Working Group on Technology Integration for Fishery-Dependent Data (WGTIFD)

Alger, Brett; Borges, Lisa; Allegaert, Wim; Bryan, Jason; Bach, Pascal; Barkai, Amos; Goienetxe, Oihane Erdaide; Fraga, Ana; González, Óscar; Hager, Mark

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WORKING GROUP ON TECHNOLOGY INTEGRATION FOR FISHERY-DEPENDENT DATA (WGTIFD)

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International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Editors

Brett Alger • Lisa Borges

Authors

Wim Allegaert • Pascal Bach • Amos Barkai • Jason Bryan • Brian Cowan • Ana Fraga • Eduardo Garcia Oihane Erdaide Goienetxe • Oscar Gonzalez • Mark Hager • Stuart Hetherington • Helen Holah • Justin Kavanaugh • Josh Keaton • Rachel Kilburn • Daniel Linden • Brant McAfee • Howard McElderry Christopher McGuire • Brad McHale • Miguel Nuevo • Daniel Oesterwind • Kristian Plet-Hansen • Iñaki Quincoces • Nichole Rossi • Farron Wallace • Morgan Wealti • Katherine Wilson

Contents

i Executive summary

The Working Group on Technology Integration for Fishery-Dependent Data (WGTIFD) met in Copenhagen, Denmark, 7-9 May 2019 for its first meeting in its three-year multi-annual cycle. WGTIFD has diverse membership including technology service providers, academic and governmental marine institutions, and non-profit environmental organizations, across a wide range of EU, US, and Canadian fisheries. The WGTIFD's primary objective is to examine the electronic tools and applications that are 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. The primary objectives of the first meeting were to inventory and review the various national fisheries dependent hardware and software applications and approaches (ToR A); define and agree on consistent vocabulary on electronic technologies (ToR B); and report on developments in machine learning and computer vision technologies and their applications in fisheries dependent data collection (ToR E). The working group was able to develop a common vocabulary of terms that can be used within the ICES community, and conducted a survey of WGTIFD participants on their experience in implementing technology for monitoring and reporting programs, and their views on strategies and incentives to engage stakeholders. This Year 1 report provides a fairly robust assessment on the available electronic technologies and how they're being used in fisheries around the world, the successes and challenges with implementing these tools, and some of the existing applications for using machine learning for processing data in fisheries. WGTIFD also started to examine the risks and benefits of different technologies (ToR C), but does not make a full assessment or recommendation at this time. The same can be said for how to integrate data from technologies (ToR D). These topics will be examined in Year 2 and will be fully reported at the end of the multi-annual cycle.

Many technologies in fisheries are relatively new, compared with traditional data collection programs, and the working group itself is new, making it difficult to determine the reach and impact of the Year 1 report. However, technology-based programs appear to be developing and expanding rapidly, and interest in future work of the group is growing too, so it is expected that the findings will have greater impact over time. Additionally, the intial work was intentional for developing a baseline of tools and vocabulary, and it is expected that work in Year 2 on exploring trade-offs of technologies and how the data is used, will be of more interest and to a wider audience. WGTIFD will be meeting in Galway, Ireland May 11-15, 2020 to expand their work.

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	1/3
Chair(s)	Brett Alger, United States
	Lisa Borges, Portugal
Meeting venue(s) and dates	7-9 May 2019, ICES HQ, Denmark

1 Terms of reference

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	3.5, 4.4	Year 3	ICES Cooperative Research Report on best practices

		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

2 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.

For the purpose of this and subsequent reports, 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. Many of these tools are defined below.

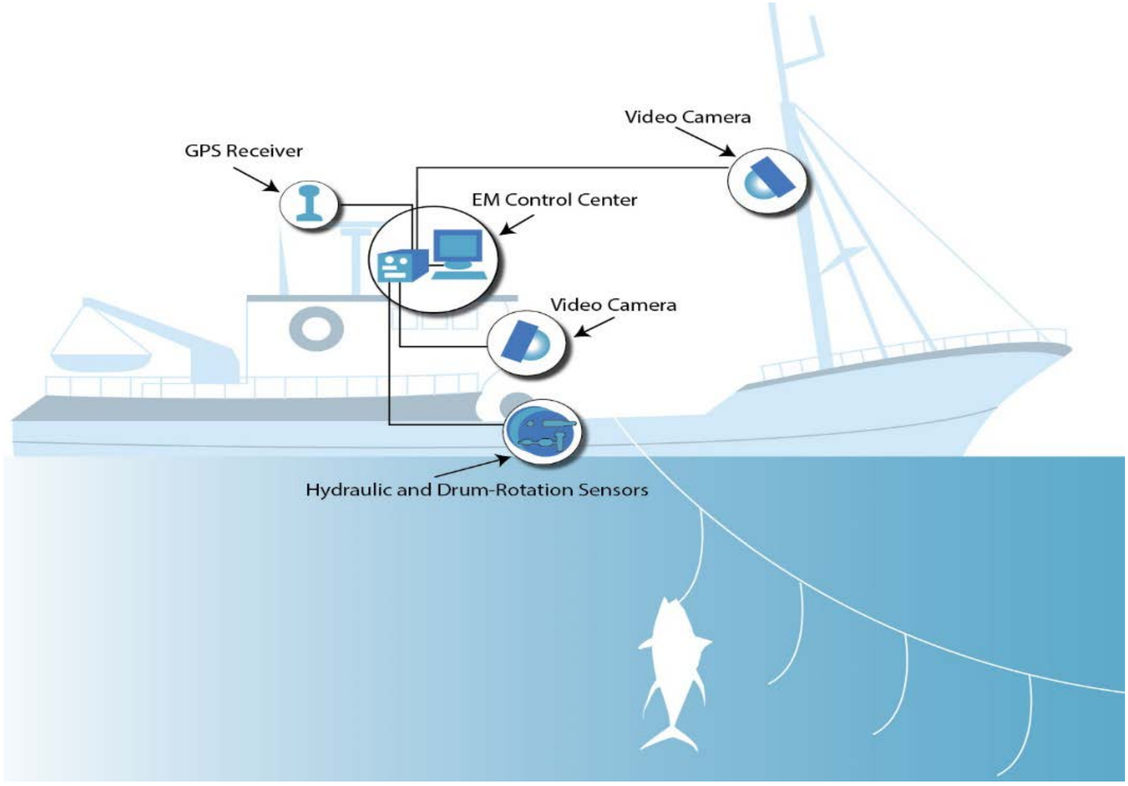

Figure 1 – Example EM system configuration.

WGTIFD is taking a step-wise approach to initially assess the ETs currently available and in development, and better understand the objectives and schemes in which they are currently deployed. Additionally, because there are a range of definitions and uses (e.g., electronic monitoring has wide applications) WGTIFD wants to better understand the different terms used between regions and countries, and acknowledges the challenges and successes for getting fisher participants in ET programs. 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 one another (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.

WGTIFD therefore 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.

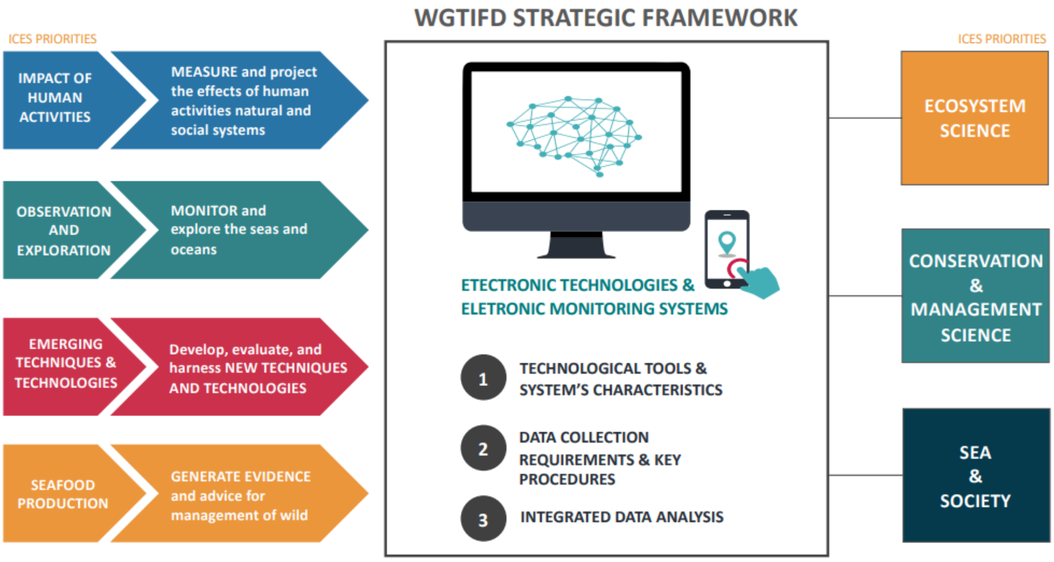

Figure 2 – Infographic of WGTIFD in ICES Strategic Plan.

The expected targeted audience of WGTIFD reports are ICES community scientists, researchers involved in the application of technologies onboard fishing vessels, technology providers, fishers, NGOs and other marine sector stakeholders, national and EU fisheries managers and control officers.

3 Inventory of vocabulary (ToR b)

There was as an in-depth discussion of the common terms used in data collection programs, across technologies, and with diverse applications between different regions and countries within ICES. WGTIFD discussed self-reported data provided by those directly involved in fishing operations, versus independently collected data from fishing operations that tends to be from ETs (e.g. gear sensors, video, and positional data). These independent (often ET derived) data collections from fishing operations are not to be confused with fishery-independent data collections from standardized surveys and research programs. These are key distinctions in describing technology applications, whether or not data is provided by the fisher or not. Self-reported and independently collected data can be compared against each other to validate the individual data collections and/or combined to make a more complete, high quality data set. The WGTIFD considered a number of ambiguous terms and settled on a common vocabulary to be defined and used within the ICES community, as follows:

There was as an in-depth discussion of the common terms used in data collection programs, across technologies, and with diverse applications between different regions and countries within ICES. WGTIFD discussed self-reported data provided by those directly involved in fishing operations, versus independent data that is provided from sources not directly involved in fishing operations, not to be confused with fishery-independent data collection (e.g., fish survey). These are key distinctions in describing technology applications, whether or not data is provided by the fisher or not. Additionally, both self-reported and independent data can be provided actively by a human (e.g., information inputted into a computer), or autonomously and not provided by a human (e.g., vessel location automatically collected by software). There are methods for using two different tools, one from that is self-reported and one that is independent, to validate the data collection. For example, electronic monitoring can be independently collected and used to validate self-reported data. The WGTIFD considered a number of ambiguous terms and settled on a common vocabulary to be defined and used within the ICES community, as follows:

Electronic technologies – 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.

Electronic monitoring – The use of imagery, sensors, and global positioning systems (GPS) to independently monitor fishing operations, effort, and/or catch.

Electronic reporting – The use of smart phones, computers, and tablets to record, transmit, receive, and store data.

Imagery - The use of one or more cameras to collect single-images or video.

Sensor - Digital or analog devices used to detect/measure fishing operations such as the vessel, fishing gear, and other characteristics

Transmitted positional data systems – GPS systems that collect and transmit data from the vessel or gear during a fishing trip (e.g., AIS, VMS)

Archival positional data systems – GPS systems that collect and archive data on the vessel or gear, and then transmitted at the end of a fishing trip(s) (i.e., store and forward)

Machine learning – Applications of artificial intelligence that provide systems the ability to automatically learn and improve from experience without being explicitly programmed, for both image-based and non-imaged-based data.

Computer vision – Machine learning applications for acquiring, processing, and analyzing digital images, and extraction of high-dimensional data from electronic monitoring systems.

Fishery-dependent data – Information from a fishery, collected before, during, and after fishing activity.

Fishery-independent data – Information collected separate from fishing activity.

Monitoring – The continuous requirement for the measurement of fishery-dependent data (adapted from FAO, 1994[1]).

Control – Regulatory conditions under which the exploitation of the resource may be conducted (FAO, 1994)

Surveillance – The degree and types of observations required to maintain compliance with the regulatory controls imposed on fishing activities (FAO, 1994).

[1] Flewwelling, P. 1994. An introduction to monitoring, control and surveillance systems for capture fisheries. FAO Fisheries Technical Paper 338. http://www.fao.org/3/V4250E/V4250E00.htm#toc

4 Review existing tools, programs goals and challenges (ToR a)

A portion of 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.

From this information, WGTIFD populated a table with the different data that are collected on a vessel during a normal fishing operation using traditional means such as paper logbooks and observer data collection by paper, against technologies that allow for automated means of collecting the same data element. 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 series of matrixes of tools and data, some of which are available in the appendix, but ultimately created a table (below) that compares four primary ETs and their capabilities of collecting a range of data elements.

Table I – 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	

During the exercise of identifying different tools and data elements, WGTIFD discussed how their respective programs were created originally and evolved over time. For example, a logbook program may have been created for collecting management information, but the information has since been used in a stock assessment or used by enforcement too. The participants found the idea of program and data evolution to be very important in the context of examining how future ET programs can be implemented more holistically, rather developing a tool for a single purpose. WGTIFD participants provided a range of case studies for examining existing ET tools for discussion at the next meeting, these examples are provided in Annex 3.

While electronic technologies 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 electronic technologies.

- **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

5 Communication, outreach and strategies (ToR b)

While technology to support data collection for fisheries monitoring programs continues to advance rapidly, there are a number of significant challenges that remain: (1) costs, (2) privacy, (3) access and ownership of data, (4) lack of standards, coordination, and consistent applications, and (5) the correct balance of incentives and regulations. Many fishers remain skeptical and even resistant to adopt ETs due given the 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.

WGTIFD discussed a wide range of ideas and principles that should be considered in order to develop robust data collection programs in partnership with fishers. Managers need to develop incentives to create accurate self-reported data programs, which can be accomplished through independent monitoring and catch accounting. EM systems can provide image-based evidence acceptable to all parties. Furthermore, EM systems can potentially be scaled across larger proportions (up to 100%) of the fleet than traditional human observers, which can reduce traditional sampling concerns about accuracy, precision, and bias because the higher monitoring coverage yields more actual data and reduces reliance on estimation. The expansion of EM is highly dependent on fishery, region, and management structure. In some cases, requiring EM through regulation may not be an option and incentives schemes (e.g. regulatory exemptions, quota, etc.) provide a means for promoting the expansion of EM. Despite these incentives, fishers can be reluctant to adopt EM. Many fishers acknowledge that having cameras on a vessel is not a problem, rather 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. Additionally, managers may need to be more flexible in how EM programs are implemented in terms of data flow, rather than seeing a program as exclusively a reporting requirement of the vessel, imposed by the government. Fisheries agencies should consider other data models, such as vessel to a 3rd party to government, vessel to government and back to vessel, or even vessel to vessel.

WGTIFD conducted a survey of meeting participants on their experience in implementing ET-based at-sea monitoring programs, and their views on strategies and incentives to engage stakeholders. Strategies were defined as the methods and goals of how participants engaged with fishers and other stakeholders to test and implement technologies (what was your approach? how did you communicate and meet with them? how did you find a balance between sticks and carrots?); while incentive was defined as the actual sticks and carrots that resonated with fishers (regulatory relief? access to more quota? use of data in a stock assessment? Etc.). This survey is also going to be provided to the WKSCINDI participants to gauge their opinion, and has the following questions:

1. Email address
2. Identify 3 effective strategies to promote participation to ET projects:
3. From the previous list, chose the strategy you believe to be more likely easier to implement:
4. Identify 3 effective incentives for fishers to participate in ET projects:
5. From the previous list choose the one you think is the most effective

6. Name 1 to 3 case studies you consider as examples of success in implementing ET projects
7. Web links to the suggested projects

The survey results show that the main strategies to promote participation to 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.

6 Risks and benefits of ET Tools (ToR c)

Through the discussion on defining ET-related terms, examining existing tools and challenges, and exploring the range of data that be collected from ETs, WGTIFD spent some amount of time discussing the trade-offs, risks, costs, and benefits for selecting tools for reporting and monitoring. That is, the group spent far more time determining what tools are in the toolbox and each tool's capabilities and limitations, and less on how these tools apply to specific fishery contexts. In the case of EM, imagery is universally used to gather catch related information, yet its feasibility for specific catch data elements (e.g., species, quantity, disposition, etc.) depends upon how fishing operations occur (e.g., longline versus trawl), as well as the distinctiveness of the catch items of interest, as influenced by size variation, species diversity, and visual similarity. The specific catch data elements selected may also depend upon the strategy chosen for how EM is used, and the degree of integration with other catch reporting tools, such as ETs and landings data. For example, EM can simply be used to verify that no discarding occurs at sea and thereby strengthen veracity of landings data, or it can be used to fully estimate composition of both retained and discarded catch while fishing operations take place. A emerging methodology using the latter approach involves auditing vessel reports with EM estimates. WGTIFD explored the idea of developing a matrix that includes each tool and suite of data elements (Table 1 above), but for a range of different fishery types (e.g., large pelagic single species, longline vs. mixed species, bottom trawl), and a range of different uses (e.g., full retention monitoring, discard monitoring, full catch accounting, etc.).

In Year 2, WGTIFD intends on developing a series of matrixes as envisioned above that will help provide guidance on to develop a program and select tools based on the fishery types, goals and objectives, and data needs. This effort will also provide best practices for hardware, software, and comprehensive ET implementation.

Table II – Fishery monitoring matrix adapted from Lowman et al., (2013)[2]. Colors reflect suitability to meet information needs using green to red, for most to least, respectively.

Information Category	Monitoring Objective	Fishery Characteristics/Data Specifics		Type of Catch Reporting Tool Used							
				Self-Reporting			Independent-Reporting				
				Slips	Logs	Hails	ASOP	EM	DMP	OGM	VMS
Discarded Catch	**Full Retention**	No Onboard Catch Sorting									
Discarded Catch	**Discarded Catch Composition**	Low Volume/Singulated Catch						Singulated			
Discarded Catch	**Discarded Catch Composition**	High Volume	Single Target Species					Aliquot			
Discarded Catch	**Discarded Catch Composition**	High Volume	Multi-species easy to Differentiate				Subsample	Aliquot			
Discarded Catch	**Discarded Catch Composition**	High Volume	Multi-Species difficult to differentiate				Subsample	Aliquot			
Retained Catch	**Retained Catch Composition**	Low Volume/Singulated Catch									
Retained Catch	**Retained Catch Composition**	High volume catch handling	Single target species					Aliquot			
Retained Catch	**Retained Catch Composition**	High volume catch handling	Multi-species				Subsample	Aliquot			
Retained Catch	**Retained Catch Composition**	Species difficult to differentiate					Subsample	Aliquot			
Protected Species	**Seabird, Turtle and Marine Mammal Interactions and Avoidance**	Species Encountered									
Protected Species	**Seabird, Turtle and Marine Mammal Interactions and Avoidance**	Handling Method									
Protected Species	**Seabird, Turtle and Marine Mammal Interactions and Avoidance**	Release Condition									
Protected Species	**Seabird, Turtle and Marine Mammal Interactions and Avoidance**	Discarded or Retained									
Protected Species	**Seabird, Turtle and Marine Mammal Interactions and Avoidance**	Other Interactions									
Protected Species	**Seabird, Turtle and Marine Mammal Interactions and Avoidance**	Mitigation Device Deployment									
Fishing Effort	**Gear and Fishing Information**	Spatial/Temporal by Fishing Event									
Fishing Effort	**Gear and Fishing Information**	Gear Characteristics									
Fishing Effort	**Gear and Fishing Information**	Trap Limits/Soak Limits						RFID required			
Fishing Effort	**Gear and Fishing Information**	Bait Characteristics									
Fishing Effort	**Gear and Fishing Information**	Economic data									
Catch Sampling	**Biological Data Collection**	Length, Sex (dimorphic)						Crew Required			
Catch Sampling	**Biological Data Collection**	Sex, Viability, Meristics, Reproductive Condition									
Catch Sampling	**Biological Data Collection**	Tissue Samples (age structures, DNA, gonads, stomachs, etc.)									

[2] Lowman, D., Fisher, R., Holliday, M., McTee, S., and Stebbins, S. 2013. Fisheries Monitoring Roadmap: A guide to evaluate, design and implement an effective fishery monitoring program that incorporates electronic monitoring and electronic reporting tools. 74 pp.

7 Data Integration from ET (ToR d)

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. For example, integrating EM, ER, and other systems in the wheelhouse to streamline fisher interactions for reporting information. WGTIFD also discussed different approaches to data-limited programs, such as when a pilot study is being conducted and there is limited participation, uncertainty in the data, and/or missing information. However, there was no time specifically allocated to discuss TOR d, these topics will be examined further in Year 2.

8 Machine Learning applications for ET (ToR e)

Commercial fisheries are moving to incorporate EM into existing fishery-dependent data collection programs to augment or replace onboard observers, however, one of the substantive barriers for broadscale implementation are the high costs of video review, transmission and storage. Currently, EM programs rely on labor intensive (and thus costly) processes, and there is a need to improve the timeliness of data management associated with new EM data streams. Computer vision (CV) applications that use machine learning (ML) based on annotated image-training datasets is a research area where tremendous technological advancement is currently occurring. CV and ML applications are also being used for underwater surveys (e.g., habitat, coral, fish) and aerial surveys (e.g., marine mammals), and there is a wide range of other applications. Much of the recent developments is derived from the speed and accuracy of newer deep learning models, which are well-suited for fisheries data because of their ability to perform detection, classification, clustering, and prediction. ML algorithms can be re-trained on any other image dataset for any other application providing a very cost effective transfer of technology especially where data collection techniques are similar.

There is interest is integrating CV and ML applications into fisheries-dependent data collection. By combining data collected from GPS, images, and other sensors, data processing could be substantially reduced and improve data timeliness for existing and future EM programs. However, it is important to take a calculated and collaborative approach to implement these technological advancements across Regions and guard against misguided and potentially wasteful efforts. This requires organized collection and annotation of data (i.e., training datasets) to use CV and ML applications widely, yet efficiently.

WGTIFD has limited scope and membership from the CV and ML community of practitioners, but is strategically and actively engaged with the WGMLEARN. They are a new WG engaged with reviewing CV and ML applications from around the world. WGTIFD developed four objectives for the WGMLEARN to consider in order to develop future recommendations on how CV and ML can support EM programs.

1. Characterize the data collected from EM programs and the environment they come from.
2. Define the existing challenges in processing the available EM data.
3. Provide the existing CV and ML applications in fisheries-dependent data programs.
4. Develop best practices for creating ML-friendly programs and operationalizing.

The WGMLEARN met May 21-23; the WGTIFD intends on coordinating closely to pursue these objectives moving forward.

9 Conclusion and next steps

Throughout the three days discussions, the WGTIFD addressed mainly ToRs a, b, and e: the WG provided an inventory and review of the various national fisheries dependent hardware and software applications and approaches; defined and agreed on consistent vocabulary on electronic technologies; and reported on developments in machine learning and computer vision technologies and their applications in fisheries dependent data collection, respectively. Other ToRs were also debated and advance, namely on evaluating risks and benefits of technologies across different fisheries (ToR c). Nevertheless, work will continue on all ToRs in future meetings, but particularly on ToRs c, d and e.

The WGTIFD agreed that the ToRs are a living document and thus can be subject to review and be amended in the future, although in the present meeting the ToRs were further specified but not redefined. Also, the vocabulary and definitions agreed may be added or even further reviewed, if deemed necessary, when more examples are added to the case study list (Annex 3).

The WGTIFD acknowledged the importance of 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, but particularly with rapidly evolving technology. The connection between ET programs and existing data collection frameworks will continue to be discussed in future WGTIFD meetings, in view of providing future EM data standardization recommendations.

WGTIFD also has close connections to at least three other ICES groups and one from the European Fisheries Control Agency - EFCA, and it is the intention of the WGTIFD to keep a close connection and cooperation with these four groups:

- WKSEATEC - Workshop on Technical Development to Support Fisheries Data Collection.
- WGMLEARN - Workshop on Uses of Machine Learning in Marine Science. WGTIFD will send the priorities identified previously to the WGMLEARN to seek their opinion.
- WKSCINDI - Workshop on Science with Industry Initiatives. A survey of the experience in implementing ET-based at-sea monitoring programs, and their views on strategies and incentives to engage stakeholders is going to be provided to the WKSCINDI participants to gauge their opinion.
- EFCA Remote Electronic Monitoring Technical Working Group.

Finally, regarding the possibility for a theme session at the 2020 ICES ASC, there was a general discussion of past and future possible topics to be covered in that session. Based on that discussion a theme session proposal was drafted, to be submitted at the 2019 ICES ASC (Annex 4).

Annex 1: List of participants

Name	Organization	Country	Email
Brett Alger	NOAA Fisheries	United States	brett.alger@noaa.gov
Lisa Borges	FishFix	Portugal	info@fishfix.eu
Wim Allegaert	Flanders Research Institute for agriculture, fisheries and food	Belgium	Wim.Allegaert@ilvo.vlaanderen.be
Jason Bryan	Archipelago Marine Research Ltd	Norway	jasonb@archipelago.ca
Pascal Bach	IRD	France	pascal.bach@ird.fr
Amos Barkai	OLSPS	South Africa	amos@olsps.com
Oihane Erdaide Goienetxe	Digital Observer Services	Spain	oeg@digitalobserver.org
Ana Fraga	Azores Fisheries Regional Direction	Portugal	anaritafraga@gmail.com
Oscar Gonzalez Suarez	Marine Instruments	Spain	ogonzalez@marineinstruments.es
Mark Hager	Gulf of Maine Research Institute	United States	mhager@gmri.org
Helen Holah	Marine Scotland Science	Scotland	helen.holah@gov.scot
Justin Kavanaugh	NOAA Fisheries	United States	justin.kavanaugh@noaa.gov
Josh Keaton	NOAA Fisheries	United States	josh.keaton@noaa.gov
Rachel Kilburn	Marine Scotland Science	Scotland	Rachel.Kilburn@gov.scot
Daniel Linden	NOAA Fisheries	United States	daniel.linden@noaa.gov
Brant McAfee	NOAA Fisheries	United States	brant.mcafee@noaa.gov
Howard McElderry	Archipelago Marine Research Ltd	Canada	HowardM@archipelago.ca
Christopher McGuire	The Nature Conservancy	United States	cmcguire@tnc.org
Brad McHale	NOAA Fisheries	United States	brad.mchale@noaa.gov
Miguel Nuevo	European Fisheries Control Agency	Spain	miguel.nuevo@efca.europa.eu
Daniel Oesterwind	Thuenen Institute of Baltic Sea Fisheries	Germany	daniel.oesterwind@thuenen.de
Kristian Plet-Hansen	DTU Aqua	Denmark	kspl@aqua.dtu.dk
Nichole Rossi	NOAA Fisheries	United States	Nichole.Rossi@noaa.gov
Farron Wallace	NOAA Fisheries	United States	farron.wallace@noaa.gov
Morgan Wealti	Salt Wire Inc.	United States	morgan.wealti@saltwaterinc.com
Katherine Wilson	NOAA Fisheries	United States	katherine.wilson@noaa.gov

Eduardo Garcia	Satlink S.L	Spain	egm@satlink.es
Iñaki Quincoces	AZTI Marine Research Department	Spain	iquincoces@azti.es
Stuart Hetherington	Centre for Environment, Fisheries and Aquaculture Science	United Kingdom	stuart.hetherington@cefas.co.uk
Brian Cowan	Anchor Lab	Denmark	bc@anchorlab.net

Annex 2: Case studies of ET monitoring programmes

1. NOAA Fisheries Highly Migratory Species pelagic longline fleet, United States

Purpose: catch-share program for bycatch of bluefin

- Over 4 yr, 4x more the base catch (self-reported)
- Individual accountability: quotas
- Exploring spatial management
- Verification, validation of self-reporting

Requirements:

- Paper logbooks (20 yr history), ER requirement (# of bluefin per set)
- Biological opinion requirement for sea turtle: min. 8% for the 20 yr history

Regulations: observers, VMS, ER

Evolution:

- Protected resources: sea turtle interactions
- Enforcement: EEZ encroachment
- Mako shark

Data collected: vessel information, position, kept or discard, size

ET systems: VMS, ER, EM

Sensors: hydraulics, magnetic (redundancy)

- Drum haul back, camera on for 2 hrs

Beginning # of vessels: 138

Current # of vessels: 138

- ~100 actively fishing

2. SIF database sea-packing/grading machine, Denmark

Purpose: Initial purpose of sea-packing was to provide additional profit to fishers, by reducing their costs of size-sorting and packing at the auctions, and by ensuring higher quality fish. The SIF database was an add-on to the sea-packing with the purpose of meeting stricter traceability requirements for food goods in the European Union

Requirements:

- Electronic logbook
- Sea-packing/grading machine on board vessel

Regulations: None directly but allow for compliance with EC regulation No 178/2002 on food safety. SIF system is industry-run. Vessel are liable for correct labelling to the fish auction, not to the control agency.

Fishery: Used on larger gillnetters and trawlers (>19 meters). Accurate positional data and retained landings records only apply to trawlers due to issues on how to define a “haul” or “tow” for gillnetters.

Evolution: The traceability requirements for the European Union on food goods turned out to be less strict than initially believed in Denmark. Therefore, rather than needing to be able to back-trace every fish to every haul, it in enough under the law to be able to back-trace a batch to a management area (as example: be able to back-trace a full load of cod from a fishing trip to area 4A in the North Sea, rather than to the actual individual hauls).
Vessel already using SIF found the system works well for easier offloading and potential record of where they catch different size classes of different species. In the summer of 2017, the German authorities found a batch of fish, that they wanted to have traceability data on. The German buyer had bought the batch in Denmark, from a wholesaler in Hanstholm. The information of the Danish suppliers (fishing vessels) were quite easily found in the SIF system and lived fully up to the expectations of the German authorities' demands.

Data collected: vessel information, position of hauls, time of hauls, retained catch if run through grading machine, commercial size class based on EU standard, weight (aggregated for each size class and species caught and retained at haul level)

ET systems: ER

Sensors: Dynamic scales for automatic weighing of each fish at sea.

Beginning # of vessels: Unknown, less than 20

Current # of vessels: Unknown, more than 70. Access to data permitted for 12 vessels

Publication:
(Plet-Hansen et al., 2018). Plet-Hansen, K.S., Larsen, E., Mortensen, L.O., Nielsen, J.R., Ulrich, C., 2018. Unravelling the scientific potential of high resolution fishery data. Aquat. Living Resour. 31, 14 pp. https://doi.org/https://doi.org/10.1051/alr/2018016

3. Smartphone application: Mobile Fisheries Log (Mofi)

Purpose: collect effort and spatio-temporal distribution data in small scale fisheries

- to estimate effort and spatio-temporal patterns in the use of fishing grounds by the small-scale fleet
- self-reporting system
- reversal of the burden of proof

Requirements:

- smartphone or iPhone with a GPS receiver
- GSM network

Regulations:

Evolution:

- Vessels <12 m wanting to fish for cod during a two-month spawning closure had to document that they were fishing in waters shallower than 20 m.
- the German control authority decided to have Mofi as the only and mandatory tool to document fishing activity during the spawning closure for smaller vessel (<12m)
- future: e-log function; photo function to document unwanted bycatch

Data collected: vessel information, position, fisheries activity

ET systems: ER

Sensors:

- GPS

- self-reporting via push bottom

Beginning # of vessels: ca 90 vessels during the spawning closure in Feb-Mar 2018

Current # of vessels: 0

4. Marine Scotland Science demersal fleet

Purpose: catch-management scheme for cod – reduce stock mortality for cod by incentivizing increased selectivity. EM used to ensure compliance with scheme conditions.

1. 2009 trial, then scheme adopted 2010-2016
2. Control Verification, validation of self-reporting (that cod was not being discarded)
3. Increase in quota 30% alongside increase in days effort (financial/flexibility incentives)
4. 30% quota increase given was lower than the discard rate for the fleet at the time

Requirements:

1. ER: Submit e-log entries on a haul by haul basis (non-scheme vessels reporting requirement daily), carry EM

Regulations: VMS, ER. No requirement for Scottish vessels to take observers.

ET systems: VMS, ER, EM, ML (onshore & still in development).

Evolution- from compliance to science

- Activity mapping
- Cost analysis
- EM vessels treated as separate fleet in Scottish catch estimation procedure.
- Post-hoc ML project in development using historic footage from scheme

Sensors: hydraulic (net drums), speed/GPS (higher frequency than VMS)

 # vessels height of scheme: ~25

Current # of vessels: 0 (scheme ended in 2016 when the EU landing obligation was implemented for cod – no longer tenable to pay a subset of vessels to comply with legislation).

Data collected: positional, species identification & lengths of discarded fish

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.

5. **Northeast US Groundfish EM Audit:** The Nature Conservancy, Gulf of Maine Research Institute, Maine Coast Fishermen's Association, Cape Cod Commercial Fishermen's Alliance, TEEM Fish (Ecotrust)

Purpose: Quota management. Validate fisherman reported discards of quota managed groundfish in a multispecies fishery

- Develop lower cost alternative to industry funded observers
- Individual accountability for quota managed groundfish discards
- Improve data used for science and management-fishery has demonstrated strong observer bias and incentive to misreport, low industry confidence in assessments
- Reduce burdens associated with human observers. ie. space, safety, logistics

Requirements:

- **ER:** All EM vessels report haul level catch using ER software
- **EM:** EM system runs on every trip in lieu of industry funded observers, review video as needed to audit fisherman reporting (current video review rate 50%)
- EM vessels also exempt from some area and gear restrictions.

Regulations: VMS, 15-30% observers, Fishermen trip reporting required-optional ER

- management developing ER requirement, considering EM approval

Evolution:

- 2013: Began with 3-year pilot with 3-5 vessels focused on reducing cost
- Fishermen pivot to focusing on value of FDD to improve science.
- 2016: 10 volunteer fishermen operating under Exempted Fishing Permit to replace industry funded observers (still have gov't funded science observers ~5% trips)
- 2017: Shift to EM on 100% of trips (with 100% review rate), fishermen granted some regulatory flexibility.
- 2018: Shift to audit approach: Fishermen's reports used for quota management unless outside accepted difference with video review. If outside range then video review report is used. Video review rate 100%.
- May 2019: Transition to 50% video review rate. 20 active vessels.

Data collected:

- ER: Haul level landed and discarded weights for all species and count for quota species, gear type, time/date etc
- GPS: Time, date, position, speed
- Data fields extracted from video review:
    - Quota managed discard species ID and length (to convert to weight) of each discard.
    - Some subsampling (measure first 30 of each species per haul and count remainder) for higher volume discard events
    - Record interactions with sharks, rays, marine mammal and seabird
    - Coast guard boardings and other events
    - Video quality, obstructions, tampering

ET systems: VMS, ER, EM

Sensors: GPS, 3-4 IP video cameras

Beginning # of vessels: 2

Current # of vessels: 20 vessels (using either trawl, gillnet, longline and jig gears)

- ~220 active vessels in entire fishery

6. OLSPS ER:

Purpose: S. Africa stock assessment, needed reliable data

- Evolved into a compliance tool, assessment remains the main priority
- Bycatch densities maps sent to vessels to inform fishing operations, selectivity

Data: all fishing operation information

Technology: sensors

Requirements:

- Commissioned by international organization for sea turtle interactions
- Development of mitigation devices for protected species
- Applicable to many fisheries, same tool with different configuration
- Working on integrated systems, solutions, ML

7. Spain EM tuna purse seine

Purpose: verification of EM to capture observer data, reduce costs, observer safety was a concern due to fishing region (Somalia)

- Evolved into Identification of MSC, FAD

Data: gear configuration, catch, catch handling from landing to storage, positional information

Technology: sensors, EM

Requirement: Minimum of 6 cameras, 100% recording

Vessels: 23

8. Satlink-DOS Ghange project

Fishery: Tropical tuna Purse seine (Atlantic Ocean)

Purpose:

- Capability of flag states to monitor the activities of vessels under their jurisdiction.
- Transparency and sustainability
- Monitoring, Control and Surveillance
- Compliance
- Catch composition information (size)
- Data collection and reporting obligations to IATTC RFMO (FAD/ free school; report turtles and sharks release methods)
- Coverage (5% minimum for ICCAT as required by recommendation 16-14 and 100% for vessels operating during FAD closure, recommendation 16-01).
- Bunkering
- Transshipments
- Encounters

Requirements: Electronic logbooks, VMS

Regulations: Observers, Fishing closures, IATTC reporting, VMS

Evolution: EMS implementation project finished (March 2019), 3 years project

Data collected:

- Date and time of fishing operations (sets)
- Geospatial location of fishing operations
- Identification of species used for bait
- Identification of all catch, both retained and discarded, to the species level if possible, and including catch that is both landed on deck and catch that is removed from the gear without being landed on deck
- Fish-well traceability
- FAD activities and description
- Disposition of all catch (alive vs. dead)
- Disposition of discarded/released catch
- Bunkering
- Transshipments
- Encounters

ET systems: EM, VMS, ML/AI, Remote alarm system, Drive health status

Current # of vessels: 14

Reference: Building the business case for EMS in the Tuna Ghanaian Purse Seine Fleet: Final Technical Report

9. Satlink-DOS Fiji project

Fishery: Tropical tuna Longline (Pacific Ocean)

Purpose:

- Capability of flag states to monitor the activities of vessels under their jurisdiction.
- Transparency and sustainability
- Monitoring, Control and Surveillance
- Compliance
- Catch composition information (size)
- Data collection and reporting obligations to WCPFC RFMO
- Bunkering
- Transshipments
- Encounters

Requirements: Logbook

Regulations: WCPFC

Evolution: Data traceability, data review.

Data collected:

- Date and time of fishing operations (start and end of sets and hauls)
- Geospatial location of fishing operations
- Identification of species used for bait
- Identification of all catch, both retained and discarded, to the species level if possible, and including catch that is both landed on deck and catch that is removed from the gear without being landed on deck
- Number of hooks deployed per set
- Number of hooks between floats

- Number of floats deployed per set
- Disposition of all catch (alive vs. dead)
- Disposition of discarded/released catch
- Hooking position of catch
- Bunkering
- Transshipments
- Encounters

ET systems: EM, VMS, ML/AI, Remote alarm system, Drive health status

Current # of vessels: 50

10. Satlink-DOS TNC Indo-Pacific Tuna program

Fishery: Tropical tuna Longline (Pacific Ocean)

Purpose:

- Increase fishery accountability
- Determine which data fields collected by human observers can also be accurately collected by the EM system
- Determine costs for EM
- Assess the time required for 'dry observers' to analyze EM system video footage
- Train observers

Requirements: VMS, logbook

Regulations: WCPFC

Evolution: Data traceability, data review

Data collected:

- Date and time of fishing operations (start and end of sets and hauls);
- Geospatial location of fishing operations
- Identification of species used for bait
- Identification of all catch, both retained and discarded, to the species level if possible, and including catch that is both landed on deck and catch that is removed from the gear without being landed on deck;
- Number of hooks deployed per set;
- Number of hooks between floats
- Number of floats per set
- At-vessel (haulback) disposition of all catch (alive vs. dead)
- Disposition of discarded/released catch
- Hooking position of endangered, threatened and protected species (sea turtles, marine mammals, elasmobranchs, seabirds)
- Gear remaining attached to discarded/released catch

ET systems: EM, VMS, ML/AI, Remote alarm system, Drive health status

Sensors: Geofencing

Current # of vessels: 24

11. Satlink-DOS OPAGAC Good Practices Code

Fishery: Tropical tuna Purse seine (Atlantic, Indian and Pacific Ocean)

Purpose:

- OPAGAC/ANABAC Good practices code (AZTI) / ISSF proactive vessel register
  - Best practices for handling and release of SSI bycatch species
  - Requires the use of 100% non-entangling FADs (NEFs) to reduce to a minimum the interactions with sensitive species like sea turtles, sharks and rays
  - The implementation of a FAD management system

Requirements: VMS, Observer, logbook

Regulations: Observers, Fishing closures, IATTC/ ICCAT/ IOTC/ WCPFC reporting

Evolution:

- Purse seine vessel coverage increased (human observers (10%) + EMS)
- Auxiliary vessels increased coverage electronically (EMS due to space problems)
- Continuous follow-up by steering committee

Data collected:

- Date and time of fishing operations (Sets)
- Geospatial location of fishing operations;
- Identification of SSI
- FAD activities and description
- Handling methods of release/retained of all SSI

ET systems: EM, VMS, ML/AI, Remote alarm system, Drive health status

Beginning # of vessels: 9

Current # of vessels: 33

Reference: https://www.azti.es/atuneroscongeladores/wp-content/uploads/2017/05/Buenas-Pr%C3%A1cticas-OPAGAC-ANABAC-feb-2017-FIRMADO_English.pdf

Annex 3: ICSE 2020 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?