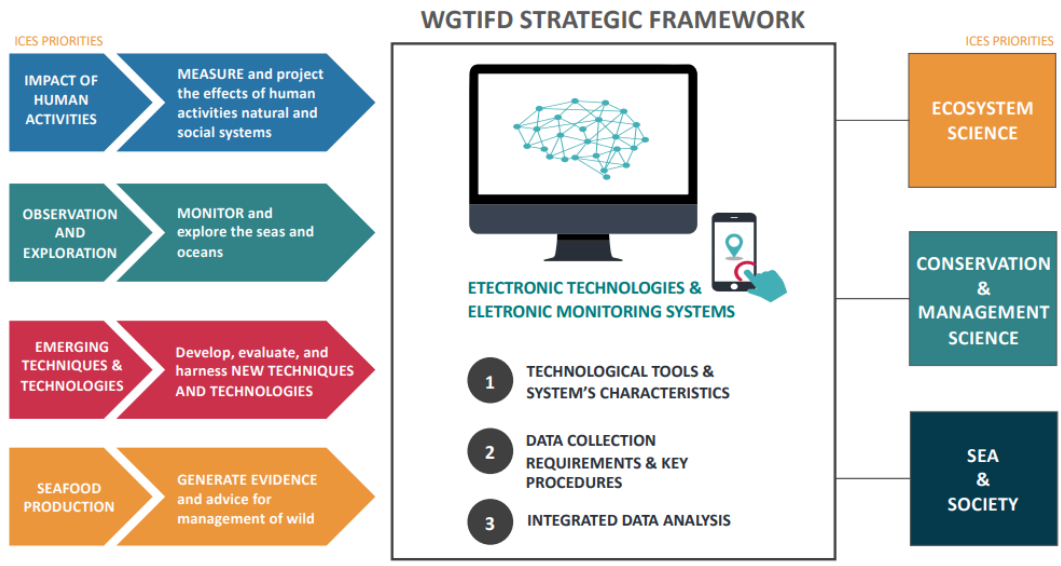

Figure 1. Infographic of WGTIFD in ICES Strategic Plan.

First TIFD meeting 2019

WGTIFD developed a vocabulary list of the common terms used in data collection programs, across technologies, and with diverse applications between different regions and countries within ICES. These efforts helped inventory and review the various national fisheries dependent hardware and software applications and approaches. WGTIFD recommends comparing self-reported data provided by those directly involved in fishing operations, vs. independently collected data from fishing operations that tends to be from ETs (e.g. gear sensors, video, and positional data). It is equally important to evaluate risks and benefits of technologies across different fisheries, data collected from ETs should be integrated while considering the dynamic nature of sampling programs with evolving objectives, but particularly with rapidly evolving technology.

WGTIFD explored different stages of a fishing trip to examine data types and elements, goals and objectives of different programs, the purpose of each data element, and the tools for how each data element may be collected. They agreed to the following 11 stages: 1) Pre-trip notification; 2) Starting a trip; 3) Transiting to fishing grounds; 4) Gear deployment; 5) Fishing activity; 6) Gear retrieval; 7) Handling catch; 8) Transiting from the fishing grounds; 9) Offloading landings; 10) End of trip; and 11) Post-trip data submission. While some fisheries may not replicate these exact stages, the exercise was intended to capture the general operations and data collection requirements of most fisheries. This provided an opportunity to compare tools that require manual collection across all systems, for example, gear type and configuration must be collected manually for paper and electronic logbooks, paper or electronic observer collections systems, or camera-based systems. However, positional data can be retrieved automatically from a variety of new tools rather than manually from paper-based systems. WGTIFD constructed a table (below) that compares four primary ETs and their capabilities of collecting a range of data elements.

Table 1. Comparison between four primary ETs: 1) Electronic reporting (ER); 2) technologies used by independent observers and inspectors (EO); 3) Electronic monitoring (EM); and 4) Transmitted positional data systems. Each tool also has capabilities of collecting a range of data elements (M - Manual, A - Automated).

Data Type	Data Element	ER	EO	EM	Transmitted positional data systems
Fishing Operations	Timestamp	A, M	A, M	A	A
Fishing Operations	Positional data	A, M	A, M	A	A
Fishing Operations	Vessel activity	A, M	A, M	M, A	
Fishing Operations	Vessel identifier	A, M	A, M	A	A
Fishing Operations	Fishery, species target	M	M		M
Fishing Operations	Gear: type, configuration, condition, fouling, bait type, unique identifiers, mitigation tools	M	M	M	
Fishing Operations	Gear sensor data		M		
Fishing Operations	Crew profiles	M	M		
Fishing Operations	Operation costs	M	M		
Fishing Operations	Crew behavior and practices	M	M	M, A	
Fishing Operations	Event unique identifiers	A, M	A, M	A	

Fishing Operations	Crew catch handling		M	M	
Ecosystem	Environmental Data	A, M	M		
Ecosystem	Weather data	A, M	M		
Catch	Bycatch	M	M	M	
Catch	Length	M	M	M	
Catch	Aggregate weight	M	M	M	
Catch	Weight Individual	M	M		
Catch	Species ID	M	M	M	
Catch	Biological/specimen data		M		
Catch	Catch condition	M	M	M	
Catch	Disposition	M	M	M	
Catch	Disposition reason	M	M		M
Catch	Size-class	M	M	M	
Catch	Protected species interaction/sighting	M	M	M	

While ETs hold a lot of promise to improve the timeliness, quality, integration, cost effectiveness, and accessibility of fishery-dependent data, there are a lot of challenges that must be resolved to realize their potential. The WGTIFD identified some of the most common challenges with collecting assessing data from ETs.

- **Costs:** Data infrastructure, storage, training users and ongoing support, scalability from pilot programs, and creating systems that are flexible and adaptable
- **Technology:** Proprietary vs. open source software, data transmission and interference, power supply and system reliability, sensor integration, environmental impediments, species identification with cameras, weight accuracy and precision
- **Timeliness:** Time to review and process imagery, delay in availability of data
- **Lack of policy and standards:** Protocol design and adherence on the vessel, chain of custody, data formats, data access and use, data confidentiality and ownership, development among multiple service providers, technology developing fast (not stable)
- **Data integrity:** Privacy, confidentiality, data loss, tampering
- **Data integration:** data element compatibility with legacy systems, linking fishery-dependent and independent datasets, data integration into management and stock assessments
- **Fisheries/Program management:** unequitable accountability, fishery management complexity, inability to collect biological data, technology/data acceptance issues of fishers

Many fishers are sceptical and resistant to adopt ETs given some of the unresolved challenges and questions about the future of ETs. In some cases, there is large difference between a traditional program built on self-reported data with limited independent monitoring, and the desire to implement fully independent and accountable monitoring programs through the use of EM. These challenges are not insurmountable, and they will only be resolved through appropriate

communication, outreach, and coordination with all stakeholders, primarily fishers, but with technology providers, academia, non-governmental organizations, scientists, and managers. For many fishers, their primary concern is having a clear set of agreements and policies on who has access to the information, and how it can be used. There needs to be a transparent and trustworthy framework of data access and ownership, if adoption of EM systems is to be increased.

A survey of WGTIFD members revealed the main strategies to promote participation in ET projects were to involve fishers from the beginning of the process from bottom up approaches to co-creation of the programs but also that incentives (positive or negative) are also fundamental. Regarding positives incentives, increase quota, access to areas, deregulation, less costs/funding, transparency and certifications were all mentioned, while negative incentives included legal obligation to monitor and sanctions.

Second TIFD meeting 2020

During the three days online discussions, WGTIFD participants documented positive changes in industry behaviour towards ET it-self, 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 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 monitoring programme.

The WGTIFD also 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 recognized 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.

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 recommended 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. WGTIFD provided the following specific 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 processes), 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 be 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.

Finally, WGTIFD provided examples of ET programmes feedback loops (2020 report, Annex 3), a large inventory of ET programmes submitted by the participants (2020 report, 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.

Third TIFD meeting 2021

The third TIFD meeting also occurred online due to the travelling restrictions associated COVID-19 pandemic. The meeting was held over three days (30 November-2 December), on a reduced 3-hour schedule to cater to the 10 different time zones of the 40+ participants. Each day addressed a different topic, covering several of the WGTIFD ToRs, and where two invited speakers presented the theme for the day and initiated discussions. Below is a summary of the discussions and recommendations made by WGTIFD during the three days.

2 Managing and sharing public datasets

Invited talks: Report on standards/guidelines for fisheries-dependent data (Neil Holdsworth, ICES); Collecting, curating, and distributing image-based data (Ben Woodward, CVision AI).

Report on standards/guidelines for fisheries-dependent data (Neil Holdsworth, ICES)

Neil Holdsworth discussed how ICES is dealing with an increase in the complexity of advice requests that require many and diverse data from multiple data sources, coupled with demands from requestors of advice for more stringent quality assurance of the evidence base. ICES has an updated data policy released in 2021 dealing with open access data, but also restricted access data, where respective conditions are specified under different data licences. ICES is also enabling experts, where data management is not their native language, by providing a Data Profiling Tool to be used by WGs as a check list for data and data products (https://www.ices.dk/data/tools/Pages/Data-profiler.aspx). ICES is also providing data governance, building transparency of data processing and assessment methods through the Transparent Assessment Framework (taf.ices.dk) and peer review process, and finally a common language (https://vocab.ices.dk/).

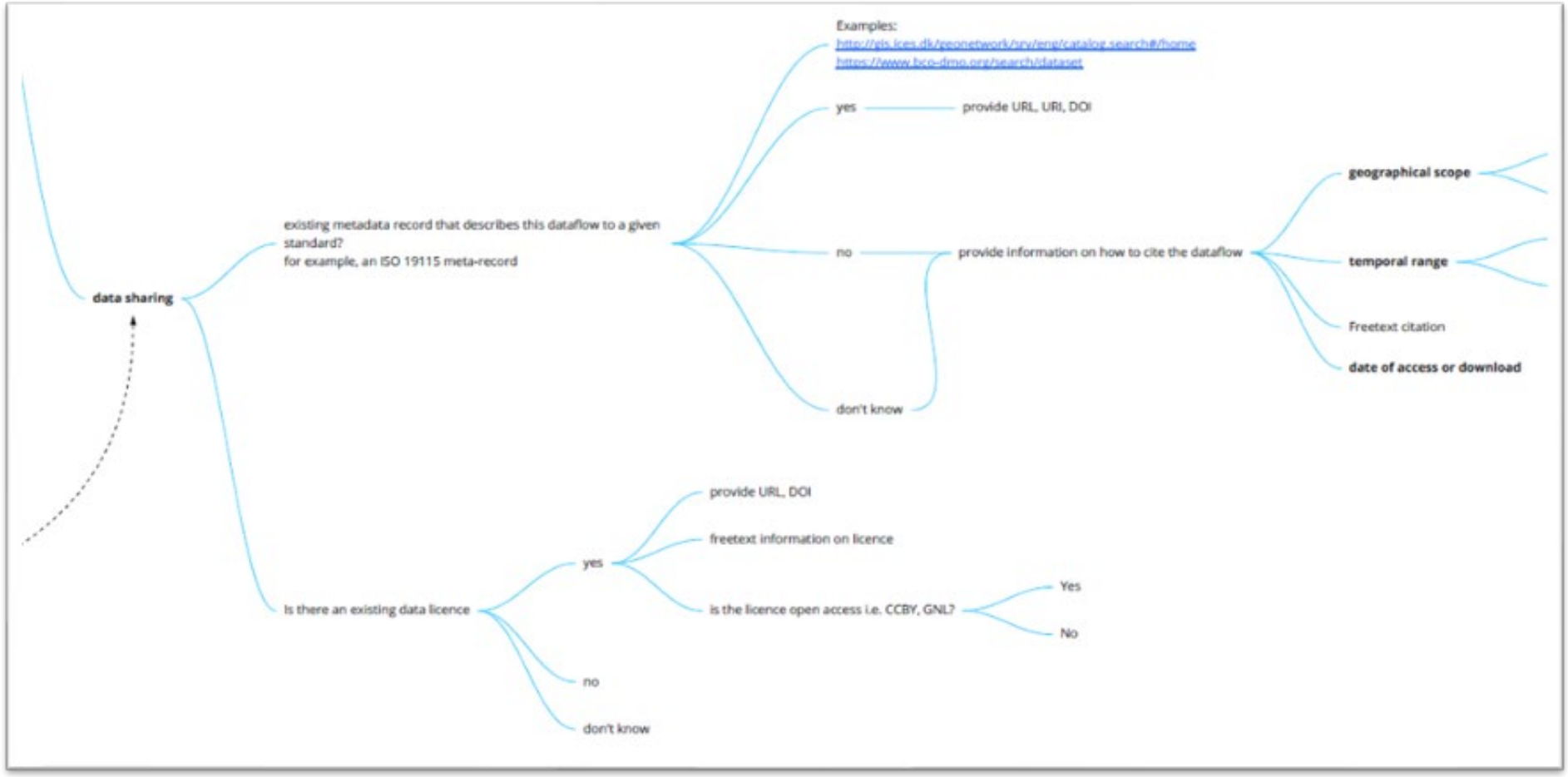

Figure 2. Schematic of Data Profile checklist (https://www.ices.dk/data/tools/Pages/Data-profiler.aspx).

Collecting, curating, and distributing image-based data (Ben Woodward, CVision AI)

Ben Woodward provided case studies for thinking about how to build annotated libraries of imagery and associated metadata for developing AI/ML tools. It is important to have a foundational understanding of the intended use of data, as well as potential future use cases, in order to establish appropriate requirements and standards for data collection and curation. In the first example, Ben highlight his work on NOAAs R/V Henry Bigelow, which conducts fishery-independent surveys for the region. CVision AI and NOAA deployed cameras above the catch sampling stations, combined that imagery with the data entered by the fishery biologists during the survey, which allowed them to create an annotated video dataset suitable for species detection, classification, and tracking. In the future, this will be leveraged to deploy AI/ML tools for collecting data in commercial fisheries. Ben's next example was a project developed in conjunction with The Nature Conservancy, to create fishnet.ai, an annotated image library for EM algorithm development. Third, Ben highlighted FathomNet, an image library for underwater species detection and classification. Each of these projects had unique requirements for data collection, metadata standards, and data sharing that needed to be considered when collecting and curating the library. Based on the totality of his work across the applications, Ben offered two key recommendations:

1. Document annotation and metadata standards for libraries aimed at ML development. Use existing standards wherever possible, but it is most important to completely document the process for the particular data you have.
2. Consider the entire life cycle of your data when setting up your library, including privacy considerations, data sharing restrictions or licensing, and use policies for stakeholders.

The discussion that followed the presentations highlighted that collecting high quality fisheries-dependent data, or cleaning it post-sampling to improve its quality is key to allow for its multiple uses and data products. Different data sources, poor-quality data, or lack of data can make data flows very complex, and makes data standardization and adopting similar data formatting, when possible, very important. Creating additional data standards may not necessarily simplify reporting processes, and can further complicate the processes/forms already in place. WGTIFD agreed that there is a need to explore this issue further, namely in finding similarities/differences between existing standards as well as going through the ICES data toolkit exercises.

The role and responsibility of cleaning data streams and data processes was also discussed. WGTIFD agreed that there should be opportunities for multiple stakeholders to engage early in the data processes to understand the issues involved, noting that trust building is a necessary component of the process to provide greater context for how the data are collected/used/outputted, but that it also requires time and a need for flexible/longer timelines. Stakeholders will need to weigh trade-offs between data access & availability and transparency & accountability, knowing that restrictive data access can limit the development of automation capabilities. Stakeholders should, nevertheless, clarify data access early on, as privacy restrictions can be easily overlooked outside the data management and collection processes. Misunderstandings regarding data responsibility and allowed uses can significantly damage project results, and thus the decisions related to data privacy and allowances should be made right at the start of any project. Data systems can also foresee and mitigate privacy disputes.

There is a delicate balance between having a large quantity of datasets and more focused datasets. Focused datasets allow for easier privacy/usage approvals, particularly for the monitoring protected, endangered, and threatened species (PET) in different fisheries, where there are large areas in the image frame to annotate, and automation would allow for a narrower scope. There are also considerations for building architectural algorithms for very specialized uses (e.g.

species identification, quantity) or for general utility (e.g. is there an activity in the camera view?). Broader algorithms and architecture can always be tailored down and trained for specific use cases. However, that requires greater responsibilities for the content and how they were generated.

WGTIFD also discussed who is best suited to host annotated image libraries, such as (inter)governmental organizations including national fisheries institutes or ICES, could be an option because of their resources and capacity, but given the data restrictions and responsibilities associated to meeting legal obligations, those options may not be the optimal host. However, that is not the case if the data are public, and compilations of restricted data can become public through extensive scrubbing. In some cases, however, NGOs may be in a better position to get data agreements in place and turn data into focused datasets (but perhaps not host the data in perpetuity). There is nevertheless a responsibility from database hosts (or projects) to show how the data are going to be used rather than policing its use. Should the data be used for something else, that's where the responsibility would end because it falls outside the stated output(s).

WGTIFD highlighted that most data collection programs and EM pilot projects are developed without specific automation goals in mind. When trying to apply AI/ML in these situations, it is recommended to test what can be automated based on discrete success/failure criteria, and then refine the scope of AI/ML development. For example, it may be necessary to shift from "Identify and count all species" to "Identify segments of video where fish are present", based upon the underlying quality and availability of annotated data. Moreover, matching automation goals with achievable/acceptable error rates and identifying the places for automation in the data analysis pipeline allows technology providers to go through specific use cases (in a contained area) and reach specific technology goals.

3 Developing standards for EM programs

Invited talks: Recommendations for electronic monitoring program design and requests for proposal (Mark Michelin, CEA Consulting), Interoperability (Joshua Wiersma, Integrated Monitoring), EM program design standards (Amanda Barney, Teem Fish Monitoring), Role of EM providers in program design (Howard McElderry).

Report: Recommendations for EM program design and requests for proposals (Mark Michelin, Director of CEA Consulting)

A group of EM service providers self-organized over the past several years to discuss recommendations on designing and standardizing certain EM program components. They developed a report that highlights the small and slow-growing market of EM in fisheries, but also make recommendations for how EM service providers could be directly involved with growing EM globally, such as improving the interoperability of EM systems, designing programs based on the characteristics and geography of the fishery, and creating requests for proposals (RFPs) and other solicitations that are more standardized across programs. There was a short discussion on each of the major recommendations from the report, and those are captured in greater detail in the rest of this section below.

Interoperability (Josh Wiersma, Integrated Monitoring)

EM service providers offer a range of business models, hardware and software, and other services. While that retains a lot of autonomy and potential innovation, it is also one of the reasons that has limited growth of EM, especially for programs that desire to have a multi-provider model and/or programs that span multiple governmental jurisdictions. Developing different approaches to interoperability could actually help with innovation, giving customers assurances of a base set of standards of EM systems, service, and data quality, while still giving each EM service provider the allowance to add services and innovation in a competitive marketplace. Josh presented a number of potential ways that EM service providers, in partnership with EM program managers and other stakeholders, could develop interoperability standards of different types while balancing the competitive and innovative nature of technology in fisheries. For example, common data standards, transparency in raw data structure, or other forms of data interchange could allow for a single video review platform to analyse data collected from a number of different EM service providers and EM systems, something that may be attractive or even necessary in many fishery monitoring programs.

The WGTIFD discussion on this topic reflected the discussions in the larger EM community, in that while it makes sense for many reasons, there are a number of outstanding issues to resolve before any significant investment of resources can be made by any stakeholders. EM programs would need to determine which organization(s) would establish, steward, and implement any interoperability standards and across what scale (i.e. fishery, country, region, entire globe). There is also a lot of uncertainty around the responsibility or compliance of any standard, for example, when one EM service provider installs and maintains the EM systems, while another provider receives the raw data from the fishing fleet and conducts data analysis.

EM program design standards (Amanda Barney, Teem Fish Monitoring)

There is a wide range of components to consider when designing an EM program, such as understanding where and how the fishery operates; establishing the objectives that will subsequently drive data collection; developing how the information will get collected, transmitted, analysed, and stored; and a number of other key questions. Ultimately, EM programs should be designed to produce accurate and validated data for monitoring the fishery, while establishing roles and responsibilities among a diverse group and holding the right party accountable. An important part of designing the program is for governments to publish Request for Proposals (RFPs), Statements of Work (SOWs), Call for Tenders (CFT) and other forms of soliciting private companies for products and services. In the past, these tend to be too prescriptive, and in some cases, a pilot project designed around an initial RFP specific to one EM service provider's technology and business model, can result in less innovation, lack of choice in the marketplace, and fishers and other stakeholders growing frustrated with how the program is designed and evolves over time. It is critical that RFPs, CFTs, etc., are well-designed and include the necessary information, are not too prescriptive, and can be flexible enough so that multiple technologies, providers, and approaches can meet the program standards established by the fishery managers.

WGTIFD discussed a range of possible ways to standardize the design of EM programs, but there remains a lot of diversity and complexities of how fisheries operate and are monitored. However, there was general agreement that developing a more standardized approach to RFPs and CFTs could be a first step towards aligning how programs are designed in the future. A well-crafted solicitation can ensure that bidders are working from a comment set of assumptions on how the fishery operates, establishes clear performance specifications for designing software and hardware, define roles and responsibilities clearly, and can provide a clearer path on how AI/ML and other technology may introduced as the program develops. WGTIFD agreed to assemble examples of RFPs and CFTs, to identify what works better and what does not, in order to share best practices and deliver a template that could be used in setting up an EM program.

Role of EM providers in program design (Howard McElderry)

There is a shared frustration among EM service providers on the slow uptake of EM and growth in the marketplace, some factors can be addressed more directly while society at-large plays a role in determining the level of transparency in fisheries in addition to the scale of public funding for monitoring. Howard offered a number of potential ways that EM service providers could collaborate and have a more direct impact on the design of a program, such as a trade association or other forms of a pre-competitive dialogue between vendors and customers. This could be an awkward concept to governments, but it would help to improve communication on the design of the program and allow all parties to have better and equitable information. That said, more thought must be given to consider the trade-offs of pre-competitive collaboration, to mitigate against stifling innovation and competition as EM grows over time.

WGTIFD discussed a number of fisheries and monitoring programs around the world that for different reasons, lack the coordination and standardization that may be necessary to rollout EM more broadly. Some of these may be opportunities for EM service providers to be more involved and help design future programs. Regional Fishery Management Organizations (RFMOs), the European Fisheries Control Agency (EFCA), and other multi-jurisdictional fishery organizations are striving to coordinate and standardize certain components of EM programs, though individual countries often prefer to retain a lot of autonomy and flexibility on program design, and the levels and types of monitoring coverage. For example, in Europe, there tends to a mix of

compliance and scientific data collection across programs, it will be important to consider how EM and other ETs can collect information to address a number of applications (i.e. management, science, compliance, business development), across governances and fisheries. Moreover, it is critical to identify the ways technology providers can provide more guidance and support for designing these future programs.

The role of ICES & WGTIFD in developing EM program standards (Lisa & Brett)

WGTIFD discussed the different presentation topics and the role that ICES could play moving forward. There was universal agreement that ICES is a predominant organization for coordinating across governments and fisheries, establishing data standards, and bringing together diverse perspectives, such as developing and implementing ETs in the case of WGTIFD. ICES is not a regulatory body for administering EM program standards, nor is WGTIFD an appropriate group to help EM service providers self-organize over the long term. That said, WGTIFD can provide a transparent and collaborative framework for bringing EM service providers together through workshops and/or dedicating time at a WGTIFD meeting to collaborate on different topics. Specifically, WGTIFD has drafted new TORs, some of which are intentionally included in order to integrate EM service providers into providing guidance on developing EM program standards. Ultimately though, it will be necessary for governments and other fishery authorities to consider the role of EM service providers in program design and uptake of WGTIFD guidance.

4 Expanding the use of ET data for stock assessments and other applications

Invited talks: Overview of ICES science advice process (Mark Dickey-Collas, ICES), Integrating EM data into stock assessments (Lisa Peterson, Haley Oleynik, Kristan Blackhart, NOAA).

Overview of ICES science advice process (Mark Dickey-Collas, ICES)

Mark Dickey-Collas summarized the ICES approach to data in fisheries advice. ICES gives advice on stock assessments, cetacean bycatch, seabed impacts, etc; but does not set management objectives, although it works with requesters to clarify those objectives. New data can be introduced in established advice, for example in data workshops that prepare for the stock assessment benchmark workshops that happen every 4-6 years or in new advice, following the ICES data policy (https://www.ices.dk/data/guidelines-and-policy/Pages/ICES-data-policy.aspx). In summary, there is a commitment in ICES to expand advice areas and incorporate new data, but new data must conform to ICES quality control, quality assurance mechanisms, data policy and the 10 advice principles.

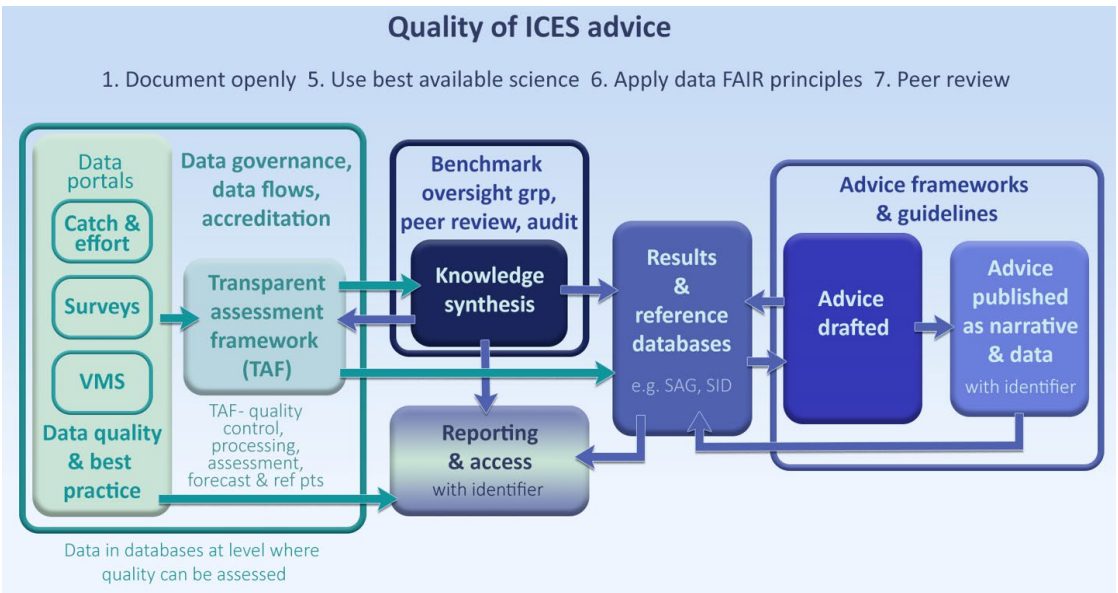

Figure 4.1. Schematics of quality of ICES advice based on four ICES advice principles.

Integrating EM data into stock assessments (Lisa Peterson, Haley Oleynik, Kristan Blackhart, NOAA)

Lisa Peterson, Haley Oleynik and Kristan Blackhart provided some considerations and good practices for successful integration of EM data in science and management, focusing on two case studies: Alaska fixed gears and trawl fisheries and the Northeast multispecies groundfish fishery. The lessons learned are that a) communication with all stakeholders is key (specifically between EM community and stock assessment community), b) cooperation with industry is also key because logbook data will become more important with EM implementation, c) observers are still needed to collect biological samples on some trips (although less), and finally d) stock assessors need to integrate multiple data streams (observer, EM, logbook).

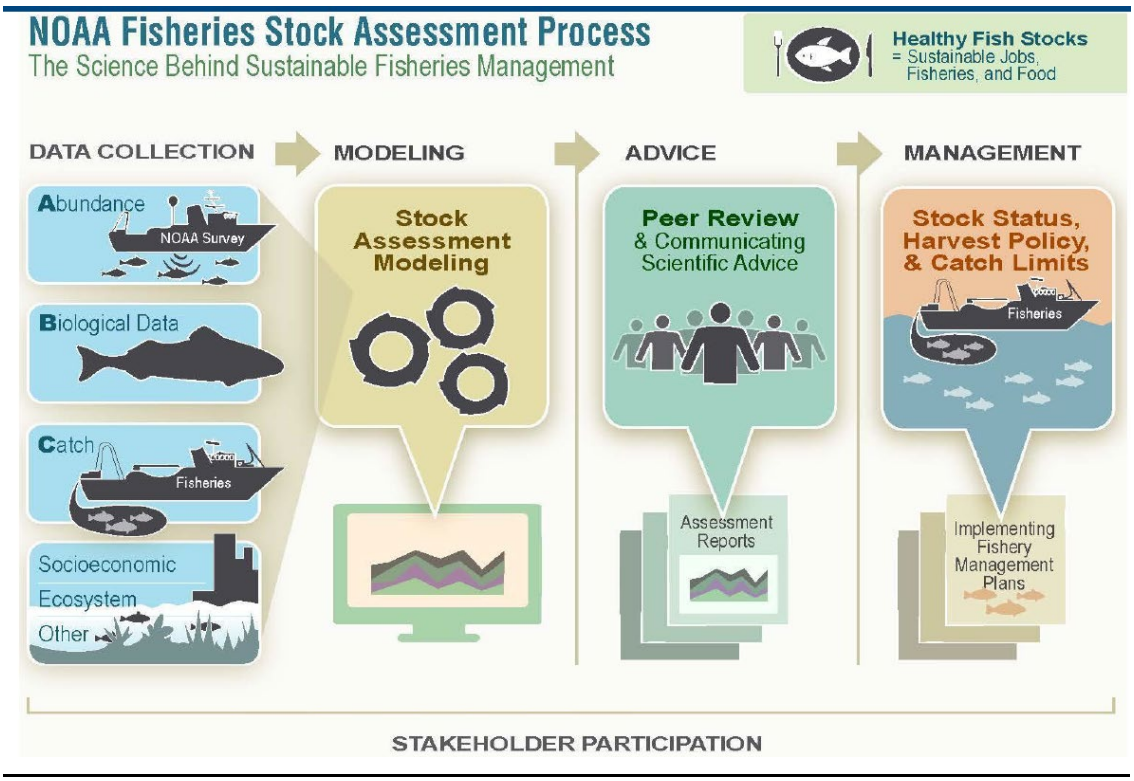

Figure 4.2. Schematics of NOAA fisheries stock assessment process.

ICES data and advice process differs from the US. The area where more time is spent in the stock assessment to management advice process is at benchmarks in incorporating new data. Both stock assessor and data person need to communicate and understand how to use the data. The ICES current data process is not working at its best in terms of spatial data, and where EM can provide a significant amount of data. Examples will need to be explored at workshops, while model and data development and testing has to be completed before the benchmark. But there are still issues with data formats and data infrastructure in order to conform to EM data. Intercatch database is used in Europe, but is shifting RDB (Regional Database) and RDBES (Regional Database and Estimation System), although there is a need to find mechanisms and data flows

that will supplement the RDBES. **WGTIFD can be the forum to develop and test data flows specific to EM data, particularly for EM programmes that are deemed to have a statistically strong signal that is representative of the fishing activity**. But ICES has an increasing demand for other advice, namely in how to avoid vulnerable marine ecosystems and bycatch, and these additional data needs may provide an opportunity for new data sources.

The issue of ET pilot projects vs. a full sampling programme was also discussed, namely regarding representativeness and bias. Small observers programmes in Europe that may be presently biased can still provide useful information, while measures can still be taken to incorporate biased data in stock assessments. But does the objective of an EM program (i.e. compliance vs. audit of data quality) affect the quality of the data collected for stock assessment? Is data quality lower in programs with compliance-only objectives? WGTIFD discussed that there will not be a one-size-fits all approach for integrating EM data in stock assessments. There are likely differences in data quality, but WGTIFD participants were unable to pinpoint those. WGTIFD also discussed the use of incentives as part of growing EM programs in many jurisdictions, and its implications in biasing data. Fishers may for example be allowed into closed areas if the carry EM systems, instead of monetary compensation, but any incentive that alters fishers fishing pattern will likely introduce bias. And it is extremely difficult to impossible to tease apart the bias in the data. There are projects studying data quality issues in EM programs, including inaccurate length measurements but also by comparing EM data with logbooks and VMS. EM data can also be used to audit logbook data and one should work with stock assessors to understand what data they could consider in the stock assessment.

5 2021 ICES ASC Theme Session H

Finally, the ICES 2021 Annual Science Conference WGTIFD Theme Session H entitled "Can technology-based monitoring deliver timely, cost-effective and high-quality fishery-dependent data?" went ahead as scheduled, with several contributions from topics such as the drivers behind the ET programs, or the cost-effectiveness of EM to data integration of new and varied data types collected by ETs. Finally, a diverse group of panellists discussed with the audience a range of topics, including how to apply AI and machine learning (ML) to imagery collected from EM systems, how to integrate EM data into stock assessment, and building relationships with the fishing industry, and how to integrate data from different types of technology. The theme session report can be found here https://www.ices.dk/events/asc/ASC2021/Documents/Theme%20session%20H%20report.pdf

6 Conclusion and Next Steps

The WGTIFD discussed the work over 2019-2021 and agreed that some initial significant work was achieved, but that a lot of work is still needed to integrate ET fishery-dependent data. While it may seem obvious to some, it was very difficult to adequately address certain TORs and other issues in a fully virtual meeting in 2020 and 2021, meaning some TORs will need ongoing attention in the future in addition to newly formed TORs. That said, the last several years help us strategize which TORs are more appropriate for virtual vs. in-person meetings. We have learned how to design our meetings for making better progress, including specific TORs towards standardizing components of EM programs as Europe and RFMOs look to scale EM over the next few years. The newly proposed TORs are listed below:

- Develop and publish a standardized format for data collected and analysed from EM systems, to include a framework of documenting how the data are collected and flows into the ICES data system to be considered for science advice
- Provide guidance and best practices on drafting Statements of Work for different types of EM programs
- Provide recommendations on how to utilize EM for monitoring bycatch of protected, endangered, and threatened species (PET) in different fisheries
- Develop and publish recommendations for interoperability of EM systems, raw data, and other appropriate guidance for ensuring that EM systems and programs can integrate across governances, fisheries, and EM systems

Annex 1: List of participants

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2019 Meeting

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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	30 November - 2 December	Online meeting	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 to establish methodological acceptance for science and management.	There are many choices in designing a monitoring program, including hardware, software, data transmission, 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.	3.5, 4.4	Year 3	ICES Cooperative Research Report on best practices
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.
Resource requirements	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 facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	
Linkages to other committees or groups	WGMLEARN, WGCATCH, WGFAST, PGDATA WGSFD, WKSEATEC ICES Data Centre, DIG
Linkages to other organizations	