Food and Agriculture Organization of the United Nations

FAO FISHERIES AND AQUACULTURE TECHNICAL PAPER

664

ISSN 2070-7010

Electronic monitoring in tuna fisheries

Strengthening monitoring and compliance in the context of two developing states

Cover photograph: ©Satlink.

Electronic monitoring in tuna fisheries

Strengthening monitoring and compliance in the context of two developing states

FAO
FISHERIES AND
AQUACULTURE
TECHNICAL
PAPER

664

Kim Stobberup & Alejandro Anganuzzi
Common Oceans ABNJ Tuna Project
FAO

Netani Tavaga
Offshore Fisheries Division
Ministry of Fisheries, Fiji

Eparama Loganimoce & Malo Hosken
The Pacific Community, Oceanic Fisheries Programme
New Caledonia

Michael Arthur-Dadzie & Godfrey Baidoo-Tsibu
Fisheries Commission
Ghana

Papa Kebe & Gerald Scott
International Seafood Sustainability Foundation
United States of America

Lauren Spurrier & Michele Kuruc
World Wildlife Fund
United States of America

and

Julien Million
World Bank
United States of America

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2021

Required citation
Stobberup, K., Anganuzzi, A., Arthur-Dadzie, M., Baidoo-Tsibu, G., Hosken, M., Kebe, P., Kuruc, M., Loganimoce, E., Million, J., Scott, G., Spurrier, L., & Tavaga, N. 2021. *Electronic monitoring in tuna fisheries: strengthening monitoring and compliance in the context of two developing states*. FAO Fisheries and Aquaculture Technical Paper No. 664. Rome. FAO. https://doi.org/10.4060/cb2862en

ISBN 978-92-5-133847-6

Preparation of this document

This document was prepared with the support of the Common Oceans ABNJ Tuna Project, more formally known as the project on Sustainable Management of Tuna Fisheries and Biodiversity Conservation in the Areas Beyond National Jurisdiction (ABNJ), which is funded by the Global Environment Facility and implemented by FAO. Following the philosophy of the project, the pilot trials on electronic monitoring in Fiji and Ghana were carried out in partnerships, involving governments, civil society organizations, and the private sector.

The views expressed in this document are those of the authors and do not necessarily reflect the views of FAO or any of the partners involved. We acknowledge the support from all the partners involved and a special thanks to the teams in Fiji and Ghana for their dedication and efforts to make these trials successful. The authors and their affiliation are the following:

- Kim Stobberup & Alejandro Anganuzzi: Common Oceans ABNJ Tuna Project, FAO
- Netani Tavaga: Offshore Fisheries Division, Ministry of Fisheries, Fiji
- Eparama Loganimoce & Malo Hosken: The Pacific Community, Oceanic Fisheries Programme, New Caledonia
- Michael Arthur-Dadzie & Godfrey Baidoo-Tsibu: Fisheries Commission, Ghana
- Papa Kebe & Gerald Scott: International Seafood Sustainability Foundation, the United States of America
- Lauren Spurrier[1] & Michele Kuruc: World Wildlife Fund, the United States of America
- Julien Million[2]: World Bank, the United States of America

[1] Now with the Pew Charitable Trusts
[2] Previously with the Common Oceans ABNJ Tuna Project, FAO

Abstract

Illegal, unreported and unregulated (IUU) fishing is a serious threat to sustainable fisheries, marine ecosystems and the livelihoods of legitimate fishers globally. To address it, the Common Oceans ABNJ Tuna Project is exploring ways to strengthen and harmonize the use of monitoring, control and surveillance tools, and combat IUU fishing in tuna fisheries across the marine areas beyond national jurisdiction.

One tool is the use of electronic monitoring systems to monitor individual vessel operations at sea. In a typical electronic monitoring application, cameras, recording video or still images, are deployed at key points on the vessel to allow a view of the fishing operation. The video footage is stored on hard drives that government officials can use to review compliance with regulations, as well as record detailed data on catch and effort. It was envisaged that industry would have access to these data for its own operational purposes.

To test the best way to incorporate this technology as a complementary compliance tool, two pilot trials were set up: one in Ghana to cover the domestic tuna purse seine fleet fishing; and one in Fiji to cover the domestic longline fisheries. Close collaboration was established between national governments and industry for implementation.

The overall aim of the pilots was to develop an effective implementation process at the national level, so that the information could be properly utilized for compliance purposes. This report documents the successful completion of these trials, and the lessons learned that could benefit electronic monitoring programmes elsewhere.

Contents

Preparation of this document iii
Abstract iv
Acknowledgements vi
Abbreviations and acronyms vii

1. Background 1
- Brief history of electronic monitoring 1
- Common objectives in electronic monitoring programmes 2
- The potential of electronic monitoring in tuna fisheries 3
- Common Oceans ABNJ Tuna Project 4

2. Ghana 5
- Background 5
- Pilot trial in Ghana 6
- Satlink SeaTube system 7
- Institutional arrangements 8
- Results 9
- Cost considerations 14
- Legal review 15

3. Fiji 17
- Background 17
- Pilot trial in Fiji 18
- Institutional arrangements 20
- Data review and analysis 21
- Results 23
- Cost considerations 26
- Legal review 28

4. Comparison 29
- Fiji and Ghana exchange 29
- General perspective 30

5. Lessons learned 33
- Defining the goals 33
- Industry buy-in 34
- Human capacity 35
- Efficiency in analysis 35
- Cost and cost-recovery 36
- Commitment and political will 36
- Regional structures 37

6. Scaling up 39

References 41

Annex 1 Satlink SeaTube system 47

Annex 2 Introduction to analysis of electronic monitoring data 51

Annex 3 Report template developed for Ghana 63

Annex 4 Report template developed for Fiji 67

Tables

1. Overview of the purse seine fishing vessels covered by electronic monitoring in Ghana 7
2. Data types identified and/or estimated in a purse seine fishery 10
3. Catch and effort monitored during the electronic monitoring trial in Ghana 11
4. Summary of key data on costs during the Ghana trial 14
5. Overview of the fishing vessels covered by electronic monitoring in Fiji 19
6. Results of the electronic monitoring trial in terms of coverage 23
7. Summary of key data on costs during the Fiji trial 26
8. Estimated annual operational costs (excluding hardware) of the electronic monitoring programme covering 50 longline vessels in Fiji 27

Figures

1.	Schematic overview of an electronic monitoring system	8
A1.1	Schematic view of camera configuration on a large purse seiner	48
A1.2	Examples of camera views as seen through the Satlink View Manager, the software developed for electronic monitoring data analysis	48
A1.3	Schematic view of camera placement in Fijian longline vessels	50
A2.1	Industrial tuna vessel showing the purse seine to encircle tuna schools	52
A2.2	Example of trajectory of a tuna purse seiner with the four activities estimated on daily VMS positions	53
A2.3	Examples of trajectories of Ghanaian purse seiners from SVM	53
A2.4	Tuna vessel showing the longline deployed	54
A2.5	Examples of trajectories of Fijian longliners from the electronic monitoring trial 2015–19	55
A2.6	Satlink View Manager screen layout	55
A2.7	Overview of controls and functions to generate reports	56
A2.8	Example of a report list showing various declarations	57
A2.9	Example of a printable SVM inspection report	57
A2.10	Overview of analysis protocol used for purse seine fishing in Ghana	58
A2.11	Overview of analysis protocol for setting the line on longliners in Fiji	59
A2.12	Example of a line setting event	59
A2.14	Example of a hauling event	60
A2.13	Overview of analysis protocol for hauling the line on longliners in Fiji	60
A2.15	Example of photographs to document events – purse seiners	61

Acknowledgements

The authors would like to acknowledge the support from all the partners involved, and wish to extend a special thanks to the teams in Fiji and Ghana for their dedication and efforts to make these trials successful. The authors would also like to acknowledge the work of the staff of Satlink and Digital Observer Services for building up capacity, providing constant support – sometimes under challenging conditions – and for keeping everything functioning in the field.

Abbreviations and acronyms

ABNJ	areas beyond national jurisdiction
BBNJ	marine biodiversity of areas beyond national jurisdiction
CLAV	Consolidated List of Authorized Vessels
CMM	conservation and management measure
DOS	Digital Observer Services
EEZ	exclusive economic zone
FAD	fish aggregating device
FFA	Pacific Islands Fisheries Forum Agency
FFIA	Fiji Fishing Industry Association
FIP	fishery improvement project
FMC	Fisheries Monitoring Centre
FNOP	Fiji National Observer Programme
FROP	Fiji Regional Observer Programme
FTBOA	Fiji Tuna Boat Owners Association
GDP	gross domestic product
GEF	Global Environment Facility
GPS	Global Positioning System, a satellite navigation system
HDD	hard disk drive
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
IOTC	Indian Ocean Tuna Commission
ISSF	International Seafood Sustainability Foundation
IUU	illegal, unreported and unregulated (fishing)
MCS	monitoring, control and surveillance
MOU	memorandum of understanding
MSC	Marine Stewardship Council
NGO	non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
PNA	Parties to the Nauru Agreement
PNAO	Parties to the Nauru Agreement Office
RFMO	regional fisheries management organization
SPC	Pacific Community
SVM	Satlink View Manager
TAC	total allowable catch
TUFMAN2	Tuna Fisheries Database Management System
t-RFMO	tuna regional fisheries management organization
VMS	vessel monitoring system
WCPFC	Western and Central Pacific Fisheries Commission
WWF	World Wide Fund for Nature

1. Background

BRIEF HISTORY OF ELECTRONIC MONITORING

Electronic monitoring using cameras is a proven technology that has been widely used for various purposes on fishing vessels, primarily in developed countries and industrial fleets. This technology was first piloted and implemented in the crab fishery in British Columbia (Canada), about two decades ago. There were problems in the fishery owing to dramatic increases in fishing effort and strong competition between fishers, and accusations of gear sabotage, theft, and fishers hauling catch from other fishers' traps were widespread (Archipelago, 2020). In order to resolve these problems, a specific measure on a trap limit for each vessel was being considered, but this had to be enforced effectively before the crab industry would be willing to accept it. A joint effort between the crab industry with Archipelago Marine Research was established to develop and pilot an electronic monitoring programme to ensure compliance with these limits and to prevent tampering with other fishers' traps. This effort was entirely funded by the industry and proved to be successful. Hence, Archipelago Marine Research was a pioneer in the field and continues to be a major player as an electronic monitoring technology service provider.

Although the first electronic monitoring programmes were piloted and implemented in Canada, there have been no new electronic monitoring programmes in Canada beyond those for the British Columbia hook-and-line and crab fisheries, which were implemented more than a decade ago. Meanwhile, a number of other countries have mandated or are evaluating electronic monitoring programmes for different fisheries (Michelin *et al.*, 2018).

Since the first electronic monitoring trial, the use of camera systems on fishing vessels has grown slowly, and it is estimated that about 1 000 vessels are currently operating with electronic monitoring on board (Michelin *et al.*, 2018). About 30 different fisheries are being monitored by electronic monitoring, either as part of a permanent effort or in some form of trial or pilot, and most of these are in Europe, North America and Oceania (Michelin *et al.*, 2018). However, electronic monitoring of industrial tuna fisheries is expanding rapidly, and these fisheries are considered global across the oceans.

Michelin *et al.* (2018) provide a recent overview of electronic monitoring trials and programmes across the world. The following builds on this overview, taking into account other sources of information and updated information, although this should not be considered an exhaustive list.

The United States of America: Various trials have been carried out over a period of 15 years, covering about 7 fisheries. There is a growing commitment and focus on electronic technologies from the National Oceanic and Atmospheric Administration (NOAA) and regional fishery management councils, and this is expected to drive the increasing use of electronic monitoring as part of fully fledged monitoring programmes.[3]

The European Union: The recent adoption of the Landings Obligation, which was implemented in phases over the period 2015–19, has generated serious discussions about how to enforce the ban on discards while vessels are at sea. Several electronic monitoring pilots have occurred in Denmark, Germany, the Netherlands and the United Kingdom of Great Britain and Northern Ireland in recent years, demonstrating

[3] A summary of United States fisheries electronic monitoring programmes is provided at NOAA Fisheries (NOAA, 2019).

the tool's usefulness in quantifying and documenting the fate of bycatch, but this has not yet led to full implementation (James *et al.*, 2019).

Australia: After initial trials, Australia adopted electronic monitoring in 2015 for the gillnet hook and trap fishery and for the tuna and billfish fisheries. The programme now covers 75 vessels and is expected to expand to eventually cover most, if not all, Australian fisheries in the next 5–10 years (Australian Fisheries Management Authority, 2014).

New Zealand: In 2017, New Zealand passed a regulation requiring electronic monitoring for all commercial fishing vessels, but implementation has been slow. There are about 20 vessels with electronic monitoring systems currently installed, but more than 1 000 additional licensed vessels that could be required to have electronic monitoring in the coming years.

Western and Central Pacific Ocean: A 5 percent observer coverage of tuna longline vessels is required in this region, but the actual coverage has been less than 2 percent (with the notable exceptions of the longline fleets based in Fiji, New Caledonia and Hawaii [the United States of America], where coverage is above 5 percent). This is linked to various issues, for example, difficult working environments on the boats, safety concerns, complicated logistics and limited observer supply. To address this problem of low coverage, various electronic monitoring trials have been carried out in the Pacific, i.e. Fiji, the Marshall Islands, Micronesia (Federated States of), Palau, Solomon Islands and Vanuatu (Hurry, 2019). These are in addition to efforts being carried out in Australia and New Zealand. In the context of the Western and Central Pacific Fisheries Commission (WCPFC), electronic monitoring is expected to grow rapidly, and the recent commitment by ministers representing Parties to the Nauru Agreement (PNA)[4] on developing a PNA E-Monitoring Program is expected to build further momentum (PNA, 2018).

Industrializing and developing countries: electronic monitoring systems have been trialled in various industrial and small-scale fisheries in other countries such as Ghana, Indonesia, Mexico, Peru, Thailand and other parts of Latin America. Chile has recently made a commitment to install electronic monitoring systems in its industrial fishing fleets. There is keen interest on finding suitable cost-efficient and effective solutions for improved data collection and monitoring of small-scale fishing fleets worldwide.

COMMON OBJECTIVES IN ELECTRONIC MONITORING PROGRAMMES

Fujita *et al.* (2018) provide details on 20 case studies on electronic monitoring implementation, and most cases concern catch monitoring. electronic monitoring has been used extensively for this purpose to obtain reliable information on catches and their composition, which is particularly relevant in fisheries managed by catch shares and quotas, but it has also been used to improve the quality of data on fishing activity.

However, electronic monitoring is also used for other purposes or may have an additional focus. For example, the primary focus may be to monitor and collect data on bycatch of protected species,[5] including those that cannot be retained and should be released safely to the extent possible. It may also be used for purposes of avoiding theft of fish and/or gear and to improve operations at sea. Recent examples of the use electronic monitoring are to monitor safety at sea and labour conditions of the crew on board (Douglas, 2019). The primary focus may be for monitoring compliance with rules and regulations, including limits on effort, discard bans, transshipment activity, and area/time closures.

In recent years, electronic monitoring has become increasingly utilized to expand the capability of flag States to monitor the activities of vessels under their jurisdiction.

[4] The Parties to the Nauru Agreement (PNA), which control most of the Western Pacific tuna purse seine fishery, are: Kiribati, the Marshall Islands, Micronesia (Federated States of), Nauru, Palau, Papua New Guinea, Solomon Islands and Tuvalu.

[5] Endangered, threatened and protected species.

This is particularly useful in distant-water fleets that operate over vast areas, where electronic monitoring offers the advantage of verifying compliance without the need for an observer on board the vessel. electronic monitoring provides a way to obtain independently verifiable information on compliance of fishing vessels, as well as an additional source of information on catch by species and size. Another aspect is that electronic monitoring addresses a number of concerns with observer programmes, as camera/video systems cannot be subject to coercion and can thus release observers from compliance-related tasks to focus on scientific tasks.

Another recent trend is the increasing use of electronic monitoring to document good fishing practices and traceability in the fishing industry. This is an example of the market as a driver, and there appear to be many large companies introducing electronic monitoring technology for their own purposes, independently of fisheries authorities.

THE POTENTIAL OF ELECTRONIC MONITORING IN TUNA FISHERIES

Tuna fisheries are highly mobile fisheries, operating over vast areas across oceans in tropical and temperate waters. The larger vessels can operate on the high seas for extended periods, and many of these vessels are authorized to fish in more than one ocean. In order to give an idea of scale, there are about 1 300 purse seine and 3 000 line (mostly longline) vessels of more than 24 m in length that are authorized to fish in the convention areas of tuna regional fisheries management organizations (t-RFMOs).[6]

These t-RFMOs require the collection of independent data on fishing activity, which is normally done with the use of human observers. A 100 percent observer coverage of large-scale purse seiners is required in the Western and Eastern Pacific (WCPFC and Inter-American Tropical Tuna Commission [IATTC]). In the Atlantic and Indian Oceans (International Commission for the Conservation of Atlantic Tunas [ICCAT] and Indian Ocean Tuna Commission [IOTC]), a minimum of 5 percent coverage is required for various gear types including purse seine. However, ICCAT also requires 100 percent observer coverage for all vessels of more than 20 m during a fish aggregating device (FAD) time-area closure, and in the bluefin fishery.

Although there are differences in requirements, the International Seafood Sustainability Foundation (ISSF) has adopted an industry-led initiative for full coverage of purse seine fleets on a voluntary basis. This requires ISSF-participating companies to "conduct transactions only with those large-scale purse seine vessels that have 100 percent observer coverage (human or electronic if proven to be effective)."[7] The argument is that this is necessary to ensure full and accurate collection of catch data, interactions with non-target species, and other scientific information for analysis and stock assessment. As the ISSF represents major tuna-processing companies in the sector, this is a measure that purse seine fleets are implementing, and the possible use of electronic monitoring for this purpose should be noted.

Various pilot studies were carried out under the auspices of the ISSF on use of electronic monitoring to substitute and/or complement human observers. These resulted in guidelines on the use electronic monitoring in the industry (Restrepo *et al.*, 2018). Purse seine fleets under the flags of France, Ghana, Seychelles and Spain have had voluntary electronic monitoring programmes in the Atlantic and Indian Oceans (Ruiz, 2018), some of which are ongoing.

In the case of tuna longliners, most countries/fleets have difficulties in reaching the current requirement of 5 percent coverage, which applies across oceans. However, there appears to be a consensus that this requirement should be increased to 20 percent or higher in order to obtain reasonably robust scientific data on longline fishing activity.

6 Consolidated List of Authorized Vessels available at Tuna-org (Tuna-org, 2020).
7 ISSF Conservation Measure 4.3 (ISSF, 2020).

Electronic monitoring is expected to play a key role in reaching such goals, avoiding many of the practical difficulties of placing human observers on board these vessels.

Another gap is the proper monitoring of transshipment activity, particularly associated with its use on the high seas. Transshipment at sea by purse seiners is prohibited by the IATTC, ICCAT, IOTC and WCPFC (with some exceptions), and it should only take place in port. However, at-sea transshipment is allowed in the case of longline vessels, and all t-RFMOs require 100 percent coverage of this activity, but monitoring and compliance need to be strengthened. This is a case where electronic monitoring is expected to be an effective solution to attain full coverage at lower cost.

COMMON OCEANS ABNJ TUNA PROJECT

The objective of the Common Oceans ABNJ Tuna Project has been to contribute to the project Sustainable Management of Tuna Fisheries and Biodiversity Conservation in the Areas Beyond National Jurisdiction (ABNJ). This is the largest of four projects that have constituted the Common Oceans Program, which has been funded by the Global Environment Facility (GEF) and implemented by FAO in the period 2014–2020 (FAO, 2020a).

The Common Oceans ABNJ Tuna Project has been a unique, innovative and comprehensive initiative, where FAO has worked with almost 20 partners, including the secretariats of the five t-RFMOs, civil society organizations, intergovernmental organizations, governments and the private sector, towards ensuring the sustainable use of tuna resources in the ABNJ. The project has focused on three areas:

- supporting implementation of sustainable and efficient fisheries management and fishing practices;
- reducing illegal, unreported and unregulated (IUU) fishing through strengthened and harmonized monitoring, control and surveillance (MCS);
- reducing ecosystem impacts from tuna fishing, including effects on bycatch and associated species.

Concerning the second point, the project has explored new ways to strengthen and harmonize the use of MCS tools, and combat IUU fishing in tuna fisheries across the marine ABNJ. This has been supported through two main strategies.

The first strategy has focused on various capacity-building efforts aimed at the development of new skills, as well as the sharing of knowledge among officials of t-RFMOs. This has included the establishment of the Tuna Compliance Network, an informal platform launched in early 2017 to exchange information and intelligence among compliance officials of t-RFMOs. Another initiative has been to help develop the first international certification-based training programme in fisheries enforcement and compliance, which offers a new career path for officers in various Pacific countries. This is seen as a step towards a global certification-based training programme in MCS to be developed and tailored to specific regions, which can contribute to building human capacity in developing countries.

The second strategy has been the strengthening of MCS tools and compliance monitoring. New tools have included legal templates for implementation of port State measures, design options of catch documentation schemes, and the automatic updating of the Consolidated List of Authorized Vessels (CLAV) from the t-RFMO databases. The project has also contributed to reviewing and updating information on MCS in tuna fisheries as well as practical implementation of MCS tools. Trials have been carried out on the use of electronic monitoring to evaluate the best way to integrate this tool as an MCS tool for developing States. The specific cases of Fiji and Ghana are the subject of this report, and are presented below.[8]

[8] Although not considered in this report, it should be noted that the project has supported another electronic

2. Ghana

BACKGROUND

Ghana has a long tradition of fishing, and this continues to be important for the national economy and socio-economic development. The fisheries sector generates more than USD 1 billion in revenue each year, and accounts for at least 4.5 percent of Ghana's gross domestic product (GDP) (Republic of Ghana, 2014). Moreover, it is estimated that about 10 percent of the population depend on fishing, either directly or indirectly.

Tuna has been fished in Ghana for centuries, but an industrial tuna fleet has developed and consolidated itself into a global industry in recent decades. Investments by major Asian seafood companies have played an important role in this. Most of the exports of these tuna products (whole, loins and canned) go to the European Union, although some volumes are exported to Japan, the Republic of Korea and the United States of America (Ministry of Fisheries and Aquaculture Development, 2018).

Ghana's total annual production of tuna has averaged about 80 000 tonnes in recent years (2014–17),[9] most of which has come from the purse seine fleet of 14 vessels and pole-and-line fleet of 21 vessels, as well as small catches taken by small-scale vessels.

There is also high demand for tuna in local markets, and women play a powerful part in supplying this demand. Female traders called "fish mammies" are responsible for virtually all sales into the local market channel from Ghana's industrial fleet, and they are major players in the industry, providing finance for fishing trips, particularly in the pole-and-line fleet (Stockholm Resilience Centre, 2018).

Available studies on estimating IUU fishing indicate that West Africa is one of the regions with the highest levels of IUU fishing in the world.[10] There have been instances of non-compliance by Ghanaian fishing vessels with existing fisheries laws and regulations within Ghana's fishery waters, and unlicensed fishing by Ghanaian-flagged vessels outside Ghana's fisheries waters (Republic of Ghana, 2014), as well as illegal fishing by foreign-flagged vessels.

Estimates of IUU fishing are generally characterized by uncertainty owing to the nature of these activities, where the IUU actors go to great lengths in keeping their activities hidden and undetected. For the Eastern Central Atlantic, IUU is estimated to be in the range of 25–50 percent of reported catches (Agnew *et al.*, 2009). The global study by Agnew *et al*. (2009) limited the analysis to illegal and unreported catches, and all unreported catches taken in high seas waters subject to an RFMO jurisdiction. However, it is important to distinguish between fisheries, and this study estimated that illegal and unreported catches of tuna were in the range of about 1–10 percent, albeit globally (Agnew *et al.*, 2009). However, these estimates should be considered conservative as they are based on detected cases of illegal and unreported fishing.

The European Commission undertook a routine evaluation mission to Ghana in May 2013. The mission's report concluded that Ghana's fisheries administration was unable to: (i) ensure flag, coastal and port State obligations; and (ii) certify fisheries products in accordance with European Union's IUU regulations. Pursuant to Council Regulation (EC) No. 1005/2008 establishing a Community system to prevent, deter

---

monitoring trial in Seychelles, with the primary objective of evaluating the use of electronic monitoring for data collection in tuna purse seiners (Jupiter, Forcada Alamracha and Sanchez Lizaso, 2017).

9 ICCAT statistics.

10 Illegal, unreported and unregulated fishing as defined by FAO (FAO, 2020b).

and eliminate IUU fishing, the European Commission issued an official notification ("yellow card") to Ghana on 26 November 2013, identifying it as a non-cooperating third country.[11] This yellow card was a formal warning linked to concerns over Ghana's lack of action to address deficiencies in combating IUU fishing.

Faced with possible trade sanctions in its main market, Ghana embarked on significant efforts, in collaboration with the European Union and other international partners, to amend the legal frameworks to combat IUU fishing, strengthen the sanctioning system, improve MCS, and improve compliance with international agreements and conventions (e.g. the United Nations Convention on the Law of the Sea). This included the adoption and/or establishment of:

- the National Plan of Action on IUU in 2014;
- the ambitious Fisheries Management Plan for the period 2015–19, including a strategy to reduce capacity in the fleet;
- revised legislation in 2014 strengthening its legal framework and introducing dissuasive sanctions;
- the Fisheries Enforcement Unit, which has become operational;
- procedures for validation and cross-checking of European Union catch certificates have been set up and implemented, ensuring improved traceability.

These efforts by Ghana resulted in the lifting of the yellow card by the European Commission in October 2015. The European Commission acknowledged the significant reforms made by Ghana and its success in addressing shortcomings in its fisheries governance system (European Commission, 2015).

The trial of electronic monitoring as a tool to reinforce MCS in Ghana should be seen in this context of considerable reform and a strong interest from the private sector to strengthen monitoring and compliance of tuna fishing vessels as part of efforts to keep the main export market open. The purse seine fleet operators under the Ghana Tuna Association have been keen to show "best practice" and, therefore, have given strong support to test electronic monitoring as a compliance tool.

PILOT TRIAL IN GHANA

The Government of Ghana has shown political commitment for testing the use of electronic monitoring as a compliance tool in tuna fisheries. This has been part of the strengthened policy to fight IUU fishing activities, achieve efficient and sustainable tuna production, and mitigate adverse impacts of bycatch on biodiversity. In February 2015, the World Wide Fund for Nature (WWF), the implementing partner responsible for this electronic monitoring trial in Ghana, signed a grant agreement with FAO.

The industry, represented by the Ghana Tuna Association, provided strong support for the initiative to pilot electronic monitoring technologies to strengthen the transparency and sustainability of the Ghanaian tuna fleet, thus contributing to the general efforts of Ghana explained above. It should be noted that TTV (Thai Union), a founding company in the ISSF, provided substantial support for the pilot and committed to substantial cofinancing for the project. There was keen interest to ensure, and to be able to demonstrate with objective and verifiable data, compliance with national and regional regulations.

Implementation involved close collaboration between the Government of Ghana and WWF, as well as support from the ISSF and FAO. At the national level, implementation was carried out in close collaboration between the Fisheries Commission (FC; Ministry of Fisheries and Aquaculture Development) and Ghana Tuna Association, which represents the fleet operators and processors.

---

[11] European Commission Decision of 26 November 2013 (2013/C 346/03).

TABLE 1
Overview of the purse seine fishing vessels covered by electronic monitoring in Ghana

No.	Phase	Company	Vessel name	Installation
1	1st	TTV[1]	Cap d'Ambre	1 October 2015
2		Agnes Park Fisheries Ltd	Agnes	5 October 2015
3		DH Fisheries Company	Iris J (ex-Cap Lopez)	8 October 2015
4		Panofi	Panofi Discoverer	11 October 2015
5		Panofi	Panofi PathFinder	13 October 2015
6	2nd	TTV[1]	Cap des Palmes	20 February 2016
7		TTV[1]	Cap Saint Paul	24 February 2016
8		Panofi	Panofi Frontier	1 March 2016
9		Panofi	Panofi Forerunner	9 March 2016
10		Panofi	Panofi Master	11 March 2016
11	3rd	Panofi	Panofi Volunteer[2]	3 April 20161
12		Afko Fisheries Company	AFKO 805	27 March 2017
13		Laif Fisheries Company	Long Tai 2	2 August 2017
14		Laif Fisheries Company	Long Tai 1	8 September 2017

[1] The ownership of the TTV vessels changed during the project implementation period.
[2] An outbreak of fire during maintenance aboard the Panofi Volunteer led to damage and loss of the electronic monitoring system. A new system was installed on 30 June 2016, thus bringing the total to 15 EM units installed.

It was decided that the trial should cover the tuna purse seine fleet, which was based on contacts and feedback from the industry. Ghana has a total of 17 vessels registered in the ICCAT list of authorized vessels, of which 14 were active during the trial period (2015–18), operating mainly in the Gulf of Guinea (Table 1).

SATLINK SEATUBE SYSTEM

In 2015, the FAO invited tenders for a company to provide a proven electronic monitoring system, including hardware, software, maintenance, services, and on-ground support. Satlink SL (Satlink, 2020), a Spanish company, was awarded the contract for trials in both Fiji and Ghana, based on a competitive offer to cover all the technical requirements and conditions.

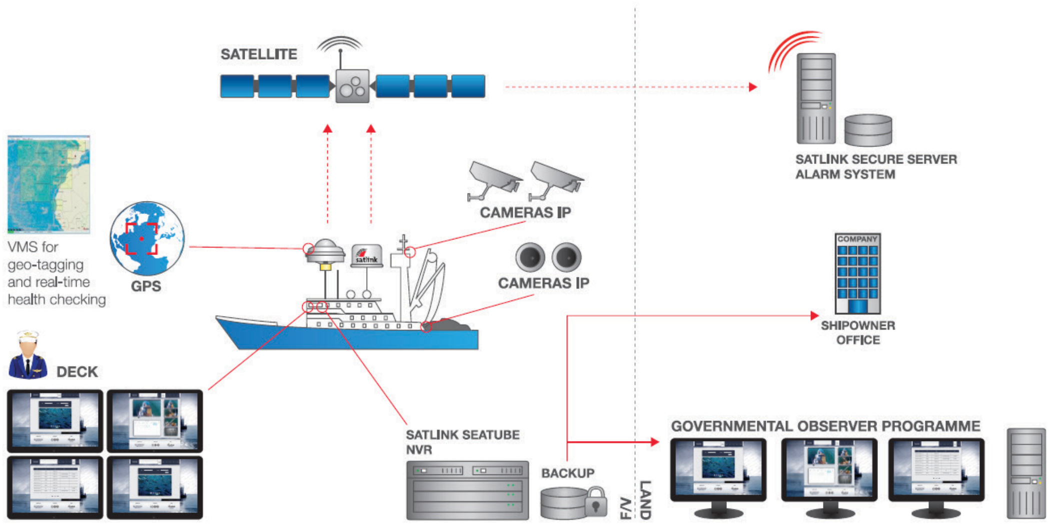
Since 2016, the SeaTube electronic monitoring system has been approved to fulfil ISSF technical requirements in terms of electronic monitoring systems for tropical tuna purse seine fisheries; hence, this system is used extensively. At present, globally, there are over 225 operational systems with the Satlink SeaTube electronic monitoring system on board (Satlink, personal communication).

Recently, there have been strong advances in electronic monitoring technology and various new companies, or new mergers and configurations, have entered the scene.[12] At the time of the tender, there were about five companies in a position to provide the technology as well as the required support. This has changed, but Satlink continues to be one of major providers globally.

Details on the electronic monitoring system provided by Satlink are provided in Annex 1. In general terms, this is a video recording solution (in high-definition quality), and the data are stored locally, on board vessels, on encrypted hard disk drives (HDDs). It is important to note that the video data were not available in real time. Real-time transmission of video data by satellite was too expensive at the time (and still is), but interesting cost-effective solutions to real-time transmission of data are currently being developed (using artificial intelligence, 5G networks, etc.).[13]

[12] See, for example, presentations by providers at the Seafood and Fisheries Emerging Technologies Conference (SAFET), 13–16 February 2019, Bangkok, Thailand (Seafood and Fisheries Emerging Technologies, 2020).
[13] Ibid.

FIGURE 1
Schematic overview of an electronic monitoring system



Source: Satlink.

The system includes an independent vessel monitoring system (VMS) where positions in the Global Positioning System (GPS) are determined by Inmarsat identity provider equipment at prescribed time intervals. Moreover, this is a sealed and tamper-evident system,[14] which works automatically, independently of the vessel crew, and its functioning is monitored remotely by satellite.

Figure 1 shows an operational schematic of the Satlink SeaTube system. The left-hand side refers to the system on board fishing vessels including cameras, satellite communication equipment, onboard computers and a network video recorder.

The right-hand side of Figure 1 shows the land-based parts of the system. They includes the Satlink secure server to monitor remotely the functioning electronic monitoring systems on board vessels, wherever they may be. This server is located in Spain at the company's headquarters. Companies and vessel operators may install electronic monitoring to monitor their operations; but in this trial, the set-up was such that they obtained copies of video footage upon request from the government.

INSTITUTIONAL ARRANGEMENTS

The electronic monitoring unit was established as part of the Monitoring, Control and Surveillance Division of the Fisheries Commission under the overall responsibility of the director. In addition, a national electronic monitoring coordinator was nominated as the main focal point between Ghana and international partners, and an international expert was hired as project manager for the implementation of the electronic monitoring trial.

Office space, equipment, transportation and human resources were dedicated temporarily to this project by the Ghanaian fisheries administration. The Ghanaian Project Team was formed, and an electronic monitoring unit was established.

The Fisheries Commission is an agency responsible for implementing fisheries policy and goals defined by the Ministry of Fisheries and Aquaculture Development.

[14] Meaning that when tampering or sabotage occurs, this can easily be detected.

It consists of five divisions:

- Marine Fisheries Management Division;
- Inland Fisheries Management Division;
- Fisheries and Scientific Survey Division;
- Monitoring, Control and Surveillance Division;
- Operations and Administration Division.

The MCS Division of the Fisheries Commission is charged with combating IUU fishing, including responsibility for port controls, and carries out various activities to monitor and control industrial vessels, such as fisheries inspections and supervision of landings and transshipments through the Fisheries Enforcement Unit. The Fisheries Enforcement Unit is a multi-agency arrangement, involving the Fisheries Commission, Ghana Navy, Ghana Air Force, Marine Police, and the Ministry of Justice, with the mandate for MCS and enforcement of fisheries legislation in Ghana (Government of Ghana and FAO, 2018).

The Fisheries Enforcement Unit was one of the covenants of the West Africa Regional Fisheries Project (Ghana component), which was financed by the World Bank in 2012–18, and strengthened further in response to the yellow card issued by the European Commission in 2013. Another related initiative was the establishment of the Fisheries Monitoring Centre (FMC), which is equipped to monitor fishing and related activities by a vessel monitoring system (VMS) and an automatic identification system. The FMC's operations are linked with those of the Ghana Navy, the Ghana Maritime Authority and the Marine Police (Government of Ghana and FAO, 2018).

The electronic monitoring unit was established with a team leader and a staff of about ten observers, who were assigned from the Fisheries and Scientific Survey Division and Monitoring, Control and Surveillance Division on a part-time basis. However, there were some difficulties in reconciling the various duties of these observers, which meant that a backlog of electronic monitoring data started to build up for analysis. Therefore, two additional staff were hired to dedicate their time exclusively to electronic monitoring data review and analysis.

Memorandum of understanding

A memorandum of understanding (MOU) was signed by the Fisheries Commission and industry partners (i.e. Panofi, TTV and Agnes Park) on 9 December 2015, specifying the roles and responsibilities of those involved in the electronic monitoring pilot trial. As specified in the MOU, the objective was to supplement the MCS system in place in Ghana, and to complement and improve the human observer programme for verifying compliance by fishing vessels with regional and national regulations, as well as to improve the collection of data for scientific and management purposes.

Some key points specified in this MOU were: (i) the Fisheries Commission would install and maintain the electronic monitoring equipment, which would be provided by FAO; (ii) the vessel owners/operators and captains would ensure proper care of the equipment to ensure its correct functioning, and notify the Fisheries Commission prior to their return to port; and (iii) the Fisheries Commission would retrieve the HDDs from each vessel and, thereafter, review their contents in order to prepare a trip report. This report was to be provided, together with a trip video, to the relevant owners, and the electronic monitoring data were to be securely stored for six months after and then erased.[15]

The responsibility for data analysis was entrusted to the Fisheries Commission. This included estimation of data on catches by species, discards, and fishing effort (including FAD activity). For each fishing trip, a report was prepared, providing these

[15] The data storage period was later extended to one year.

data estimates and to document compliance with regional and national management measures.

Data ownership was attributed to the Government of Ghana for the period of the trial, although industry partners could request copies of the data concerning their vessels and use these for their own operational purposes. All electronic monitoring data were treated as confidential, and it was decided that the primary focus was to monitor and collect data on fishing operations. Thus, these data could not be used for the purpose of enforcement during the trial period, but there was a tacit understanding that this would be an opportunity to improve on compliance through a collaborative approach between government and industry.

RESULTS

Starting up the electronic monitoring programme was a substantial undertaking that involved not only the installation and set-up of equipment but also entailed the building of human capacity, creating a formal structure in which to insert an electronic monitoring unit (as explained above), and developing a data storage and information management system, as well as standard operating procedures and a chain of custody – all of which were essential.

Six desktop computers were provided to the Fisheries Commission in Tema; thus, there were six stations for analysis of video footage. The computers were equipped with: Satlink View Manager (SVM; a Satlink proprietary analysis software), an extra monitor for better viewing, and a Synology HDD server, which was necessary for decryption of the HDDs.

It was decided at the start of the trial that the electronic monitoring system should monitor all fishing activity and review 100 percent of the video footage of the Ghanaian purse seine fleet. The electronic monitoring equipment was installed in phases in 2015–17 (Table 1), and full coverage of the 14 purse seiners was achieved by mid-2017.

Electronic monitoring analysis training

Training was provided by Satlink and Digital Observer Services (DOS). The latter is a Satlink sister company, providing services such as the analysis of electronic monitoring data from the SeaTube system and provision of data on fishing activity. Many of the staff at DOS are experienced observers and experts in the use of SVM. In fact, the development and continuous improvements in the software are driven by DOS staff, as well as feedback from clients, but the actual software development is undertaken by Satlink staff.

Two one-week training sessions were provided to staff of the Fisheries Commission in Ghana (in October 2015 and October 2016 with 11 and 10 trainees, respectively),

TABLE 2
Data types identified and/or estimated in a purse seine fishery

Full Observer PS	SET_PS + FAD_PS + OTH_PS	→Set identification →Set type description. →Timestamping of Start, brailing and End →Encounters with other vessels →Pollution events →FAD activity description
	CAT_PS + ESP_PS + BYC_PS	→Catch and Bycatch species identification →Condition and fate →Size and sex →Description of discard events →SSI interactions descriptions

Source: Satlink.

most of whom were at-sea observers. These were typically observers deployed in the purse seine fleet (eight people). However, two new staff were hired in 2016 to augment the capacity of the team and work full-time on the analysis of the electronic monitoring data. These new staff were women and did not have a background as at-sea observers, but they participated in the second training session and received support from the observer staff.

Training was given in the use of the SVM software and the protocols to be followed for the analysis of data (Table 2). This included the types of information needed in the context of regional tuna management under the ICCAT, such as: catch and discard estimates; details of sets made on FADs and free schools; and reports on bycatch species and the live release of certain species such as sharks and turtles (Annex 2). Annex 3 presents a template that was developed to report on the findings for each fishing trip, which includes compliance with national and regional measures.

One very important aspect in analysis is efficiency – how much time is needed to analyse the video footage. The time recorded as used by the electronic monitoring analysts to review video footage (and prepare the relevant report) was one working day to analyse four fishing days, on average. Training was given on rapidly identifying the setting of gear, based on the behaviour of the vessel (GPS data on speed, course, etc.) (Annex 2). The time spent on setting and hauling the fishing gear is of much more interest, as opposed to the time spent on steaming to and back from fishing grounds. Other aspects are understanding the operations on board a purse seine vessel, and being able to identify species, both target and non-target.

Data protection and storage

Data were encrypted, and an encryption key was generated to encrypt and decrypt data on a specific HDD disc. When an HDD was replaced in the system, a random password was generated and sent through the VMS approved unit on the vessel to a remote secure server, which was monitored by DOS. Using this procedure, HDDs could only be decrypted by obtaining the decryption key from DOS.

Additional HDDs were provided for the storage of data, and for rotation between vessels and the electronic monitoring unit, taking into account the time needed to analyse the data and possible backlogs. One person was nominated to be in charge of managing these HDDs, keeping track of rotation, and storing the HDDs in a safe and secure location.

Electronic monitoring coverage

The installation of the electronic monitoring equipment on the purse seine vessels was carried out in phases. This started in October 2015, and, by mid-2017, all active vessels in the tuna purse seine fleet were operating with electronic monitoring on board (Table 1).

At the time of project closing (January 2019), a total of 233 fishing trips had been monitored by the electronic monitoring system, of which 213 had been analysed by the dedicated staff, and reports produced for each trip. However, the backlog was eliminated subsequently at the beginning of 2019, thus reaching the target of

TABLE 3
Catch and effort monitored during the electronic monitoring trial in Ghana

		Catch (tonnes)					
Year	Effort (fishing days)	Skipjack	Yellowfin	Bigeye	Others	Frigate	Total
2015	295	6 001	1 375	838	–	193	8 406
2016	1 910	44 531	17 324	4 884	3	1 245	67 987
2017	1 862	50 902	15 402	4 012	61	1 402	71 779
2018	1 058	30 045	7 276	2 153	–	447	39 921

100 percent coverage. Table 3 shows the summary of effort and catch by year. In 2018, coverage of fleet activity was complete, but it should be noted that effort decreased substantially, albeit the catch per unit of effort remaining at about the same level. A large amount of data were generated on a per-set basis, including size sampling, bycatch species composition, and discards.

It should be noted that Ghanaian statistics for catches of yellowfin, bigeye and skipjack tuna have recently been reviewed, resulting in a complete re-estimation of the historical time series from 2006 to 2014 (Ortiz and Palma, 2017). It was envisaged that catch monitoring data, stemming from electronic monitoring, would be a valuable input to the work carried out in support of data collection, but this did not take place during the trial period.

The Monitoring, Control and Surveillance Division manages the tasks related to control and inspection work, while the Fisheries and Scientific Survey Division manages the at-sea observer programme. Reports generated by both divisions should include similar information, and, in the trial, there was an interest in cross-checking as part of a verification process. Both divisions were expected to share and exchange information gathered from fishing trips, but there were a number of challenges of an administrative and organizational nature as well as a lack of human capacity to carry this out.

In this context, there is a clear interest in developing an integrated database for the tuna sector in Ghana, with specialist support from the ICCAT and other partners, but this has not progressed as expected. There appear to be two issues involved here: (i) port sampling methodology to estimate species composition of catches taken by purse seiners; and (ii) an information system bringing together and linking various fisheries data for management and compliance purposes (Bannerman, Chavance and Daertner, 2013).

Compliance issues

As stated in the MOU concerning the trial in Ghana, all electronic monitoring data were treated as confidential, and the fisheries authorities were reluctant to release more detailed information on compliance issues. Hence, the impact of electronic monitoring could not be measured quantitatively. However, there was general agreement between the authorities and industry that compliance improved significantly as a result of using electronic monitoring. This was the result of collaboration between authorities and fishing companies – identifying the need for improvement/rectification when compliance issues were identified. However, one should also bear in mind that installing cameras on a vessel is an important deterrent in itself.

Reports were prepared for each trip, providing a wealth of information that is valuable for compliance and scientific purposes (Annex 2). On this basis, fisheries authorities proceeded with the identification of good and bad practices that were identified through electronic monitoring. For example:

- bad practices:
  - discards (and dumping) of tuna and bycatch species (according to national legislation, it is prohibited to dump any fish that is fit for human consumption in the fishery waters of Ghana),
  - transshipment, including the so-called collaborative fishing between purse seine and baitboat vessels (which was officially banned through a ministerial directive in 2017),
  - retention of protected species (e.g. sharks and marine turtles);
- good practices:
  - safe release of protected species, such as silky shark, whale shark, ocean whitetip shark, manta ray and/or marine turtles. This involved a process of disseminating good practices on the release of various species.

Good results were achieved, particularly in relation to the safe release of bycatch and reducing discards. It is estimated that about 80 percent of bycatch of endangered species were released safely, bearing in mind that some individuals die in the process.

Another achievement was monitoring and ensuring the stopping of transshipment, which was occurring with transfers of catches from purse seine vessels to pole-and-line vessels. Historically, all or part of the Ghana pole-and-line fleet has collaborated with purse seiners to catch tuna, but this was prohibited by the Ghanaian fisheries authorities (as of 22 June 2017), and the Ghana Tuna Association has informed the Ghanaian authorities that they no longer use this practice (Defaux, Gascoigne and Huntingdon, 2018).

The following statement included in the electronic monitoring fishing trip reports can be considered the best possible result, and constitutes a form of catch certification as required by the European Union authorities for exportation to the European Union:

"Vessel XXX is a Ghanaian registered tuna purse seine vessel and has a valid licence to fish; all catches were hauled to deck and, hence, there was no evidence of unreported catch, no evidence of fishing in a prohibited area, no evidence of endangered species caught and retained, no evidence of using prohibited fishing gear to fish, and no evidence of vessel conducting any activity with vessels branded as illegal, unreported and unregulated (IUU)."

Quality control

There was provision for a review of data analysis for 16 fishing trips by DOS, which was included in the contract with Satlink. The objectives of this were to determine the possible need to fine-tune certain aspects and identify the need for additional/refresher training for Ghanaian electronic monitoring analysts. This was carried out by DOS towards the end of 2018.

A sample of 14 trips were selected for a review and comparison of aspects such as fishing events, species identification and catch estimation. The sample consisted of 14 trips carried out by 8 vessels and analysed by 5 different electronic monitoring analysts in Ghana.

The methodology used by DOS was a full review of fishing-trip video footage to identify fishing activity (i.e. fishing start, gear set, gear retrieval, fishing end and FAD activity). From the total amount of sets detected, 30–50 percent of the sets were analysed in detail, identifying catches by species (in weight) and identifying bycatches (number of individuals).

Overall, the comparison of analysis showed that the Ghanaian analysts had demonstrated their skills and ability as electronic monitoring analysts. However, the comparison did show a need to provide further training to fine-tune certain aspects such as: identifying FAD activities more accurately; more precise estimation of target species quantities (overestimated and underestimated); and improved identification of discard species and quantities (normally overestimated). This would in fact be a refresher course for experienced users of SVM, and an opportunity to clarify any doubts. Another important aspect is also that Satlink has continued to develop the SVM, introducing new features and capabilities of the software.

This further training was expected to take place after the formal closing of the trial (January 2019), and there was also to be a second exchange of experiences between Fiji and Ghana. However, the lack of progress in securing the continuation of electronic monitoring in Ghana meant that this was put on hold. This is explained in more detail below.

TABLE 4
Summary of key data on costs during the Ghana trial

Cost Items	Value (USD)
Fixed	
Electronic monitoring onboard equipment (17 units)	262 652
Electronic monitoring onboard equipment (per vessel)	15 450
Onshore equipment (6 units)	26 000
Total fixed costs	**288 650**
Variable	
Training sessions (two)	5 060
Maintenance, service costs, and satellite up-time (3 years)	138 850
Remote data review services	14 400
Government staff costs (3 years)	57 000
Industry staff costs (3 years)	54 000
Total variable costs	**269 310**
Total costs	**557 960**

Source: Modified from MRAG, 2017.

COST CONSIDERATIONS

Another task stipulated during the electronic monitoring trial was the preparation of a business case for electronic monitoring in the Ghanaian purse seine fleet (MRAG, 2017). This business case included an assessment of the costs and benefits of implementing electronic monitoring, and it concluded that there were clear benefits that justify a continuation of electronic monitoring beyond the trial period, and proposed cost-recovery scenarios.

As mentioned above, the WWF was responsible for providing support for implementation, but FAO carried out the procurement of electronic monitoring equipment and services, as this was a requirement by FAO as the GEF Implementing Agency for the Common Oceans ABNJ Tuna Project. Most of the costs of implementing electronic monitoring in Ghana were in fact covered by the contract between FAO and Satlink, except for government and industry staff costs. This contract specified equipment, installation, maintenance and various services such as training and regular systems checks to guarantee that the electronic monitoring system was functioning properly.

Total costs for the trial period of 3 years were about USD 558 000, excluding in-kind cofinancing from industry and other sources, which greatly exceeded this amount. Hardware costs amounted to USD 289 000, or 52 percent of the total (Table 4). Variable costs were about USD 269 000, of which a substantial amount concerned maintenance and services (USD 139 000). Satlink provided the licence to use its SVM analysis software as part of the full package. Variable costs included data review (remote data review) by a third party in order to assess the quality of reports produced. This was carried out by DOS.

It should be noted that Table 4 does not include the costs of having an international expert as project manager, nor the substantial support provided by the WWF to cover staff-related and training costs. This was important during the implementation phase, but the goal was for the Ghanaian authorities to take over at the end of the trial and absorb these costs.

Various cost-recovery options were presented in the business case. If the industry were to cover all costs, this would amount to about USD 10 000 per vessel, annually, including the cost of service delivery by government. The business case presented clear benefits of electronic monitoring, with high positive return to industry, based on the price differential of maintaining access to the European Union market. Improving compliance contributed to a better standing of the fleet with respect to the markets, including the implementation of the electronic monitoring trial, thus contributing to the lifting of the yellow card. Numerous other benefits were identified, although it was difficult to attribute a value to these. Some examples are (MRAG, 2017):

- source of verifiable and objective data for compliance and MCS;
- potential to reduce IUU by domestic and foreign vessels;
- potential to demonstrate good practices (both for the Government and for industry);
- potential use for future product certification;
- collection of a certain amount of scientific data.

Consultations were held based on the information presented by the business case (6 February 2018). Industry confirmed that electronic monitoring had been important to the industry, and its main focus was on certification, maintaining access to key markets (European Union), transparency, and documentation of good practices. The industry (Ghana Tuna Association) is currently supporting a fishery improvement project (FIP) for the Eastern Atlantic tuna purse seine fishery, where electronic monitoring is expected to be instrumental (Fishery Progress, 2020a). It is also important to stress the role of government to achieve and maintain certification, as this involves proper management, including compliance issues.

Support for the continuation of electronic monitoring was clear from the Ministry of Fisheries and Aquaculture Development, and it was indicated that a similar model to the current VMS system would be considered, such as the installation of electronic monitoring as a condition of entry to the fishery. Industry also indicated that electronic monitoring should continue, and that the cost recovery would be negotiated with the government. There was a tacit understanding that industry would bear all onboard installation costs, and that the fisheries authorities would only need to recover the service delivery costs.

However, these negotiations between government and industry have not progressed as expected since the end of external support at the end of 2018. The main issues appear to have been securing funding from the state budget and agreement on the costs to be borne by industry. Satlink continued to provide services during a grace period to give time for these negotiations, but as progress was limited, this assistance ended in early 2019. This was a disappointment, considering the efforts and investment that had gone into the trial and its successful completion, proving the benefits of electronic monitoring as a compliance tool.

LEGAL REVIEW

The contractor tasked with building a business case for electronic monitoring in the Ghanaian purse seine fishery was also asked to review the legal framework, considering the use of electronic monitoring as a compliance tool (MRAG, 2017). It concluded that Ghana's fisheries legislation did not address the use of electronic monitoring as an MCS tool, and that existing regulations should be amended to allow for the use of electronic monitoring as an MCS tool. The electronic monitoring trial was carried out on a purely voluntary basis in accordance with the MOU introduced above.

MRAG (2017) points out that fisheries offences in Ghana are prosecuted under criminal law. Given the particular requirement of the rules of evidence relating to criminal offences, if electronic monitoring data are to be used as the main body of evidence available to the prosecution, it is suggested that a suitable amendment should be made to the Fisheries Act to allow this. The use of electronic monitoring technologies also raises important data protection issues, and new legislation for electronic monitoring would need to be carefully aligned with the data protection legislation (MRAG, 2017).

In more general terms, the best option would be to consider a more generic provision in law to allow new technologies to be adopted and required by the government in fisheries or any other sector, provided that these technologies meet specific requirements (e.g. reliability, accuracy, and being tamperproof). This was also the approach recommended in the case of Fiji, as presented in Chapter 3.

It is important to note that a full and comprehensive review of the fisheries legal framework was carried out (Cacaud and Sekor, 2015), indicating the need for a comprehensive reform, including the area of MCS. This is part of a larger context, where the Government of Ghana has embarked on an ambitious programme to reform the country's fisheries and aquaculture activities. The World Bank and the GEF have supported the programme as part of the World Bank's six-year investment in the West Africa Regional Fisheries Project. However, progress in the revision of the legal framework has been slow owing to a lack of legal staff within the Ministry of Fisheries and Aquaculture Development, and thus reliance on the Attorney General's office, as well as a lack of political commitment. The required legal revision for the use of electronic monitoring for compliance is just part of a much larger and complex situation, and this revision was not achieved during the trial.

3. Fiji

BACKGROUND

In Fiji, as in many Pacific island countries, fish plays an important role in livelihoods, nutrition, food security, employment, and wealth generation. The fisheries industry is the third-largest natural-resource-based sector on Fiji economy, contributing about 1.8 percent to GDP and 7.0 percent of total export earnings (Ministry of Fisheries, 2018).

Fiji has a wide range of fishery resources, and it is estimated that more than 350 species are harvested, including various species of finfish, invertebrates and plants. However, there is generally a paucity of information in relation to fishing that takes place in coastal and inshore areas (Lee *et al.*, 2018). FAO fisheries statistics indicate a production of about 18 000 tonnes in 2017, but this concerns mainly tuna and tuna-like species that are taken offshore, plus an estimated 660 tonnes of catches taken by coastal fisheries (wahoo and narrow-barred Spanish mackerel). However, one study (Gillett, 2016) provides alternative production estimates, indicating that coastal and subsistence fisheries contribute about 11 000 tonnes and 16 000 tonnes, respectively.

Most tuna catches are taken by the domestic longline fleet. Production has averaged 15 600 tonnes in recent years (2014–17), where the main target has been South Pacific albacore (*Thunnus alalunga*), contributing about 54 percent of total catch. Other important species are yellowfin (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*), which account for about 28 percent and 9 percent, respectively, of total catches. The remaining 9–10 percent of catches consist of various tunas, billfish and other species as bycatch.

Fiji is a founding member of the WCPFC, which was established in 2004 to manage highly migratory fish stocks in the region. The compliance of members with WCPFC conservation and management measures (CMMs) is the subject of regular reviews, which are carried out by the Technical and Compliance Committee and the Commission of the WCPFC. It is worth noting that Fiji has a generally good performance and is compliant with all relevant CMMs (WCPFC, 2018a).

However, Fiji was subject to a formal warning, or a yellow card, from the European Union in November 2012. This warning stemmed from what the European Commission considered to be a lack of measures to address IUU fishing, and a lack of rules for inspection, control and monitoring of vessels. This forced Fiji to take action on a number of fronts in order to continue to have access to the European Union market. New legislation was adopted, and the framework for monitoring, control and inspection of fishing activities was strengthened through the following (Vakalevu, 2014):

- Offshore Fisheries Management Decree 2012;
- Offshore Fisheries Management Regulation 2014;
- Revised Tuna Development and Management Plan 2014–18;
- Revised Plan of Action on IUU 2014.

Subsequently, the European Union officially lifted the yellow card in October 2014 in recognition of Fiji's efforts to tackle IUU fishing (European Commission, 2014).

It should be noted that the Tuna Development and Management Plan 2014–18 introduced limits in the longline fishery, setting a cap of 60 vessels that can be licensed to fish within the exclusive economic zone (EEZ). This is to be reviewed every two years. A total allowable catch (TAC) across all target tuna species was specified, including a specific TAC for South Pacific albacore.

A recent study on the quantification of IUU fishing in the Pacific islands region came to several conclusions that shed light on various aspects of IUU fishing in the region and an evolving situation (MRAG, 2016). Estimates of IUU were found to be dominated by the licensed fleet, and not by illegal fishing activity per se. The purse seine sector accounted for 70 percent of overall volume of the IUU catch, which was largely driven by reporting violations and illegal FAD fishing during the closure period. The tropical longline and the southern longline sectors accounted for 19 percent and 11 percent, respectively, of the overall IUU volume. In both cases, IUU volumes were largely driven by misreporting and post-harvest risks, principally illegal transshipping, although there is a high level of uncertainty in estimates. Among the various recommendations, the study advocates for stronger catch monitoring arrangements, particularly in the longline sector, and strengthening of MCS in the high seas.

Another aspect to consider is the economic performance of Fiji's longline fleet. Recently, a socio-economic analysis has been carried out to evaluate the impact of various management options for Fiji's longline fleet to improve profitability, revenue and the fishery's competitiveness in the global market (Pacific Catalyst, 2019). The key issue is that the fleet is ageing and operating with limited profit margins. The study suggests that increasing tenure of fishing rights (without transferring them in perpetuity), and allowing for transferability among vessels within fishing companies, would likely enable the entry of new, more-efficient vessels, thus making the fleet more competitive without increasing effort (and catches) (Pacific Catalyst, 2019).

PILOT TRIAL IN FIJI

South Pacific albacore is of great importance to the longline fishery in Fiji, although there are substantial catches of yellowfin and bigeye tuna as well (see above). Fiji is rather unique in the region as the longline fleet is a domestic, unsubsidized fleet, consisting mostly of locally owned vessels. However, albacore is also targeted by foreign fleets that fish in the high seas between and among EEZs in the region, using Fiji as a convenient base of operations in many cases. Efforts at reducing the effort of foreign fleets in the high seas have not yet been successful, although Fiji and other Pacific island countries have attempted this through the WCPFC. Many foreign fleets operate with fuel (and other) subsidies provided by their governments, which makes it challenging for domestic fleets to compete on a level playing field (CEA, 2016).

A major concern of the fishing industry and the Government of Fiji is to protect the viability of the local, domestic fleet. A major achievement was the Marine Stewardship Council (MSC) certification of Fiji's albacore tuna longline fishery, which was awarded in December 2012. This increased the competitiveness of this fishery in the international market. A re-assessment was carried out in 2017, where this was expanded to include both yellowfin and albacore tuna, as well as extending the fishing ground beyond Fiji's EEZ to include high seas pockets bordering the EEZ. As at 2019, there were 57 vessels fishing under MSC certification, which is managed by the Fiji Fishing Industry Association (FFIA) (MSC, 2020).

The trial of electronic monitoring as a tool for compliance in Fiji should be seen in this context, where industry was keen to explore the use of electronic monitoring to document best fishing practices and maintain access to international markets, including possible uses of this tool as part of maintaining MSC certification. It was also envisaged that electronic monitoring would serve as a tool to improve operations on board vessels (i.e. setting and hauling operations), including safety conditions. Thus, the focus of the trial were the vessels fishing inside Fiji's EEZ, which was related to the conditions of the MSC certification at the time, and a target of 50 vessels was set (Table 5).

The industry, represented by the Fiji Tuna Boat Owners Association (FTBOA), which later became the FFIA, and the processing industry were instrumental in developing the concept in close collaboration with the Government of Fiji. Strong

TABLE 5

Overview of the fishing vessels covered by electronic monitoring in Fiji

No.	Phase	Company	Vessel	Installation date
1	1st	Hangton Pacific Company Ltd	*Hangton 9*	28 September 15
2		Hangton Pacific Company Ltd	*Hangton 2*	05 October 15
3		Solander Pacific Ltd	*Solander XI*	22 October 15
4		Sea Quest (Fiji) Limited	*Rabi 1*	22 November 15
5		Winfull Fishing Co. Ltd	*Winfull 1*	15 December 15
6	2nd	Solander Pacific Ltd	*Solander IV1*	16 February 17
7		Solander Pacific Ltd	*Solander XII*	20 February 17
8		Solander Pacific Ltd	*Solander X*	28 February 17
9		Sea Quest (Fiji) Limited	*Sea Jiko*	05 March 17
10		Solander Pacific Ltd	*Solander III*	16 March 17
11		Solander Pacific Ltd	*Solander IX*	06 April 17
12		Hangton Pacific Company Ltd	*Hangton 8*	29 April 17
13		Sea Quest (Fiji) Limited	*Sea Beluga*	10 May17
14		Sea Quest (Fiji) Limited	*Sea Quence*	19 May 17
15		Solander Pacific Ltd	*Solander VI*	17 June 17
16	3rd	Solander Pacific Ltd	*Solander V*	02 July 17
17		Winfull Fishing Co. Ltd	*Winfull 2*	20 July 17
18		Ocean Harvest (Fiji) Ltd	*Winstar 1*	25 July 17
19		Sam Weon Fishery Co. Limited	*Sam Weon 11*	27 July 17
20		Solander Pacific Ltd	*Solander Kariqa*	13 August 17
21		Services Marine Ltd	*Ben 10*	13 August 17
22		Zhong Da Company Limited	*Zhong Da 5*	17 August 17
23		Cleveland Limited	*Lady Ama*	20 August 17
24		Services Marine Ltd	*Dae Jin*	31 August 17
25		Zhong Da Company Limited	*Zhong Da 2*	03 September 17
26		Ocean Harvest (Fiji) Ltd	*Winstar 2*	05 September 17
27		Zhong Da Company Limited	*Zhong Da 3*	07 September 17
28		Sea Quest (Fiji) Limited	*Sea Malibu*	16 September 17
29		Wistar (Fiji) Ltd	*Winfull 6*	22 September 17
30		Services Marine Ltd	*Yue Yuan Yu 139*	29 September 17
31	4th	Vaerua Fishing Company Limited	*Scorpion 68*	06 October 17
32		Solander Viti Limited	*Solander XIV*	03 November 17
33		Sea Quest (Fiji) Limited	*Seaka II*	23 February 18
34		Solander Pacific Ltd	*Solander II*	05 March 18
35		Wistar (Fiji) Ltd	*Winfull 168*	12 March 18
36		Green Tuna Fisheries Co. Ltd	*Green Tuna 1*	31 March 18
37		Hangton Pacific Company Ltd	*Hangton 115*	12 April 18
38		Sunshine Fisheries Ltd	*Sunshine 18*	17 April 18
39		Sunshine Fisheries Ltd	*Sunshine 89*	30 April 18
40		Sunshine Fisheries Ltd	*Sunshine 86*	21 May 18
41	5th	Hangton Pacific Company Ltd	*Hangton 111*	14 June 18
42		Sunshine Fisheries Ltd	*Sunshine 16*	18 June 18
43		Rising Fisheries Ltd	*Rising 18*	21 June 18
44		Green Tuna Fisheries Co. Ltd	*Green Tuna 3*	28 June 18
45		Sunshine Fisheries Ltd	*Sunshine 88*	04 July 18
46		Juls Fiji Limited	*Yong Xing 3*	13 July 18
47		Rising Fisheries Ltd	*Rising 16*	20 July 18
48		Juls Fiji Limited	*Yong Xing 1*	05 October 18
49		Sunshine Fisheries Ltd	*Sunshine 8*	06 February 19
50		Island Endeavour	*Northern Odyssey*	15 March 19
51		Island Endeavour	*Pacific Endeavour*	19 March 19

[1] Solander IV was lost at sea in October 2017 with all equipment and catch on board but without loss of life. Hence, the installation of an additional electronic monitoring system (no. 51) to reach the target of 50 vessels.

support was given for the initiative to pilot electronic monitoring technologies to strengthen the transparency and sustainability of the longline fishery. Thus, the Common Oceans ABNJ Tuna Project established a partnership with the Government of Fiji and the FTBOA for the implementation of the pilot trial in Fiji.

The electronic monitoring provider selected for both trials in Ghana and Fiji was Satlink SL. As in the case of Ghana, the contract specified the provision of hardware, software, maintenance, services and on-ground support. The characteristics of the system used on longline vessels in Fiji were basically the same as those in Ghana, although the system was more compact and in a three-camera configuration, instead of the six-camera configuration used on purse seine vessels in Ghana (Annex 1).

In the case of Fiji, Satlink established an office locally to provide adequate support for the installation of equipment and associated maintenance and services to the fishing fleet and to the national authority during the trial phase. It is generally recognized that the Satlink office, based at the port of Suva in Fiji, was crucial to the success of the trial, avoiding some of the technical problems experienced by other trials in the Pacific. Apart from technical support, this also provided for good communication between stakeholders.

INSTITUTIONAL ARRANGEMENTS

An electronic monitoring unit was established as part of the Offshore Fisheries Division of the Ministry of Fisheries. The Offshore Fisheries Division is the technical and advisory arm of the Ministry of Fisheries on matters relating to Fiji's offshore fisheries sector. It provides technical and policy support to its industry stakeholders, and manages and regulates the sector in respect of the Offshore Fisheries Management Act 2012 and its Regulations of 2014.

The Offshore Fisheries Division is responsible for a wide range of issues and activities pertaining to the offshore fisheries sector, including the effective fisheries monitoring, control, surveillance and enforcement to ensure the operations of stakeholders are performed according to national regulations and regional CMMs. Moreover, the Offshore Fisheries Division is tasked with collecting and managing all offshore fisheries data and related data within the Ministry of Fisheries's jurisdiction for it various uses (Ministry of Fisheries, 2020).

The Offshore Fisheries Division manages the VMS and the observer programme for national and regional observers. It is primarily responsible for "hands on" operational work through utilizing VMS, electronic monitoring, observers, investigation, and authorized officers. It is also responsible for daily MCS duties, which include: boarding and inspections; managing vessel notifications and coordinating enforcement activities; overseeing industry activities; facilitating fishery permits for all activities including exports and imports; and maintaining profiles of all persons and entities involved in the sector through in-depth MCS analysis and investigations.

A team leader was appointed from the staff of the Ministry of Fisheries and Aquaculture Development to establish the electronic monitoring unit, and this person was designated as the project coordinator for the electronic monitoring trial. The unit started with only two electronic monitoring analysts, recruited from the observer programme, but this number increased rapidly to 11 electronic monitoring analysts during the trial. The Ministry of Fisheries provided the necessary office space, furniture and support facilities, including utilities. Towards the end of the trial, steps were being taken to formally establish the electronic monitoring unit in line with other programmes of the Ministry of Fisheries and Aquaculture Development, making this a permanent structure within the division. Efforts were made at securing better office facilities and absorbing the staff into the Ministry of Fisheries as permanent staff.

Memorandum of understanding

It was considered important to prepare and approve an MOU, specifying the roles and responsibilities of those involved in the electronic monitoring pilot trial in Fiji. This was signed on 22 September 2017 by the Ministry of Fisheries and the FFIA.

The objectives were that electronic monitoring would be used as an additional MCS tool and that both parties would collaborate in the implementation of the electronic monitoring trial. The responsibility for data analysis was given to the Ministry of Fisheries. Data ownership was attributed to the Government of Fiji, although industry partners could request copies of the data concerning their vessels and use them for their own operational purposes. All electronic monitoring data were to be treated as confidential, and any dissemination of information had to be approved by the Ministry of Fisheries. The MOU was not considered legally enforceable, but there was a tacit understanding that this would be an opportunity to improve compliance through a collaborative approach between government and industry.

DATA REVIEW AND ANALYSIS

Twelve desktop computers were provided to the Ministry of Fisheries and Aquaculture Development to carry out the analysis of video footage. The computers were equipped with the SVM software, an extra monitor for better viewing, and a Synology HDD server, necessary for decryption of the HDDs. The stated objective was to monitor and review 100 percent of the 50 Fiji longline vessels, which were equipped with electronic monitoring installed in 5 phases (Table 5).

Satlink View Manager software

Review and analysis of video footage was carried out with SVM, the Satlink proprietary software developed for this purpose as part of the electronic monitoring system.

It is important to note that, although Satlink was an established electronic monitoring provider at the time of the tender, this was primarily on tuna purse seine vessels. Software and analysis protocols for tuna longline fisheries were first developed during the trial carried out in New Caledonia in 2014, but significant improvements were made during the trial in Fiji.

In addition to the Fiji trial, Satlink was also selected to provide the electronic monitoring systems for various small-scale trials in the region that The Nature Conservancy was sponsoring. These covered 25 vessels distributed among the Marshall Islands, Micronesia (Federated States of), Palau (including Okinawa-based vessels), and Solomon Islands, where installation started in 2016. Satlink was also contracted to provide electronic monitoring systems to private companies (Bumble Bee – FCF), which meant that more than 100 longline vessels in the Western Pacific were using the SeaTube system by 2019.

In the region, organizations such as the Pacific Community (SPC) play an important role as the principal scientific and technical organization (SPC, 2020). In particular, the Oceanic Fisheries Programme plays a crucial role in tuna fisheries research, fishery monitoring, stock assessment and data management. Considering its role in monitoring, the SPC provided support and guidance by developing draft electronic monitoring process standards, inviting all stakeholders and electronic monitoring providers to participate in the process. Four workshops were held with the participation of Fiji, including one workshop on 22–24 May 2018 in Suva, Fiji, partly sponsored by the Common Oceans ABNJ Tuna Project (SPC, 2018). The workshop held in Fiji placed more emphasis on practical implementation and data analysis, bringing together the people involved in analysis for an exchange of experiences across the various trials.

The purpose of establishing the draft process standards for electronic monitoring was to provide guidance on how the agreed standard observer data fields can (or cannot) be collected using electronic monitoring systems. It is important to note that the data to be collected by observers have been established and are mandatory through the WCPFC Regional Observer Programme minimum data field standards and the SPC / Pacific Islands Fisheries Forum Agency (FFA) Data Collection Committee. The main task of the electronic monitoring process standards workshops was to evaluate each required data field to determine how electronic monitoring could be used to collect equivalent observer data.

This support to electronic monitoring programmes was important and necessary in order to standardize the approach being used in the region, but it should be noted that the emphasis was on data collection for scientific purposes in particular. It was essential for Fiji to be part of this process, but in this case, there was a focus on trialling the use of electronic monitoring as an MCS tool for compliance objectives, which added more complexity to efforts. Nonetheless, observer minimum data requirements were established, which were a good basis to start from. As the trial progressed, Fiji contributed with the development of MCS data requirements and associated MCS standards. These have become very relevant in the regional context, as developments indicate a shift towards addressing compliance issues with particular emphasis on the high seas (discussed in the following sections).

Satlink participated in these workshops and developed and/or adapted the analysis software accordingly. Data analysis protocols were developed, which were applied across the region in the various trials taking place. However, the software was not particularly well designed for longline fishing at the start of the Fiji trial. It was rather cumbersome and not particularly user-friendly, which meant problems with efficiency in analysis. This situation improved considerably over time, with various software upgrades, which also coincided, in 2017, with a more rapid deployment of electronic monitoring on vessels in Fiji.

Electronic monitoring analysis training

Fiji has a WCPFC-certified observer programme operating under the Ministry of Fisheries and Aquaculture Development, which is contracted to the Fiji National Observer Programme (FNOP) and the Fiji Regional Observer Programme (FROP). Candidates were selected from this large pool of observers, based on extensive at-sea experience. Moreover, additional staff from the Ministry of Fisheries and Aquaculture Development, such as investigation and enforcement officers, were also selected.

Fourteen observers and four additional staff from the enforcement/investigation units were selected for training, which took place on 2–6 November 2015, carried out by Satlink and DOS staff (Annex 2). A second training session was held on 17–21 October 2016, in which 17 observers were trained, in addition to the supervising officer for the national and regional observer programmes, as well as the at-sea observer coordinator. On 22 October 2016, a "training of trainers" workshop was held with the participation of four senior observers from both the FNOP and FROP.

It soon became apparent that the observers were both able to grasp the software's analytical components of the catch and haul process, and able to identify the species that were being caught. In addition, they were also able to identify the hook setting and hauling process and its subtleties with a limited range of camera field of view. This was by virtue of the FFA/SPC Pacific Islands Fisheries Regional Observer training, in addition to their extensive at-sea experience of more than 1 000 hours, for the more experienced observers.

The number of electronic monitoring analysts carrying out data review and analysis increased from 2 in 2015 to 11 at the end of the trial (end of 2019). Moreover, five of these were selected to train new incoming electronic monitoring analysts.

A template was developed to report on the findings for each fishing trip, which includes compliance with national and regional measures (Annex 4).

TABLE 6
Results of the electronic monitoring trial in terms of coverage

Year	Total no. trips	Total no. trips covered by electronic monitoring	electronic monitoring trips / total	No. electronic monitoring trips reviewed	electronic monitoring trips reviewed / total electronic monitoring trips
2015	1 182	14	1%	0	0%
2016	1 348	60	4%	60	100%
2017	1 587	296	19%	107	36%
2018	1 204	410	34%	177	43%
Total	5 321	780	15%	344	44%

RESULTS

Electronic monitoring coverage

Table 6 presents the results of the electronic monitoring trial, indicating how much of the total fleet effort was covered by electronic monitoring, and how much of the video footage was reviewed/analysed. Coverage of the fleet increased slowly during the initial phase, reaching 34 percent in 2018. This was linked to the number of vessels with electronic monitoring installed, which started with five vessels in 2015, but installations came to a halt in 2016. electronic monitoring installations could not proceed until 2017, as the trial had to wait for the completion of the vessel licensing period and renewal process for a three-year period. Installations restarted in 2017, but continued in 2018 and early 2019 because of the delay (Table 5). Data for 2019 are not yet available, but fleet coverage is now expected to be about 56 percent, corresponding to 50 vessels out of a total of 89 vessels in the fleet.

Out of a total of 780 fishing trips monitored by electronic monitoring, 344 trips were reviewed, corresponding to an analysis rate of 44 percent. The target of reviewing 100 percent of the fishing trips covered by electronic monitoring was not met, but the result is still considered more than satisfactory in terms of coverage. There is currently a requirement for 5 percent observer coverage in longline fisheries in the WCPFC area. Most countries do not meet this requirement, with the notable exceptions of New Caledonia, the United States of America (Hawaii-based longliners), and Fiji, the latter with an observer coverage of about 20 percent. This level of 20 percent is generally presented as an appropriate level of coverage from a scientific point of view, although the SPC has committed to investigate this and recommend whether this should be revised up or down.

Analysis of video footage from longline fishing is time-consuming, also bearing in mind the draft electronic monitoring process standards developed for the region, which are demanding in terms of detail (hook counting, catch according to hook number and depth, etc.). The nature of longline fishing is such that the setting and hauling process takes time and involves many hours of video footage. At the end of the trial, electronic monitoring analysts were capable of reviewing two sets per day. As a general rule of thumb, a longliner will carry out one set per day while fishing, including the setting and hauling process, which implies that it takes 10 working days to review a 20-day fishing trip. Efficiency in electronic monitoring analysis is a key issue in effectiveness and cost considerations (discussed in the following sections).

Databases

The SPC plays a key role in the region in areas such as tuna fisheries monitoring, development and maintenance of databases, as well as national capacity building. The Tuna Fisheries Database Management System (TUFMAN2) is a database tool developed by the SPC for Pacific island countries and territories (including Fiji) to manage their tuna fishery data (SPC, 2020b). This tool provides for data entry, data management, data quality control, administration and reporting. Considering the various initiatives that were ongoing, the SPC developed the database to include electronic monitoring data analysis reports. Hence, Fiji considered it essential that the data resulting from the analysis of video footage (not the video footage itself) would feed into TUFMAN2 together with observer reports, logbook data and other data.

However, there were a number of technical issues to resolve and hurdles to overcome. One problem was related to do data formats and conversion to file format types that could be read and incorporated into SPC databases. Another issue was that, during conversion, many errors were detected (missing data fields according to the analysis protocol), indicating the need for error-checking during data entry (data quality control in the software). Another issue was data confidentiality, where rules in Fiji meant that data conversion could not be carried out by the company (through an automatically operated remote server based in Spain). Error-checking and data flow to SPC databases was a challenge and took considerable time, but data from 229 trips had been imported to SPC databases by the end of 2018.[16]

At the electronic monitoring workshop held in Fiji (22–24 May 2018), the first exercise in comparing data from different sources was undertaken using the DORADO tool, which is a web-based fisheries database reporting module (FAO, 2018). This comparison considered electronic monitoring analysis reports, logbooks and observer reports. A general conclusion from this first exercise was that the analysis of electronic monitoring data resulted in much more complete and reliable data than from other sources of information. This may appear obvious in hindsight, but observers cannot be expected to perform non-stop during fishing trips and they cannot cover all activities taking place on-deck. In relation to logbooks, electronic monitoring provides for a much more detailed review of events, and bycatch information, in particular, is of better quality. Based on these preliminary results, discussions centred around the usefulness of electronic monitoring data for verification of data from observers and logbooks.

Quality control

There was provision for carrying out a review of electronic monitoring analysis reports from 50 fishing trips, which was intended as a quality control, and the possible need for fine-tuning and follow-up training of electronic monitoring analysts. However, this was much delayed because of confidentiality concerns. Owing to time constraints, it was decided to analyse a smaller sample of about 10–15 fishing trips, which was carried out in the period June–September 2019 by DOS.

In the end, 9 fishing trips were available for analysis, which concerned 9 different vessels and 9 different electronic monitoring analysts.[17] This involved the detailed review of video footage to identify all sets during a fishing trip, and to identify when setting and hauling took place and where. A more detailed review of sets was carried out for about 30 percent of sets, where catch of tuna and bycatch species were identified individually. It is important to point out that this quality control exercise also considered compliance issues, but these were limited to WCPFC CMMs. No compliance issues were identified by DOS, but one should bear in mind that these fishing trips took place during the final year of the trial.[18]

---

[16] There are currently 355 trips by Fiji vessels incorporated in SPC databases.

[17] Five out 14 HDDs shipped to Spain were found to be damaged or unreadable.

[18] However, a comparison of data analysis results involving Fiji electronic monitoring analysts and DOS electronic monitoring analysts (nine selected fishing trips) is still pending.

Compliance issues

Using electronic monitoring for compliance purposes involves the gathering of information that is generally considered to be of a confidential nature. This stems from the possibility of using such information for prosecution of possible transgressions and the need for confidentiality in prosecution cases.

For the trial period, it was agreed in the MOU that identified compliance issues would not be the subject of legal action. Instead, the approach envisaged was to provide feedback to companies/vessels on the outcomes of analysis, and to highlight operational and compliance issues that should be corrected and/or improved during trials. However, if the incident was identified by an observer on board the vessel, the relevant systematic investigative and prosecution processes were followed.

There was general agreement between authorities and industry that compliance improved significantly as a result of using electronic monitoring. However, the information was considered confidential and a quantitative assessment could not be carried out. Improvements were the result of feedback from the authorities to the companies on identified issues, as well as the direct result of installing cameras on board vessels.

Compliance issues were identified in the following type of events:

- Bycatch of silky sharks should be released in a manner that results in as little harm to the shark as possible (CMM 2013-08). Based on footage, it became evident that fishers had to learn to be more careful with handling, and in most cases need to cut the lines to release the shark.
- Bycatch of oceanic whitetip sharks should be released in a manner that results in as little harm to the shark as possible (CMM 2011-04). Same as above.

Under the Offshore Fisheries Management Regulations 2014:

- 34. Transshipment:
  (2) "The operator of a fishing vessel intending to conduct transshipment shall in accordance with sub-regulation (1) - (a) provide 72 hours' notice to the Director of a request to transship any or all of the fish on board."
  (3) "A fishing vessel authorized to conduct transshipment in accordance with this regulation shall – (a) only transship at the time, port, and approved designated areas within Fiji fisheries waters authorized for transhipment by the Director."
- 36. Provisioning:
  (1) "The operator of a fishing vessels shall – (b) provide 72 hours' notice to the Director."
- 4] Subject to Decree 72 – Duties to authorized officers and observers:
  (3) "Any person who contravenes subsections (1) or (2), or – (a) assaults, obstructs, resists, delays, refuses boarding…"
- 5] MARPOL
  Subject the relevant articles on garbage and their disposal, the Fisheries Department has continued to see to the provision of garbage bins placed on vessels for later disposal of wastes on land receptacles rather than at sea.
- 6] Landing discrepancy
  Subject to Regulation 49 (4) "Within 3 days upon the completion of landing, the master or operator of a fishing vessel shall be required to provide a report on all catch landed …"
  "As part of Fiji's mass balancing exercise and traceability work, will need the industries provisioning of accurate information on landed catch which would compare with the electronic monitoring catch for discrepancies, if any."

TABLE 7
Summary of key data on costs during the Fiji trial

Cost items	Value (USD)
Fixed	
Electronic monitoring onboard equipment (50 units)	464 200
Electronic monitoring onboard equipment (per vessel)	9 284
Onshore equipment (12 units)	59 075
Total fixed costs	**523 275**
Variable	
Training sessions (two)	11 440
Maintenance, service costs, and satellite up-time (3 years)	183 940
Remote data review services	45 000
Government staff costs (3 years)	207 900
Industry costs (3 years)	15 000
Total variable costs	**463 280**
Total costs	**986 555**

Source: Modified from Hurry, 2019.

COST CONSIDERATIONS

As part of the trial, the Common Oceans ABNJ Tuna Project contracted an independent consultant to develop a business case, including an assessment of the costs and benefits of implementing electronic monitoring in Fiji, and to propose cost-recovery scenarios to sustainably use electronic monitoring as an MCS and data collection tool beyond the Common Oceans ABNJ Tuna Project (Hurry, 2019). The intention was to provide all the relevant information to the Government of Fiji, as the client, to inform the decision on the future of electronic monitoring in Fiji and define a proposal for cost-recovery.

Table 7 provides a summary of the costs during the trial period of about three years (2015–2018) which totalled USD 987 000. In relation to fixed costs, hardware and equipment amounted to USD 523 000, including equipment on vessels and onshore; however, it is important to note that this includes software licences and analysis solutions. Fixed costs accounted for about half of the total cost (53 percent). Variable costs amounted to USD 463 000, which included two 5-day training sessions and maintenance/services, the latter increasing every year, based on the number of vessels operating with electronic monitoring. Variable costs include the possibility of carrying out data review and analysis (remote data review) by a third party in order to assess the quality of reports produced in Fiji.

Most of the costs during the trial were associated with a specific contract between FAO and Satlink, the electronic monitoring provider, except for the last two budget lines in Table 7. These were contributions by FAO to cover internal costs in the Ministry of Fisheries, as well as contributions from industry. It was difficult to specify the cost borne by industry; hence, the approach used was to attribute a small cost for the basic maintenance of electronic monitoring equipment (cleaning, drying, etc.) on board vessels (Hurry, 2019).

This business case was the subject of consultations (29 January 2019), where relevant stakeholders were invited to participate, including regional partners such as the SPC, FFA and WCPFC. The Ministry of Fisheries expressed a strong commitment to continue with electronic monitoring, considering the identified benefits, although some are still potential future benefits. Industry was also supportive during the consultations, although there was concern about the costs involved. The need to find an acceptable reasonable sharing of costs between government and industry was stressed, and there were calls for more tangible benefits from electronic monitoring to industry. Industry called for rapid release of video footage, so that these data can be used for their own operational purposes and thus achieve additional benefits.

TABLE 8
Estimated annual operational costs (excluding hardware) of the electronic monitoring programme covering 50 longline vessels in Fiji

Budget items	Cost (USD)	Comment
Fixed		
Staff salaries	38 112	2.2 full-time equivalent
Onboard equipment	n/a	provided in trial
Maintenance / services / technical support	150 000	USD 3 000 per vessel
Onshore equipment	n/a	provided in trial
Maintenance / services / technical support	95 000	estimated for 50 vessels
Regional cooperation and development	14 000	
Office and other costs	28 000	
Total fixed costs	**325 112**	
Variable		
Electronic monitoring data review (analyst fees)	68 169	2 420 days @ FJD 60/day (USD 28.17/day)
Total costs	**393 281**	

Source: Hurry, 2019.

The outcome of the consultations was to propose an "interim" decision to maintain the current electronic monitoring programme in Fiji (50 longline vessels), and to continue with Satlink as the service provider, until a WCPFC decision on a region-wide electronic monitoring programme is made, which is expected in the next 2–4 years. This takes into account the regional perspective and the importance of developing a regional electronic monitoring policy for a harmonized implementation of electronic monitoring across Pacific island countries.

This was one of the proposed scenarios in the business case, maintaining the current electronic monitoring programme at 50 vessels (Hurry, 2019). The fixed costs of maintaining the electronic monitoring programme under this scenario are estimated to total about USD 325 000 (Table 8). This does not include the hardware that was provided during the trial, assuming that there would be no additional costs in the short term, except for possible replacements owing to wear and tear.

If vessel operators were to bear the full operational fixed costs, this would mean about USD 6 500 per vessel annually (Table 8). However, if vessels operators were only to cover onboard costs, this would be USD 3 000 per vessel for maintenance and services. This would account for about half of fixed operational costs.

Considering variable costs and using a risk-based approach to the analysis of video footage, it is assumed that there would be a total of 11 000 sea days in terms of fishing activity, and that this would require the analysis of about 2 400 sea days, which corresponds to a data analysis rate of about 20 percent.

Using the specified fee for data analysis (FJD 60 or USD 28.2 per set) and a conservative estimated productivity of 528 sea days reviewed per year per analyst (2 sets per working day), the total cost of data analysis would be about USD 68 000 (Table 8). This does not take into account quality control or debriefing, which is assumed to be absorbed by the fixed staff costs.

Assistance was provided to the Ministry of Fisheries in preparing costs and cost-sharing proposals to be considered at cabinet meetings of the Government. These were based on the scenario for continuing with the current electronic monitoring programme, covering 50 vessels, in the short term (2–4 years). There appeared to be consensus in Fiji that the industry would cover the vessel costs (onboard costs) and the Government would cover the rest, which corresponded roughly to a 50–50 sharing of costs. However, the Ministry of Fisheries did not take the necessary steps to seek the required state budget allocation for the financial year (August 2019 – July 2020). Therefore, potential donors have been approached for support during the current financial year, and possibly during a 2–4 year period.

LEGAL REVIEW

The need to assess the current legal framework for the possible use of electronic monitoring as a compliance tool was also envisaged in the case of the Fiji trial. The Development Law Service of the FAO Legal Office was requested to provide assistance to the Ministry of Fisheries on the use of electronic monitoring equipment in the Fijian longline fishery. Manoa (2017) concluded that the existing provisions in the legislation reviewed were not adequate to provide effectively for the use of electronic monitoring and related requirements. However, the recommendations specify the introduction of relevant provisions in the Offshore Fisheries Management Regulations 2014, which appear to be relatively straightforward. Manoa (2017) proposed draft amendments, including explanatory notes.

Fisheries legislation in Fiji has recently been reformed, for example, by the Offshore Fisheries Management Decree in 2012 and the Offshore Fisheries Management Regulations in 2014, which facilitates the introduction of new technologies such as electronic monitoring in the context of MCS. However, the consultation process for legislative changes can be lengthy, and consultations with industry in Fiji, which will be one of the crucial steps in the process, are still to take place and the proposed amendments remain to be discussed and passed.

4. Comparison

FIJI AND GHANA EXCHANGE

The Common Oceans ABNJ Tuna Project supported an initiative of bringing together the staff involved in the Fiji and Ghana electronic monitoring trials to exchange experiences and to identify lessons learned and areas for improvement.

The exchange of experiences was held on 5 February 2018 at the premises of the Fisheries Commission in Tema, Ghana. Participants included the staff based in Tema, including the heads of the Monitoring, Control and Surveillance Division and the FSSD, observers, ABNJ local coordinators, and the team from Fiji. The four participants from Fiji were the electronic monitoring trial coordinator, the senior electronic monitoring analyst, the principal fisheries officer of the Ministry of Fisheries and Aquaculture Development, and the executive secretary of the FFIA. The Fiji team were given a tour of the VMS and electronic monitoring monitoring centres. This was followed by introductions to electronic monitoring pilot trials in each country and a subsequent discussion of experiences, benefits, problems and needs/recommendations.

Electronic monitoring was considered to be very useful, as it makes it possible to track all movements of fishing vessels, obtain good estimates of catch and effort, and the video footage can be used as reliable information or evidence if needed (objectively verifiable). It is another tool to complement and strengthen the MCS framework in each country. electronic monitoring has played an important role in: improving the image of the tuna industry; and resolving issues related to the yellow cards of the European Union, transshipment, and theft of fish. Moreover, improvements in compliance are primarily in relation to bycatch and bycatch mitigation.

The following are the main issues identified, with some additional comments:

- During the running of the pilot trials, there was increasing acceptance from and cooperation with industry. Although the companies were keen to adopt the technology, there was resistance from crews at the beginning, as this was seen as encroaching on their privacy. However, tampering and sabotage incidents decreased over time as a result of sensitization to the objectives of the trial.
- There were limitations related to blind spots of the camera set-up and the fact that monitoring was not real-time. Ideally, an additional camera with a 360° view is needed in order to be able to have a full or more complete view of the deck as well as the area in proximity to the fishing vessel. These blind spots can be crucial in relation to compliance issues, allowing, for example, the clear identification of other parties involved in transshipment or theft. Companies in Fiji were encouraged to purchase an additional camera as the system allowed for this, but there was limited response.
- The issue of frequent equipment breakdown/failure was identified (computers, HDD stations, cables, etc.). Hence, the maintenance component of the contract with Satlink was reinforced during the trial in Fiji, where this was most relevant.
- There were also issues with the durability of equipment on board vessels, particularly in the smaller vessels in Fiji. The equipment was found to be lacking in terms of robustness and weatherproofing (cameras and equipment installed on the bridges of the vessels). This resulted in more frequent substitution of parts, mostly in Fiji.
- Further/regular training of electronic monitoring analysts is needed (by DOS), also considering recent updates to software. This should focus on ways of

making analysis more efficient and less time-consuming. Satlink continues to make improvements to the software, including technological advances such as automating some tasks, and has pointed out that regular refresher training should be part of an electronic monitoring programme.

- There were various problems that appear to be bugs in the software. Software error messages are in Spanish, making it difficult to understand the problem and how to resolve it. This was brought to the attention of Satlink.
- Auditing of a selection of trip reports should be carried out to assess the quality of analysis *in situ* (non-disclosure agreements were needed for this to go forward). This was developed in Fiji, akin to observer debriefing, as there is a more developed and structured approach in place at the regional level.
- The conversion tool (from EDI – the output file format of SVM – to Excel format) should be provided to both Fiji and Ghana to facilitate analysis/reporting and avoid the need for non-disclosure agreements.
- Satlink local technical support should improve (i.e. HDD retrievals in Ghana). Additional local technicians were hired by Satlink to reinforce this.
- Career progression and distinct roles and functions need to be developed (e.g. debriefing, coordination, analysis and intelligence). This was a concern in Fiji in particular.

Some of the above issues have been discussed in preceding sections (e.g. training, software, data analysis, data conversion, employment and career progression). The exchange focused mostly on technical issues, and the importance of local technical support became evident. The local Satlink office established in Fiji was found to be the best solution, as the technicians are Satlink staff and more versed in the systems. In Ghana, Satlink contracted a local technician to carry out technical support, but some issues had to be dealt with remotely with support from Madrid, Spain. This was essentially a decision based on costs, where the distance to Fiji was a major factor in the decision to establish a local office.

As noted above, the issue of equipment durability was identified, and this was primarily an issue of concern for the Fijian vessels. The equipment on board longline vessels was more exposed to weather conditions, and equipment failure was more common. The costs of replacement increased over time, and this is important to consider as an additional onboard vessel cost. The lifetime of equipment is probably not more than five years, and there are a few vessels with equipment that have already almost exceeded this period (Table 5).

GENERAL PERSPECTIVE

The overall aim of the electronic monitoring pilot trials was not to test the technology itself, but to develop an effective implementation process at the national level, so that the information is properly utilized for compliance purposes. Bearing this in mind, both trials were considered successful in implementing electronic monitoring as an MCS tool to identify compliance issues and improve on the practices carried out on board vessels, although participation was voluntary, and electronic monitoring was not used for enforcement purposes. The approach of identifying "good" and "bad" practices at the initial stages of the pilots led to improving the performance of the vessels by gradually substituting the bad practices with good practices. This was a collaborative process between government and industry to achieve common goals, which also resulted in strengthened communication and trust.

Industry support was key to the success of the trials in the initial concept phase, and also during the implementation of the trials. As participation by industry was voluntary and the approach was to improve compliance and document best practice, the preparation and signing of MOUs was essential in order to specify the tasks and responsibilities during the trial period. Vessel crews were initially reluctant, and there were various incidents of tampering and sabotage. However, acceptance and cooperation increased over time, which resulted in a decrease in incidents.

The electronic monitoring service provider, Satlink, played a key role in implementation at different levels, such as installation of hardware, regular maintenance, ensuring systems were functioning, installing/retrieving HDDs, and remote monitoring by satellite. In relation to the land-based electronic monitoring unit, this technical support included hardware and software (continuously upgraded), as well as expert support in the analysis of video footage. Numerous technical difficulties were experienced during the start-up phase, such as equipment failure, camera blind spots, and adequate and stable power supply. Local technical support was key to the success of the trials, was particularly so in Fiji, considering the distance from Satlink headquarters in Madrid.

Human capacity to manage and sustain the electronic monitoring programme was developed with the support of the electronic monitoring service provider, Satlink (in collaboration with DOS), in the form of training and continuous technical support. The performance of the electronic monitoring analysts was generally good and, in terms of efficiency (sets analysed per day), this was similar to the levels by DOS staff during the course of the trial – noting that the latter specialize in this type of service and have vast experience. However, it was noted that fine-tuning is needed to improve on quality of data, and that the best approach is to carry out regular refresher training workshops to bring all electronic monitoring analysts up to the same level and to introduce new developments in software and analysis protocols.

Particularly in the Pacific, a career as an observer is well established, with certification of training and the existence of national and regional observer programmes (SPC, 2020c). Introducing electronic monitoring was met with resistance and seen as a potential threat to employment in Fiji, not only by the authorities and observers but at a higher political level. However, the perspective has changed in recent years, and the potential benefits of scaling up electronic monitoring programmes have been recognized as a complement to observer programmes and the opening up of new career and employment opportunities.

The electronic monitoring units were created and placed within the corresponding structures dealing with fisheries MCS in each country. This was an obvious choice, considering the objective of improving compliance by using electronic monitoring as a tool. This functioned well as expected, but making electronic monitoring a formal part of the institutional structure can take time, and this is also related to policy development and the legal framework. In this respect, Fiji can be considered to have advanced more, which is related to the context, where a review of legislation has been carried out recently and where policy development is supported by regional structures that are well developed in the South Pacific.

On the other hand, Ghana appears to be in the middle of a substantial reform of the fisheries sector, where electronic monitoring becomes a lower priority in the whole process. A review process of fisheries legislation is under way, and it is expected that this will also consider electronic monitoring and other forms of electronic monitoring tools, but this has progressed slowly and will take time. The functioning of electronic monitoring in Ghana has been stopped since the end of support from international partners (December 2018). This may be restarted in connection with two FIPs being developed: the Ghana pole-and-line fishery; and the Eastern Central Atlantic purse seine fishery (Fishery Progress, 2020b). However, the objectives may be re-defined for the purposes of documentation and certification; thus, losing the opportunity for strengthening compliance. If the delay is prolonged, this could become an academic discussion as the human and institutional capacity will be lost.

In terms of sustainability, the benefits of electronic monitoring were clearly established and documented by the business cases developed for both countries, although it can often be difficult to attribute an economic value to these (Hurry, 2019; MRAG, 2017).

However, it is important to note that there are policy and legal aspects to consider. This process takes time to mature and bring to conclusion. The situation in Ghana shows that the continuation of electronic monitoring will probably be industry-driven for market purposes, at least in the short term. The fact that 13 out of the 14 active purse seine vessels are currently on the ISSF ProActive Vessel Register shows commitment to sustainable tuna fisheries, including programmes for full coverage of fishing activity by observers and/or electronic monitoring.

In Ghana, there was a sharing of information with industry, which was based on the review of electronic monitoring data. This appears to have functioned well, leading to improvement in compliance and introduction of best practices in the handling and release of bycatch. It should be noted that at least two of the companies were private clients of Satlink, paying for an independent analysis of electronic monitoring footage (by DOS) for their own purposes. In fact, this was also a form of quality control, which confirmed that the authorities have become well versed in analysis and produced reliable results. This also shows that companies in Ghana have the capacity to pay for this type of service, considering the future financing of electronic monitoring.

In the case of Fiji, the Government committed to the sharing of data with industry (under the MOU), so that these could be used for operational purposes (e.g. safety and labour conditions, improving fishing operations, and documenting various processes). However, this did not function as well as expected, creating discontent and reluctance to finance a continuation of electronic monitoring. Both the Government and industry continue to support electronic monitoring in Fiji, but data-sharing arrangements should be resolved for the future. However, it is important to point out that profit margins in the longline fishery are marginal, which has important implications for financing and cost-recovery.

An additional and significant benefit of the trials has been the quantity and quality of data generated, which are valuable for scientific purposes. It was envisaged that these data would feed into an integrated information system including data from observers, VMS, port controls and inspections. This has not been possible in Ghana owing to various constraints, and resolving these issues should be the subject of a directed effort outside the scope of the trial. Integration has been possible in Fiji because of an existing regional information system and significant support from the SPC and FFA for this purpose. It should be noted that integration and intelligence gathering for MCS purposes is still under development for Pacific island countries, also with support from the Common Oceans ABNJ Tuna Project.

5. Lessons learned

The body of knowledge and experience on the use of electronic monitoring in fisheries has grown considerably in recent years, which provides valuable information on numerous electronic monitoring programmes or trials that have been carried out or are ongoing (Emery *et al.*, 2018; Fujita *et al.*, 2018; Helmond *et al.*, 2020; James *et al.*, 2019; Mangi *et al.*, 2015; Michelin *et al.*, 2018; Ruiz *et al.*, 2015; Sylvia, Harte and Cusack, 2017). It is outside the scope of this report to review the identified benefits, strengths and weaknesses. Instead, this chapter attempts to contribute to this growing body of knowledge, particularly in the context of a developing State. This is important as most of the information currently available concerns experiences from fisheries in developed countries.

There is considerable interest in exploring the use of electronic monitoring for fisheries MCS, and it is stated that the sector is at a "tipping point" or "inflection point" where the use of electronic technology (including electronic reporting) is rapidly gathering momentum (Michelin *et al.*, 2018; Sylvia, Harte and Cusack, 2017). The Western and Central Pacific is a region where this appears more advanced, where the trials supported by FAO and The Nature Conservancy have gathered valuable experience (FFA, 2020).

DEFINING THE GOALS

The findings presented in this publication support the general conclusion that clearly defined objectives result in more effective and efficient electronic monitoring programmes. The overall objective in these two trials was to use electronic monitoring to monitor compliance with all relevant national and regional management regulations. However, it is important to bear in mind that the design and associated costs will depend on whether electronic monitoring should be used primarily for science or compliance purposes, or both.

In the case of Fiji, although the stated project objective was related to compliance, the development of electronic monitoring process standards in the region placed emphasis on data collection and on gathering as much detail as possible for scientific purposes (Emery *et al.*, 2018). Thus, the trial attempted to address both types of objectives depending on circumstances: scientific data collection, and monitoring of compliance. This resulted in a significant workload for the electronic monitoring analysts, and it became impossible to reach the target of 100 percent coverage. Despite this, the trial in Fiji performed well by reviewing video footage from about 40–50 percent of fishing trips, which is much higher than the expected level of 5 percent for WCPFC longline fisheries. In the case of Ghana, achieving the stated objectives was more straightforward, also because the review of video footage is not as time-consuming in purse seine fisheries.

electronic monitoring has proved to be a powerful and effective tool for monitoring fishing activity and for monitoring compliance. Identified bad practices occurring in the fleets decreased over time. An added benefit was the collection of valuable data for scientific purposes. This was tested in the case of Fiji, showing that electronic monitoring data are more complete and more robust compared with other sources (e.g. logbooks and observer reports). However, it is important to note that observers perform certain tasks not covered by electronic monitoring, such as biological sampling (Emery *et al.*, 2018). On the other hand, purse seine fishing is characterized by high volumes where the total catches and species composition are difficult to estimate accurately by either human observers or electronic monitoring. The final estimates involve a reconciliation of different data sources such as logbooks, landing declarations, sales notes and port sampling in order to produce robust estimates of total catch by species (Jupiter, Forcada Alamracha and Sanchez Lizaso, 2017; Ruiz *et al.*, 2015).

INDUSTRY BUY-IN

The participation and support of industry was essential for the success of the trials, which supports the published literature on the subject. Bearing in mind that industry participated on a voluntary basis, the trials would not have been possible without its support.

There are three major issues that are of concern to industry: (i) the cost of EM; (ii) access to data so these can be used for its own purposes; and (iii) ensuring a level playing field. Cost considerations are dealt with below. Access to data ensures added benefits from electronic monitoring programmes, but this did not function as intended in the case of Fiji.

Initially, the Ministry of Fisheries decided that video footage would be released only after review/analysis. As a result of the considerable delay associated with a range of challenges, the backlog grew. When the video footage and electronic monitoring reports were eventually released upon request, they were found to be of limited or no value. Hence, rapid release of data by cloning HDDs upon arrival of vessels to port is important for industry.

Industry should be granted access to video footage. However, at the same time, there should be a recognition that industry will not have the capacity for effective use of these data unless it is willing to invest in terms of human capacity or pay a third party for analysis. Alternatively, company staff could receive training in rapidly identifying samples of data that are of interest. A form of collaborative arrangement should be established between industry and government, so that the use of data by industry becomes more effective and efficient.

Ensuring a level playing field becomes a major issue when considering scaling up the use of electronic monitoring. If this is not compulsory across an entire fleet, the countries that introduce electronic monitoring will be at a disadvantage in terms of costs of fishing. Tuna fleets are highly mobile and can easily move to avoid extra costs. This is not so much the case for domestic fleets, but using electronic monitoring in domestic fleets places them at a cost disadvantage compared with foreign fleets.

Another important aspect from the industry perspective was the general resistance from the crews to introducing electronic monitoring on vessels. Although the companies were supportive, considering the potential benefits in documenting best practices and improving operations on board vessels, the crews considered this to be an intrusion on their privacy. There were frequent tampering and sabotage incidents at the start, but these decreased over time through communication and building trust concerning the use of the data. Nonetheless, this is an issue that also needs to be considered in legal terms, such as the right to privacy and data protection of individuals, something that was highlighted in the legal review (MRAG, 2017).

Data ownership was attributed to government in both trials in Fiji and Ghana, and the electronic monitoring data were treated as confidential. It was decided that these data would not be used for the purpose of enforcement during the trial period, but that instead the focus would be on improving compliance through a collaborative approach between government and industry. It was envisaged that electronic monitoring would be adopted as an MCS tool. However, the trials brought to light specific issues that have to be considered in legal terms such as: ownership and data-sharing arrangements; confidentiality; the uses of data; chain of custody of evidence; and liability. Fishers may also be concerned that the formal adoption of electronic monitoring will dramatically increase sanctioning even for minor violations, although authorities are generally not interested in minor issues (Michelin *et al.*, 2018). However, this does highlight the need for in-depth consultations to clarify and build consensus, including a common understanding on how electronic monitoring should and will be implemented.

HUMAN CAPACITY

At-sea observers were chosen as the obvious candidates for training as electronic monitoring analysts, although the level of observer experience was much higher in Fiji than in Ghana. Following the two training sessions offered by the electronic monitoring service provider, these analysts demonstrated and proved their skills and ability. However, it is important to follow up with regular refresher courses to fine-tune certain aspects, bring all electronic monitoring analysts up to the same level, introduce new developments in software and analysis protocols, and clarify any doubts.

In Ghana, the local trained personnel continued with their tasks as at-sea observers, and this created difficulties and a backlog of video footage to be reviewed. In order to address this problem, two women were hired and trained as electronic monitoring analysts without having any at-sea observer experience. This functioned well with much higher performance, which opens up the possibility of employing women in this field – which was considered a very positive outcome – as opposed to observers who are usually male.

In general terms, the trials demonstrated the potential for the creation of jobs linked to the creation and running of electronic monitoring programmes. There was initial resistance, particularly in Fiji, but the trials showed that developing human capacity creates future potential in terms of employment and career progression; for example, progression from electronic monitoring analyst to debriefer, auditor, and intelligence, compliance or enforcement officer.

However, there are many other aspects to consider, such as: developing/updating data analysis protocols; debriefing protocols; data storage and information management; standard operating procedures; and a chain of custody. This requires different skill sets and experience – thus, opening up a whole new field of work.

EFFICIENCY IN ANALYSIS

Analysis of video/image footage is time-consuming and costly (Annex 2). Advances in technology are needed to make electronic monitoring more effective by reducing the time needed for analysis and/or by automating certain tasks. Significant technological advances are taking place, such as in the use of artificial intelligence, machine learning and automated analysis, which are expected to reduce the time needed for analysis in the near future.[19]

Full coverage by using electronic monitoring is easily achieved, but it is not necessary to review/analyse all the footage. Installing cameras on all vessels is a deterrent in itself, which leads to better compliance in general. Complete analysis of footage can be reduced to a certain percentage, based on a risk assessment. The Australian electronic monitoring programme has set the detailed review of electronic monitoring footage at 10 percent, which is a trade-off between cost considerations and a sufficient coverage to cover high-risk vessels and trips. A 20 percent coverage is generally assumed to be adequate for scientific purposes (acceptable variability), but this will be reviewed by the SPC in connection with the development of the electronic monitoring policy for longliners in the region.

[19] See, for example, presentations by providers at the Seafood and Fisheries Emerging Technologies Conference (SAFET), 13–16 February 2019, Bangkok, Thailand (Seafood and Fisheries Emerging Technologies, 2020).

Electronic monitoring can be combined with an observer programme that concentrates on scientific data collection, making this a more effective use of resources and releasing observers from possible pressures when on board vessels.

COST AND COST-RECOVERY

There is general recognition that cost is a major factor to consider, and the trials in Fiji and Ghana confirm this. In various reviews, one comes across the argument that electronic monitoring programmes can potentially lead to cost-effectiveness or savings when compared with observer programmes. This depends on various factors such as video review rates and storage costs, but more importantly on scale. If the objective is large-scale or full coverage, electronic monitoring is presented as a cost-effective solution compared with observers. The finding in the present report is that this is not the case in a developing-country context. As daily fee rates for observers are relatively low, achieving full coverage with observers will still be cheaper than implementing electronic monitoring. Currently, service providers are based in developed countries, and costs for both equipment and services are based on this.

However, placing observers on board all vessels can be impossible both from a logistics point of view and also because of the poor safety conditions on many vessels. Observers sometimes refuse to board vessels that are in poor condition and/or if they have concerns for their safety.

On the issue of cost-recovery, it became apparent during consultations that the profitability of the fleets is a key issue. While purse seine fishing is characterized by high volume and turnover, the longline fishery in Fiji appears to be struggling with low profit margins. The capacity for industry to take on additional costs of doing business are very different in these two trials.

Although electronic monitoring entails higher costs in a typical developing-country context, there are numerous benefits that have been identified in the business cases developed for Fiji and Ghana. During the recent initiative to develop a draft longline electronic monitoring policy for the Western and Central Pacific, much of the discussion revolved around possible ways of reducing costs (SPC, 2019). The following are possible solutions, also supported by experiences in Fiji, but considering a larger-scale implementation and supported by regional cooperation:

- Develop data and technical standards for approval of electronic monitoring providers, thus creating space for multiple providers and a more competitive market. This would also ensure interoperability of systems from different providers.
- Develop in-house capacity to carry out regular maintenance and system checks of electronic monitoring on board vessels.
- Develop software for analysis of electronic monitoring data and regional training programmes, thus reducing service provider costs.
- Reduce data storage costs by using cloud-based systems and satellite technology for data transfer. The expectation is that data may be transferable through the cloud within 3–5 years.
- Pursue economies of scale – cost savings can be made by implementing electronic monitoring on a large scale, involving thousands of longliners and operating a small number of electronic monitoring data review centres.
- Integrate technological solutions, such as combining VMS, electronic monitoring and e-reporting, in one system.

COMMITMENT AND POLITICAL WILL

The logical result of the successful trials should have been the formal use of electronic monitoring as a tool for monitoring compliance, but experience showed that this involves factors outside the control of the project. A revision of fisheries legislation would normally be required, and in the case of Ghana, electronic monitoring is just one of the many issues to consider in a general reform of the sector. The need for a policy on electronic monitoring was also identified, specifying the principles, goals and objectives, and linking this to other policy and strategies (e.g. MCS and management).

Political commitment and engagement are essential. It became evident that the engagement of international partners was important in order to communicate the success of the trials and the benefits of sustaining the electronic monitoring programme and formally introducing it as a tool for MCS. Nonetheless, electronic monitoring is just another tool, albeit with great potential, and there are often many other priority issues in a developing State context.

In Ghana, the electronic monitoring programme has stopped as government and industry have not taken the necessary steps to secure finances for its continuation. The future of electronic monitoring is uncertain, but one likely scenario is that electronic monitoring will re-start as part of FIPs and be industry-driven for market purposes.

In Fiji, steps are being taken to secure financing for the continuation of electronic monitoring in the short term (2–4 years), thus giving time for the development of a regional electronic monitoring programme. Regional developments have gathered momentum, and this was a fortunate situation, as it created awareness at a high political level about the potential of electronic monitoring.

At the sixteenth Forum Fisheries Committee Ministerial Meeting in Pohnpei, Micronesia (Federated States of), in June 2019, Ministers welcomed the initiative of Micronesia (Federated States of) on electronic monitoring through the Technology for Tuna Transparency Challenge, recognizing the potential for electronic monitoring to be a game changer in improving the management of longline fisheries. The FFA Secretariat was tasked with developing an electronic monitoring policy in collaboration with the Parties to the Nauru Agreement Office (PNAO) and the SPC to be considered at their meeting in 2020. A draft longline electronic monitoring policy was developed during a workshop held on 16–18 October 2019, Honiara, Solomon Islands (SPC, 2019). This was organized by the FFA, SPC and PNAO, and counted on the participation of 14 FFA members, the WCPFC, non-governmental organizations (NGOs), as well as industry representatives such as from the FFIA (Fiji), Luen Thai Fishing Venture, and Tri Marine.

This draft longline electronic monitoring policy addresses both compliance and science-related objectives. There is now lesser emphasis on developing an electronic monitoring programme that is based on science objectives and mimicking the Regional Observer Programme. The objective of compliance has become much more central in this discussion, particularly as regards longline fisheries in the high seas. The linkages with the WCPFC were discussed, and it was considered essential that this electronic monitoring policy should be implemented in the EEZs and adjacent seas in such a way as to create a level playing field.

REGIONAL STRUCTURES

One important aspect of the trial in Fiji was this country's membership of regional organizations such as the SPC, FFA and WCPFC. The Western and Central Pacific is rather unique in that it benefits from the existence of organizations such as the SPC and FFA to support its members (Pacific island countries and territories). The SPC is the primary science provider and technical adviser in tuna fisheries, working for the benefit of its members in the region. This is complemented by the role of FFA, which was established to help its 17 members sustainably manage their fishery resources within their EEZs. The FFA is an advisory body providing expertise, technical assistance and other support to its members. These members make sovereign decisions about their tuna resources and participate in regional decision-making on tuna management through agencies such as the WCPFC.

Fiji has benefited from being part of this regional framework in various ways. It was part of the process of developing electronic monitoring process standards, which was driven by the SPC (SPC, 2019). It participated in the workshops and meetings of intersessional working groups on electronic reporting and electronic monitoring (ER+EM) of the WCPFC, which was and still is working on the development of a CMM on electronic monitoring to be applied in the convention area (WCPFC, 2018b). Fiji participated and made valuable contributions to the Longline electronic monitoring Planning Workshop, where a draft longline electronic monitoring policy was developed.

Fiji is now in the unique position of being able to influence the development of electronic monitoring in the region. This is because of the scale of the trial (50 vessels) and the valuable experience on how to keep a larger-scale national electronic monitoring programme functioning successfully. There is general recognition of this in the region, and keen interest in the findings of the business case (and its costing options), which can be used for the benefit of Pacific island countries. At the same time, it must be recognized that Fiji received considerable support from regional partners and is dependent on developments in the region for the definition of policy and a harmonized implementation of electronic monitoring across the region.

6. Scaling up

The Common Oceans ABNJ Tuna Project specifies an output that states: "Pilot trials of electronic observer systems aboard tuna fishing vessels successfully completed in Fiji and Ghana with lessons learned and best practices disseminated to sub-regional Organizations and t-RFMOs for upscaling." The objective of this output is to facilitate the integration of this new technology electronic monitoring into domestic MCS activities in order to improve compliance with, and enforcement of, international, regional and national regulations. The experience gained and lessons learned from these two trials have been presented in the preceding sections; hence, this section focuses on the perspective of scaling up.

The report *Catalyzing the Growth of electronic monitoring in Fisheries* deals with this issue specifically and identifies the opportunities, barriers and recommendations for scaling the technology of electronic monitoring (Michelin *et al.*, 2018). There is increasing demand for the monitoring of fishing activity, and there is a need for more reliable information to improve fisheries management as well as generate information that can be useful for ecosystem-based management. Independent data on the activity of tuna longline fisheries are generally poor, but it is unrealistic to expect that observer programmes can be scaled up significantly to cover these fisheries. However, electronic monitoring has great potential to cover this gap, as well as in other tuna fisheries such as purse seine and pole-and-line fisheries. It is in the combination of available MCS tools and the design of monitoring programmes, taking into account the specificities of each type of fishery, that effective and efficient monitoring and data collection can be achieved.

Michelin *et al.* (2018) identify the need for more work in demonstrating the benefits of electronic monitoring, identifying new opportunities for the technology, and breaking down the barriers that are slowing adoption. They give recommendations in the following four areas:

- Support electronic monitoring cost reductions and technological advancements.
- Build broad demand for electronic monitoring through national and regional prioritization of electronic monitoring.
- Assist regulators with electronic monitoring programme design and implementation.
- Build fisher and industry support for electronic monitoring and cultivate private-sector leadership.

The authors who have contributed to this report share the view that affirms the benefits and opportunities of electronic monitoring as a tool and the need to address the various barriers to take full advantage of electronic monitoring. They subscribe to this view, and they have contributed with experiences and lessons learned to these four areas, bearing in mind that this focuses on industrial fleets. Their experience shows that, although achieving 100 percent coverage of fleet activity is possible, the capacity for financing and cost-recovery may be a crucial factor when addressing different types of fisheries. Moreover, the potential for the use of electronic monitoring differs from fishery to fishery, which makes the design of the monitoring programme of crucial importance where the use of various MCS tools should be considered.

The costs of implementing electronic monitoring can be substantial, and ways of reducing these costs have been discussed in Chapter 5. Cost reductions become more feasible with the scaling up of the use of electronic monitoring as the economies of scale come into play. Another key issue is the existence of regional structures or platforms that can assist in a harmonized implementation, ensure a level playing field, and take on several of the tasks normally provided by electronic monitoring service providers (e.g. standards, training, analysis software, interoperability of systems, and integration with other MCS tools).

One major gap that these trials did not explore is how to address the deficiencies in monitoring small-scale fisheries, which should also be the focus of future efforts (Bradley *et al.*, 2019). This is a problem in both the developing and the developed world, where there has generally been a lack of attention, also because addressing this can be a complex and daunting task. The Common Oceans ABNJ Tuna Project has been supporting efforts by WWF-Pakistan to cover information gaps of the gillnet fisheries in the Northern Indian Ocean (Arabian Sea) with promising results, including mitigation measures to reduce and avoid bycatch (Kiszka *et al.*, 2018; Moazzam and Farhan Khan, 2019). This type of effort combined with electronic monitoring and other monitoring tools and technologies should be explored further.

The ABNJ have become a priority, and are currently the subject of negotiations by an intergovernmental conference on an international legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (BBNJ) (United Nations, 2020).

There have been numerous calls for far greater transparency and accountability in fisheries, particularly from the NGO community and civil society organizations, and these should also be seen in the context of how to make best use of the available information in the context of ecosystem-based management of the ABNJ. It is crucial that the fisheries community become a central part of these efforts and contributes to the process, also by making use of available information.

These and many other issues were discussed at the International Symposium on Sustainable Fisheries on 18–21 November 2019, which was organized by FAO (FAO, 2019). As stated by FAO, the fisheries sector needs to develop a new vision for capture fisheries in the twenty-first century, in the context of the 2030 Agenda for Sustainable Development, one that better reflects the way capture fisheries are perceived and used. The importance of "proactive" engagement of the fisheries community in the dialogue for biodiversity (Convention on Biological Diversity and BBNJ negotiations), plastic pollution, climate change, and the blue economy were stressed (Ridgeway, 2019).

Another theme of the symposium was data collection and how to address data-poor situations and the available tools to improve fisheries management in such situations (Parma, 2019). Development in technologies can transform fisheries data into a public commodity through the use of intelligent reporting apps and sensors, edge computing, artificial intelligence and machine learning (Castelli, 2019). Costs are expected to fall significantly. The new generation of information systems is expected to support more efficient, participatory and inclusive data-driven scientific approaches in addressing challenges such as food security, adaptation and resilience to climate change, and ecosystem management. For this to happen, principles must be defined for the sharing and use of data, and these should be based on trust and transparency. The global scientific community, including fisheries, will have to identify appropriate shared regulations, guidelines and best practices for information systems to adopt and so make use of the full potential of these new technologies (Castelli, 2019).

FAO can play an important role as a facilitator and a convenor for the setting of standards, defining best practices and developing guidelines. Monitoring and data collection in fisheries should be strengthened further, and electronic monitoring is one of the tools available.

References

Agnew, D.J., Pearce, J., Pramod, G., Peatman, T., Watson, R., Beddington, J.R. & Pitcher, T.J. 2009. Estimating the worldwide extent of illegal fishing. *PLOS ONE*, 4(2): e4570 [online]. [Cited 19 August 2020]. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0004570

Archipelago. 2020. Monitoring the Area A crab fishery. In: *Archipelago* [online]. [Cited 19 August 2020]. www.archipelago.ca/case-studies/area-a-crab-fishery/

Australian Fisheries Management Authority. 2014. electronic monitoring program. In: *Australian Fisheries Management Authority* [online]. [Cited 19 August 2020]. www.afma.gov.au/monitoring-enforcement/electronic-monitoring-program

Bannerman, P., Chavance, P. & Daertner, D. 2013. Strengthening Ghanaian industrial purse seine fishery monitoring in the Gulf of Guinea. *Collective Volume of Scientific Papers ICCAT*, 69(5): 2037–2044.

Beverly, S., Chapman, L. & Sokimi, W. 2003. *Horizontal longline fishing methods and techniques: a manual for fishermen.* Secretariat of the Pacific Community. 132 pp.

Bez, N., Walker, E., Gaertner, D., Rivoirard, J. & Gaspar, P. 2011. Fishing activity of tuna purse seiners estimated from vessel monitoring system (VMS) data. *Canadian Journal of Fisheries and Aquatic Sciences*, 68(11): 1998–2010. https://doi.org/10.1139/f2011-114

Bradley, D., Merrifield, M., Miller, K.M., Lomonico, S., Wilson, J.R. & Gleason, M.G. 2019. Opportunities to improve fisheries management through innovative technology and advanced data systems. *Fish and Fisheries*, 20(3): 564–583 [online]. [Cited 19 August 2020]. https://onlinelibrary.wiley.com/doi/abs/10.1111/faf.12361

Cacaud, P. & Sekor, E. 2015. *Legal framework review: final report*. Produced for the Minister of Fisheries and Aquaculture Development by a consortium of Poseidon, Innovative Services and GIMPA Consulting as part of the Legal, Operational & Organizational Framework to Enable Implementation of the Ghana Fisheries and Aquaculture Sector Development Plans component of the 'West Africa Regional Fisheries Project (WARFP). 333 pp.

California Environmental Associates (CEA). 2016. *Fiji fisheries: 2015 review*. Prepared for The David and Lucile Packard Foundation.

Castelli, D. 2019. *Beyond augmented intelligence while leaving no one behind* [online]. [Cited 19 August 2020]. www.fao.org/fishery/static/symposiumfisheriespresentations/PPT7.2DonatellaCastelli.pdf

Defaux, V., Gascoigne, J. & Huntingdon, T. 2018. *Action plan for the preparation of an Eastern Atlantic – Ghana based - pole and line tuna Fishery Improvement Project (FIP)*. 53 pp.

Douglas, J. 2019. *AI @ sea*. Paper presented at Seafood and Fisheries Emerging Technologies Conference. February 13-16, 2019, Bangkok, Thailand, 2019. (also available at https://114973d1-ff11-4a1e-aeae-708c3e9c607f.filesusr.com/ugd/a17859_50407ff1b2034ce0997d117cafc59d45.pdf).

EM4Fish. 2020. Resource Library. In: *EM4Fish* [online]. [Cited 19 August 2020]. https://em4.fish/browse-our-library/

Emery, T.J., Noriega, R., Williams, A.J., Larcombe, J., Nicol, S., Williams, P., Smith, N., Pilling, G., Hosken, M., Brouwer, S., Tremblay-Boyer, L. & Peatman, T. 2018. The use of electronic monitoring within tuna longline fisheries: implications for international data collection, analysis and reporting. *Reviews in Fish Biology and Fisheries*, 28(4): 887–907 [online]. [Cited 19 August 2020]. https://doi.org/10.1007/s11160-018-9533-2

European Commission. 2014. *European Commission awards Fiji a Fisheries "Green Card"!* [online]. [Cited 19 August 2020]. https://eeas.europa.eu/archives/delegations/new_zealand/documents/press_corner/news/20141028_fiji_fisheries.pdf

European Commission. 2015. Fighting illegal fishing: Commission warns Taiwan and Comoros with yellow cards and welcomes reforms in Ghana and Papua New Guinea. In: *European Commission* [online]. [Cited 19 August 2020]. https://ec.europa.eu/commission/presscorner/detail/en/IP_15_5736

FAO. 2018. Technical workshop on electronic monitoring in Suva, Fiji. In: *FAO* [online]. [Cited 19 August 2020]. www.fao.org/in-action/commonoceans/news/detail-events/en/c/1142116/

FAO. 2019. International Symposium on Fisheries Sustainability. In: *FAO* [online]. [Cited 19 August 2020]. www.fao.org/about/meetings/sustainable-fisheries-symposium/en/

FAO. 2020a. Common Oceans - A partnership for sustainability in the ABNJ. In: *FAO* [online]. [Cited 19 August 2020]. www.fao.org/in-action/commonoceans/background/en/

FAO. 2020b. What is IUU fishing? In: *FAO* [online]. [Cited 19 August 2020]. www.fao.org/iuu-fishing/background/what-is-iuu-fishing/en/

FAO. 2020c. Fishing techniques – tuna purse seining. In: *FAO* [online]. [Cited 19 August 2020]. www.fao.org/fishery/fishtech/40/en

Fishery Progress. 2020a. Eastern Atlantic tuna - purse seine. In: *Fishery Progress* [online]. [Cited 19 August 2020]. https://fisheryprogress.org/fip-profile/eastern-atlantic-tuna-purse-seine

Fishery Progress. 2020b. *Fishery Progress* [online]. [Cited 19 August 2020]. https://fisheryprogress.org/

Forum Fisheries Agency (FFA). 2020. Fisheries observer safety a key focus, as FFA wraps up annual meeting: media release. In: *Forum Fisheries Agency* [online]. [Cited 19 August 2020]. www.tunapacific.org/tag/electronic-monitoring/

Fujita, R., Cusack, C., Karasik, R. & Takade-Heumacher, H. 2018. *Designing and implementing electronic monitoring systems for fisheries: a supplement to the Catch Share Design Manual*. San Francisco, USA, Environmental Defense Fund. 63 pp.

Gillett, R.D. 2016. *Fisheries in the economies of Pacific island countries and territories*. Pacific Community.

Helmond, A.T.M. van, Mortensen, L.O., Plet-Hansen, K.S., Ulrich, C., Needle, C.L., Oesterwind, D., Kindt-Larsen, L., Catchpole, T., Mangi, S., Zimmermann, C., Olesen, H.J., Bailey, N., Bergsson, H., Dalskov, J., Elson, J., Hosken, M., Peterson, L., McElderry, H., Ruiz, J., Pierre, J.P., Dykstra, C. & Poos, J.J. 2020. electronic monitoring in fisheries: lessons from global experiences and future opportunities. *Fish and Fisheries*, 21(1): 162–189 [online]. [Cited 19 August 2020]. https://onlinelibrary.wiley.com/doi/abs/10.1111/faf.12425

Hurry, G. 2019. *Building a Business Case for electronic monitoring (EM) for the Fiji long line (LL) fishing industry*. Prepared for the Ministry of Fisheries, Government of Fiji. MRAG Asia Pacific. 87 pp.

International Seafood Sustainability Foundation (ISSF). 2020. Conservation Measures & Commitments. In: *ISSF* [online]. [Cited 19 August 2020]. https://iss-foundation.org/what-we-do/verification/conservation-measures-commitments/

James, K.M., Campbell, N., Viðarsson, J.R., Vilas, C., Plet-Hansen, K.S., Borges, L., González, Ó., van Helmond, A.T.M., Pérez-Martín, R.I., Antelo, L.T., Pérez-Bouzada, J. & Ulrich, C. 2019. Tools and technologies for the monitoring, control and surveillance of unwanted catches. In S.S. Uhlmann, C. Ulrich & S.J. Kennelly, eds. *The European Landing Obligation: Reducing Discards in Complex, Multi-Species and Multi-Jurisdictional Fisheries*, pp. 363–382. Cham, Springer International Publishing. (also available at https://doi.org/10.1007/978-3-030-03308-8_18).

Jupiter, D.C., Forcada Alamracha, A.S. & Sanchez Lizaso, J.L. 2017. *Pilot activity to assist the implementation of an electronic monitoring system on Seychelles flagged tuna purse seiners*. Alicante, Spain, Universidad de Alicante. 218 pp.

Kiszka, J.J., Moazzam, M., Nivière, M., Shahid, U., Khan, B. & Nawaz, R. 2018. *Cetaceans in the tuna drift gillnet fishery off Pakistan (Arabian Sea): can we reduce bycatch at low cost with no impact on targeted species catch rates?* Working Party on Ecosystems and Bycatch. Indian Ocean Tuna Commission. IOTC-2018-WPEB14-41_Rev3. 7 pp.

Lee, S., Lewis, A., Gillett, R., Fox, M., Tuqiri, N., Sadovy, A., Batibasaga, A., Lalavanua, W. & Lovell, E. 2018. *Fiji fishery resource profiles: information for management on 44 of the most important species groups*. Suva, Gillett, Preston and Associates and the Wildlife Conservation Society. 240 pp.

Mangi, S.C., Dolder, P.J., Catchpole, T.L., Rodmell, D. & de Rozarieux, N. 2015. Approaches to fully documented fisheries: practical issues and stakeholder perceptions. *Fish and Fisheries*, 16(3): 426–452 [online]. [Cited 19 August 2020]. https://onlinelibrary.wiley.com/doi/abs/10.1111/faf.12065

Manoa, P. 2017. *Legislative provision for the use of electronic monitoring equipment on the Fijian longline fishery*. Technical Report. Development Law Service, FAO Legal Office. FAO. 18 pp.

Marine Stewardship Council (MSC) 2020. Certificates Fiji Albacore, Yellowfin and Bigeye Tuna longline - MSC Fisheries. In: *MSC* [online]. [Cited 19 August 2020]. https://fisheries.msc.org/en/fisheries/fiji-albacore-yellowfin-and-bigeye-tuna-longline/@@certificates

Michelin, M., Elliott, M., Bucher, M., Zimring, M. & Sweeney, M. 2018. *Catalyzing the growth of electronic monitoring in fisheries: building greater transparency and accountability at sea. Opportunities, barriers, and recommendations for scaling the technology*. California Environmental Associates and The Nature Conservancy. 64 pp.

Ministry of Fisheries. 2018. *Fiji Fisheries Sector Investment Guide; August 2018 – July 2019*. Fiji. 49 pp.

Ministry of Fisheries. 2020. Offshore Fisheries Division. In: *Ministry of Fisheries* [online]. [Cited 19 August 2020]. www.fisheries.gov.fj/index.php/divisions-fisheries/offshore-fisheries-division

Moazzam, M. & Farhan Khan, M. 2019. *Issues related to adoption of subsurface gillnetting to reduce bycatch in Pakistan*. Working Party on Ecosystems and Bycatch. Indian Ocean Tuna Commission. IOTC-2019-WPEB15-48. 13 pp.

Ministry of Fisheries and Aquaculture Development. 2018. *Draft National Strategy and Plan of Action for PSMA Implementation.* Ministry of Fisheries and Aquaculture Development, Ghana. 40 pp. (draft version)

MRAG. 2016. *Towards the quantification of illegal, unreported and unregulated (IUU) fishing in the Pacific Islands region.* 101 pp.

MRAG. 2017. *Building the business case for EMS in the tuna Ghanaian purse seine fleet: final technical report*. London.

National Oceanic and Atmospheric Administration (NOAA). 2019. electronic monitoring. In: *NOAA* [online]. [Cited 19 August 2020]. www.fisheries.noaa.gov/national/fisheries-observers/electronic-monitoring

Ortiz, M. & Palma, C. 2017. Estimation of Ghana's Tasks I and II purse seine and baitboat catch 2006-2014: data input for the 2016 yellowfin stock assessment. *ICCAT*, 73(2): 482–498.

Pacific Catalyst. 2019. *Benefits of secure and transferable fishing rights with catch and effort restrictions in the Fijian longline fleet* [online]. [Cited 19 August 2020]. https://pacificcatalyst.org/wp-content/uploads/2019/10/Fijian-Longline-Fleet-Paper_2019.pdf

Parma, A. 2019. *Evidence-based fisheries management: What is needed to achieve biological sustainability of global fisheries?* [online]. [Cited 19 August 2020]. www.fao.org/fishery/static/symposiumfisheriespresentations/PPT1.2AnaParma.pdf

Parties to the Nauru Agreement (PNA). 2018. PNA focuses on electronic monitoring program. In: *PNA* [online]. [Cited 19 August 2020]. www.pnatuna.com/content/pna-focuses-electronic-monitoring-program

Republic of Ghana. 2014. *National Plan of Action IUU, 2014, Republic of Ghana* [online]. [Cited 19 August 2020]. www.fao.org/fishery/docs/DOCUMENT/IPOAS/national/Ghana/NPOA_IUU.pdf

Restrepo, V., Justel-Rubio, A., Koehler, H. & Ruiz, J. 2018. *Minimum standards for electronic monitoring systems in tropical tuna purse seine fisheries*. ISSF Technical Report 2018-04. Washington, DC, International Seafood Sustainability Foundation.

Ridgeway, L. 2019. *Policy opportunities for Fisheries* [online]. [Cited 19 August 2020]. www.fao.org/fishery/static/symposiumfisheriespresentations/PPT8.1LoriRidgeway.pdf

Ruiz, J. 2018. Five years of electronic monitoring onboard tropical tuna purse seiners. In S.J. Kennelly & L. Borges, eds. *Proceedings of the 9th International Fisheries Observer and Monitoring Conference, Vigo, Spain*.

Ruiz, J., Batty, A., Chavance, P., McElderry, H., Restrepo, V., Sharples, P., Santos, J. & Urtizberea, A. 2015. electronic monitoring trials on in the tropical tuna purse-seine fishery. *ICES Journal of Marine Science*, 72(4): 1201–1213 [online]. [Cited 19 August 2020]. https://academic.oup.com/icesjms/article/72/4/1201/801387

Satlink. 2020. *Satlink - Satellite solutions by land, sea and air* [online]. [Cited 19 August 2020]. https://satlink.es/en/

Seafood and Fisheries Emerging Technologies. 2020. *Seafood and fisheries emerging technology* [online]. [Cited 19 August 2020]. www.seafoodandfisheriesemergingtechnology.com

Stockholm Resilience Centre. 2018. No place for big mama. In: *Stockholm Resilience Centre* [online]. [Cited 19 August 2020]. www.stockholmresilience.org/research/research-news/2018-11-02-no-place-for-big-mamma.html

Sylvia, G., Harte, M. & Cusack, C. 2017. *Challenges, opportunities, and costs of electronic fisheries monitoring*. Prepared for the Environmental Defense Fund. 34 pp.

The Pacific Community (SPC). 2018. E-reporting & e-monitoring. In: *SPC* [online]. [Cited 19 August 2020]. https://oceanfish.spc.int/meetingsworkshops/e-reporting-a-e-monitoring?lang=en

The Pacific Community (SPC). 2019. Sub-Regional electronic monitoring Workshop - Oct 2019. In: *SPC* [online]. [Cited 19 August 2020]. https://oceanfish.spc.int/en/meetingsworkshops/e-reporting-a-e-monitoring/499-e-monitoring-oct-2019

The Pacific Community (SPC). 2020a. About us. In: *The Pacific Community* [online]. [Cited 19 August 2020]. https://www.spc.int/about-us

The Pacific Community (SPC). 2020b. Database systems. In: *SPC* [online]. [Cited 19 August 2020]. https://oceanfish.spc.int/en/ofpsection/data-management/spc-members/dd

The Pacific Community (SPC). 2020c. Pacific Islands Regional Fisheries Observer (PIRFO). In: *SPC* [online]. [Cited 19 August 2020]. https://oceanfish.spc.int/en/ofpsection/fisheries-monitoring/observers

Tuna-org. 2020. CLAV - the tuna-org Consolidated List of Authorized Vessels. In: *Tuna-org* [online]. [Cited 19 August 2020]. http://clav.iotc.org/browser/search/;jsessionid=D9D645B1A1F22EF544D23A14582D7DF6

United Nations. 2020. Intergovernmental Conference on Marine Biodiversity of Areas Beyond National Jurisdiction |. In: *United Nations* [online]. [Cited 19 August 2020]. www.un.org/bbnj/

Vakalevu, V. 2014. *Fighting against illegal, unreported and unregulated fishing (IUU)* [online]. [Cited 19 August 2020]. https://brusselsbriefings.files.wordpress.com/2014/10/bb38-iuu-presentation-wainiqolo-en.pdf

Walker, E., Gaertner, D., Gaspar, P. & Bez, N. 2010. Fishing activity of tuna purse seiners estimated from VMS data and validated by observers' data. *Collective Volume of Scientific Papers ICCAT*, 65(6): 2376–2391.

Western and Central Pacific Fisheries Commission (WCPFC). 2018a. Progress on eletronic reporting and electronic monitoring implementation in the region. In: *WCPFC* [online]. [Cited 19 August 2020]. www.wcpfc.int/node/31029

Western and Central Pacific Fisheries Commission (WCPFC). 2018b. *Final Compliance Monitoring Report. 15th Regular Session of the Western and Central Pacific Fisheries Commission. Honolulu, Hawaii, USA, 10 – 14 December 2018*. WCPFC15-2018-FinalCMR.

Annex 1 Satlink SeaTube system

In 2015, Satlink SL (Satlink, 2020), a Spanish company, was awarded the contract by FAO for both electronic monitoring trials in Fiji and Ghana, based on a competitive offer to cover all the technical requirements and conditions. This covered a full package including hardware, software, maintenance, services, and on-ground support.

The trademark name of the Satlink electronic monitoring system is the Satlink SeaTube system, which is a video recording (or still-image) solution. Videos are recorded at 1280 × 720 resolution at 24 frames per second (high-definition quality) and these data are stored locally, on board vessels, and on encrypted hard disk drives (HDDs). It is important to note that the data are not available in real time.

Real-time transmission of video data by satellite was too expensive at the time (and still is). Thus, HDDs were used to store and encrypt the data on board the vessels chosen and then retrieved/substituted when the vessels came to port.

The SeaTube system includes an independent vessel monitoring system (VMS) where Global Positioning System (GPS) positions are determined by Inmarsat identity provider equipment at prescribed time intervals. This GPS information is used to georeference the videos and to store the vessel's tracks for subsequent analysis.

The SeaTube is a sealed and tamper-resistant system.[1] It works automatically, independently of the vessel crew, and its functioning is monitored remotely by satellite. In this aspect, it is similar to the VMS that are already installed on many industrial vessels. While the SeaTube data recording system is tamper-resistant, the cameras, in particular, can be sabotaged, a feature that requires further improvements.

Integrated sensors can be linked to vessel equipment (e.g. on hydraulic winches) and programmed to trigger systems for the commencement and completion of recording. However, the solution used was to record continuously (24/7) without the need for the installation of sensors, starting when the vessel leaves port. This is the preferred solution proposed by Satlink, as it functions independently of vessel systems and avoids possible complications that arise when coupling the system to vessel hydraulics. This would also be able to monitor possible illegal activities that occur when not fishing (e.g. provisioning, transshipment and theft).

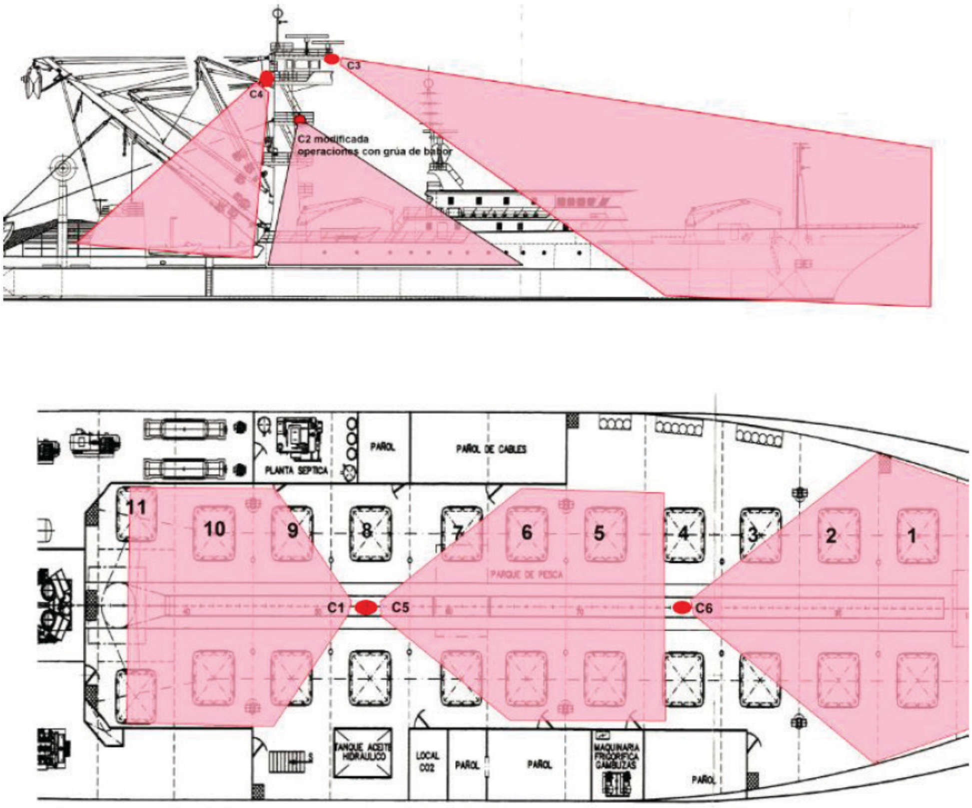
CAMERAS AND THEIR COVERAGE

The SeaTube system used in Ghana included six cameras to provide adequate coverage of the area above and below deck. Three cameras were positioned above deck: one facing forward to cover operations related to fish aggregating devices (FADs); one viewing the portside of the vessel to primarily identify the fishing set type as well as aid in assessing FAD-related activity; and one viewing the working deck to primarily estimate total catch and large bycatch (Figure A1.1). The other three cameras were placed below deck, covering different sections of the conveyor belt, primarily to estimate catch composition and small bycatch (Figures A1.1 and A1.2).

Cameras are protected from manipulation by being housed in securely fastened, weatherproof, dome housings. This, combined with the system health checks performed remotely, ensures the proper functioning and integrity of the system.

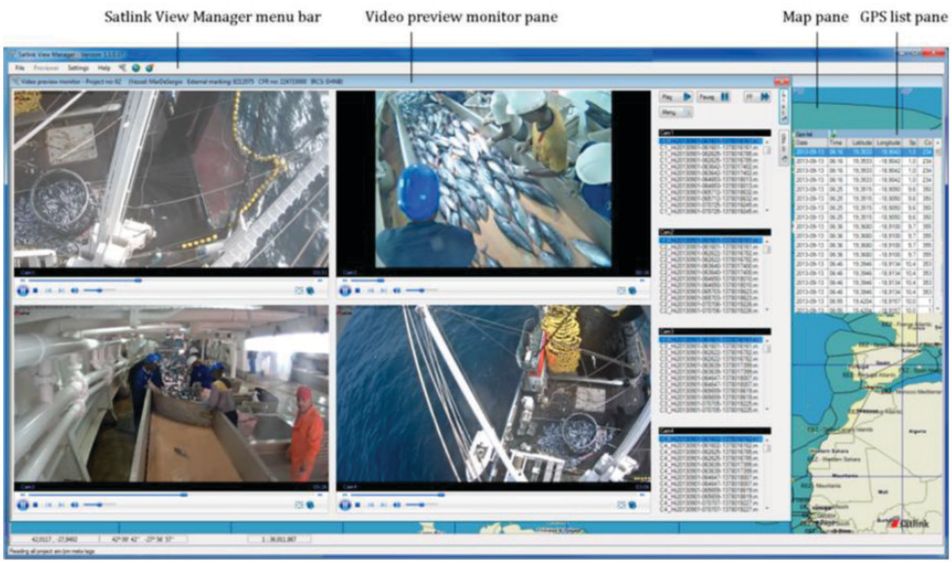
1 Or tamper-evident, in that when tampering or sabotage occurs, this can easily be detected.

FIGURE A1.1
Schematic view of camera configuration on a large purse seiner



Source: Satlink.

FIGURE A1.2
Examples of camera views as seen through the Satlink View Manager, the software developed for electronic monitoring data analysis



Source: Satlink.

MAINTENANCE AND SERVICES

The procurement contract between FAO and Satlink specified the need for local technical support to cover issues such as maintenance, malfunctioning equipment, replacements and other services. Satlink had a key role in implementing and supporting the electronic monitoring trial. This included maintenance of both onboard and onshore equipment, remote monitoring of the proper functioning of electronic monitoring equipment on board vessels (health statements), and training in the analysis of video footage (including software features and analysis protocols).

Satlink provided local support by hiring local technicians to carry out the day-to-day tasks. Services included regular retrieval and installation of HDDs with video footage, and regular systems checks to guarantee that the electronic monitoring system was functioning properly, which were carried out whenever the vessels came to port. This took place in the ports of Tema and Takoradi, the latter being the base of the Panofi fleet (six purse seiners). The checklist used was the following:

- The firmware or software is up-to-date in the electronic monitoring system.
- The cameras are properly focusing and pointing to designated areas.
- The HDDs are working properly.
- The VMS is working properly.
- The CAMS Repeater is working properly (refers to network connection of cameras).
- There is no damage on cables or power supply.
- The uninterrupted power supply is functioning correctly.

SeaTube has a built-in alarm and reporting service for the purpose of monitoring the functioning of equipment remotely. System health reports are automatically sent on a daily basis via satellite with information on videos created, memory consumed and backup memory remaining. There are also a number of other system health checks that are sent automatically if a problem is detected, such as:

- unreachable camera;
- unreachable identity provider;
- unreachable network video recorder;
- unreachable backup unit;
- camera not recording;
- GPS too old;
- metadata not updated in video footage;
- high number of videos not copied to backup;
- shutdown detected in the system;
- disk problems;
- low space on disks;
- user logged in to server.

The SeaTube system uses a number of features to ensure that it is tamper-resistant. The system is connected to a separate VMS unit that provides position, date, time, course and speed of the vessel. These data, along with the camera number and vessel identification, are simultaneously recorded and encrypted and embedded in the video prior to being sent to the HDD.

SEATUBE LITE: SPECIFICS RELATED TO THE FIJI TRIAL

The characteristics of the system used on longline vessels in Fiji were basically the same as those used in Ghana, although the system was more compact and in a three-camera configuration (hence, the name SeaTube Lite), instead of the six-camera configuration used on purse seine vessels in Ghana.

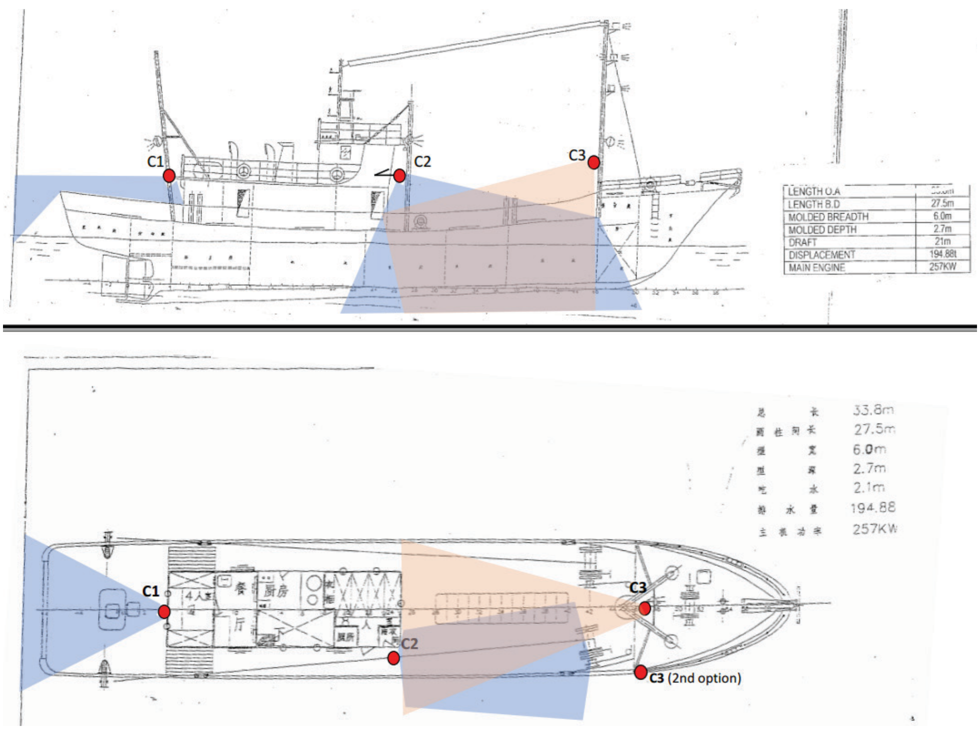
Hardware components on longline vessels were:

- an integrated computer and screen;
- HDD unit from Synology;
- a mounted GPS unit;
- HDDs;
- three cameras positioned at key points on the vessel to cover both setting and hauling operations;
- an uninterrupted power supply unit.

One camera was placed on the rear deck to monitor the setting process, while two cameras were placed on the front deck to monitor the hauling process. Figure A1.3 shows an overview of camera placement on the vessel. However, it quickly became clear that camera position C3 was not viable, as it was often obstructed by clothing and personal items, this being the resting area of crew members. C3 “2nd option” was also not a viable position, as sea spray often covered the camera’s field of view, making it blurry. The final option was to remove the camera from the C3 position and place it adjacent to C2 on the port side of the vessel. In this way, by angling the field of view of the camera inward towards the front deck area, it was possible to see the fish enter the “sea door” at a lower angle. This was important as it also assisted with the viewing of hooks being retrieved by the crew, thus assisting with the hook/float counting process.

There was a requirement for local technical support to cover issues such as maintenance, malfunctioning equipment, replacements and other services. In the case of Fiji, Satlink established an office locally in the port of Suva to provide adequate support for the installation of equipment and associated maintenance and services to the fishing fleet and to the national authority during the trial phase. The Satlink office had three staff, who were Satlink employees, and the costs of this in-country office support were offset by funding under the contract with FAO (as part of maintenance and services). It is generally recognized that this Satlink office was crucial to the success of the trial, avoiding some of the technical problems experienced by other trials in the Pacific. Apart from technical support, this office also enabled good communication among stakeholders. Satlink has benefited from this arrangement with a local base in Fiji, in that it also serves other business interests such as selling VMS, e-logs, communications and satellite buoys, and provides a base to serve other trials in the Pacific (albeit at a greater distance).

FIGURE A1.3
Schematic view of camera placement in Fijian longline vessels



Source: Ministry of Fisheries (Fiji).

Annex 2 Introduction to analysis of electronic monitoring data

There is currently strong interest in electronic monitoring, and significant efforts are taking place to advance the technology. One area that needs improvement is in the analysis of video/image footage, which is still a time-consuming process that needs to become more effective and efficient. It is important to bear in mind that, if electronic monitoring analysts were to review all footage in actual time, this would be equivalent to assigning one person full-time on each vessel, although the person would not actually be on board the vessel.

In order to reduce the time needed for analysis, in the Fiji and Ghana trials, electronic monitoring analysts were trained to focus on the time spent on setting and hauling the fishing gear, which is of much more interest, as opposed to the time spent on steaming to and back from or between fishing grounds. Training was given on interpreting the behaviour of the vessel using Global Positioning System (GPS) data on speed and course in order to rapidly identify the footage for further analysis. In this way, the electronic monitoring analysts used one working day to analyse four fishing days, on average, in the case of the Ghanaian purse seiners.

However, the nature of longline fishing is such that the setting and hauling process will take up most of the day and part of the night, resulting in many hours of footage for review. At the end of the trial, electronic monitoring analysts in Fiji could review two sets per day, or in other words, it took one working day to analyse two fishing days.

Significant technological advances are taking place, such as the use of artificial intelligence, machine learning and automated analysis, that are expected to reduce the time needed for analysis in the near future.[2] Some initiatives involve the analysis of GPS data to detect fishing events, or the analysis of footage to identify activity of potential interest, thus reducing the time of the footage to be reviewed. Various initiatives are ongoing on automating the analysis itself, such as species identification, counting and measuring (EM4Fish, 2020).

Satlink is one of the providers currently working on various improvements, but these were not available during the trials. Therefore, this introduction focuses on the approach and procedures used during the trials and the software developed by Satlink for the purpose of electronic monitoring data analysis, called Satlink View Manager (SVM). However, it is important to bear in mind that Satlink continues to develop the SVM, introducing new features and capabilities (Satlink, 2020).

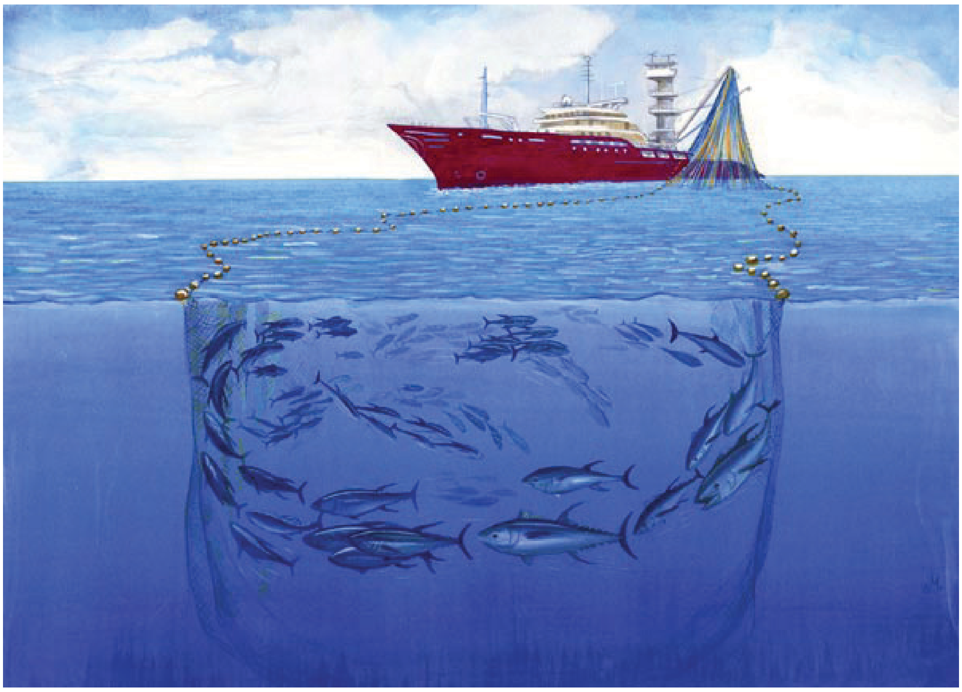
Before introducing the software, the following section starts by describing vessel behaviour based on GPS data. This will give an idea of how to predict when footage should be reviewed, and this is already a part of algorithms being used and developed for automated analysis.

TUNA PURSE SEINERS

Tuna purse seining involves surrounding tuna schools with a net, pursing the net by tightening the purse line at the bottom, and then hauling the net so that the fish are crowded and can be brailed out (Figure A2.1).

[2] See, for example, presentations by providers at the Seafood and Fisheries Emerging Technologies Conference (SAFET), 13–16 February 2019, Bangkok, Thailand (Seafood and Fisheries Emerging Technologies, 2020).

FIGURE A2.1
Industrial tuna vessel showing the purse seine to encircle tuna schools



Source: FAO, 2020c.

Tuna purse seiners use two different fishing modes or strategies: free-swimming schools versus logged schools under fish aggregating devices (FADs). Purse seine fishing is essentially a daylight activity, using a combination of visual detection cues and electronic equipment to find and track the tuna schools. However, about one-quarter of the daylight time at sea is used to cruise between fishing grounds or towards a FAD with a radio beacon or GPS locator.

A study of the French purse seine fleet defined three types of behaviour based on VMS data (Bez *et al.*, 2011):

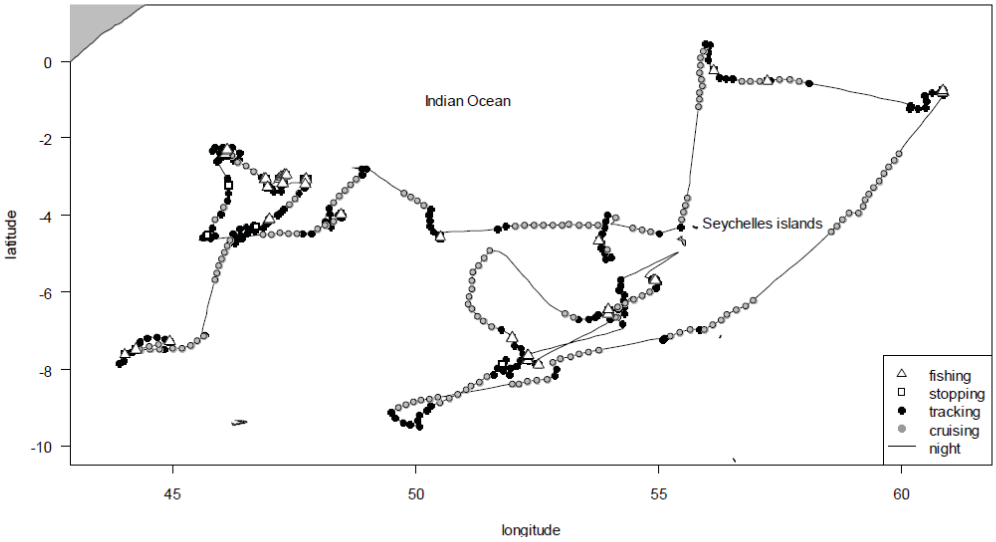
- Cruising: high vessel speeds (10–15 knots) and relatively straight course for movement towards or between fishing grounds or towards FADs.
- Tracking: trajectory of the vessel is more sinuous and hourly speeds are lower on average, although high instantaneous speeds occur, and turning angles vary greatly, depending on the detection of schools on both sides of the vessel.
- Fishing: the vessel remains still (i.e. immobile) to set the net and/or to observe the behaviour of a school prior to setting. In rare cases, this may be to repair engine breakdown, but this would normally be postponed until night, if possible.

Hence, these types of vessel behaviour were identified based on vessel speed and course (including turning angles). The time spent in each type of activity was estimated to be 24 percent in fishing, 49 percent in tracking, and 27 percent in cruising, the latter not including time spent navigating at night (Bez *et al.*, 2011).

The behaviour of a vessel before a fishing operation is a clue for the fishing mode selected. Sets on free-swimming schools are likely to be performed after a tracking phase. However, sets on FADs are likely to be performed after a cruising phase (Bez *et al.*, 2011). Figure A2.2 illustrates this, based on a model used for prediction.

In the Ghana trial, this type of information was used to identify when fishing was likely to be taking place. Figure A2.3 shows examples of trajectories, where the selected vessel positions (immobile) are marked red for further analysis. However, it should be noted that other activities may be taking place such as

FIGURE A2.2
Example of trajectory of a tuna purse seiner with the four activities estimated on daily VMS positions



Source: Walker *et al*., 2010.

FIGURE A2.3
Examples of trajectories of Ghanaian purse seiners from SVM

Source: Fisheries Commission (Ghana).

bunkering, FAD checking or deployment, and transshipment, which are then viewed in the footage.

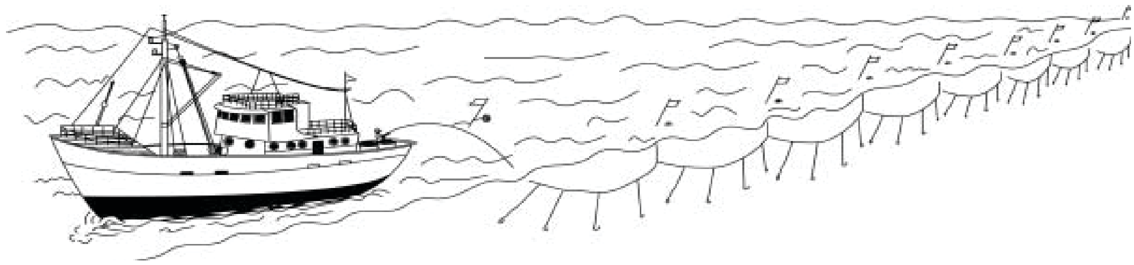
TUNA LONGLINERS

The following is based on Beverly, Chapman and Sokimi (2003), who present a detailed overview of longline fishing:

"Longline fishing uses a long mainline made of tarred rope or nylon monofilament to which are attached hundreds or thousands of branchlines, each with a single baited hook. The mainline can be from 5 to 100 nm long. The line is suspended in the water by floatlines attached to floats, which may have flagpoles, lights, or radio beacons. Longlines are usually set and hauled once daily and are allowed to drift freely, or soak, for several hours while fishing. Longlines are set, either by hand or mechanically, while the boat steams away from the line and are usually hauled mechanically while the boat steams toward the line. The species targeted are tunas and some billfish."

The normal procedure when fishing for tuna is to set the line early in the morning (04.00–08.00 hours) and start hauling in the afternoon (14.00–18.00 hours). If possible, the line is set while the vessel is moving with the wind, and the line is hauled going

FIGURE A2.4
Tuna vessel showing the longline deployed



Source: Beverly, Chapman and Sokimi, 2003.

against the wind. Several radio buoys are deployed together with the longline to keep track of the location of the longline (Figure A2.4). Usually, the last radio buoy out is the first radio buoy in, which gives the first hooks in the set a much longer soak time than the last hooks in the set, but it also gives the crew a chance to rest without having to backtrack to the first buoy (Beverly, Chapman and Sokimi, 2003). There are other procedures, such as backtracking, but the main reason for hauling the last buoy first is that this would follow the preferred practice of setting the line with the wind and hauling against the wind.

Depending on conditions at sea, the ideal practice is to set the line at an angle to the current. As the line is carried sideways by the current, the longline will cover a wide area of ocean and thus fish a larger area (Beverly, Chapman and Sokimi, 2003). Generally, the line is set in a straight pattern but an L-shaped pattern or a U- or horseshoe-shaped pattern is employed when accounting for wind, current and other conditions.

According to (Beverly, Chapman and Sokimi, 2003), a good average setting rate is considered to be 400 hooks per hour, so it would take 5 hours to set 2 000 hooks at a speed of 10 knots (about 50 m between hooks). However, Fijian longliners appear to set at a somewhat lower speed, depending on the vessel.

The speed of the boat and the speed of hauling the line have to be matched, which takes a good deal of coordination. A good hauling rate for monofilament gear is 200 hooks per hour, thus taking 10 hours to haul 2 000 hooks at that rate (at speeds of about 5 knots), but the rate is usually slower (up to double the time) because the line has to be stopped for fish and when problems are encountered (e.g. tangling of lines, and sea and weather conditions) (Beverly, Chapman and Sokimi, 2003). Fijian longliners will normally haul the line at a speed of 2–6 knots.

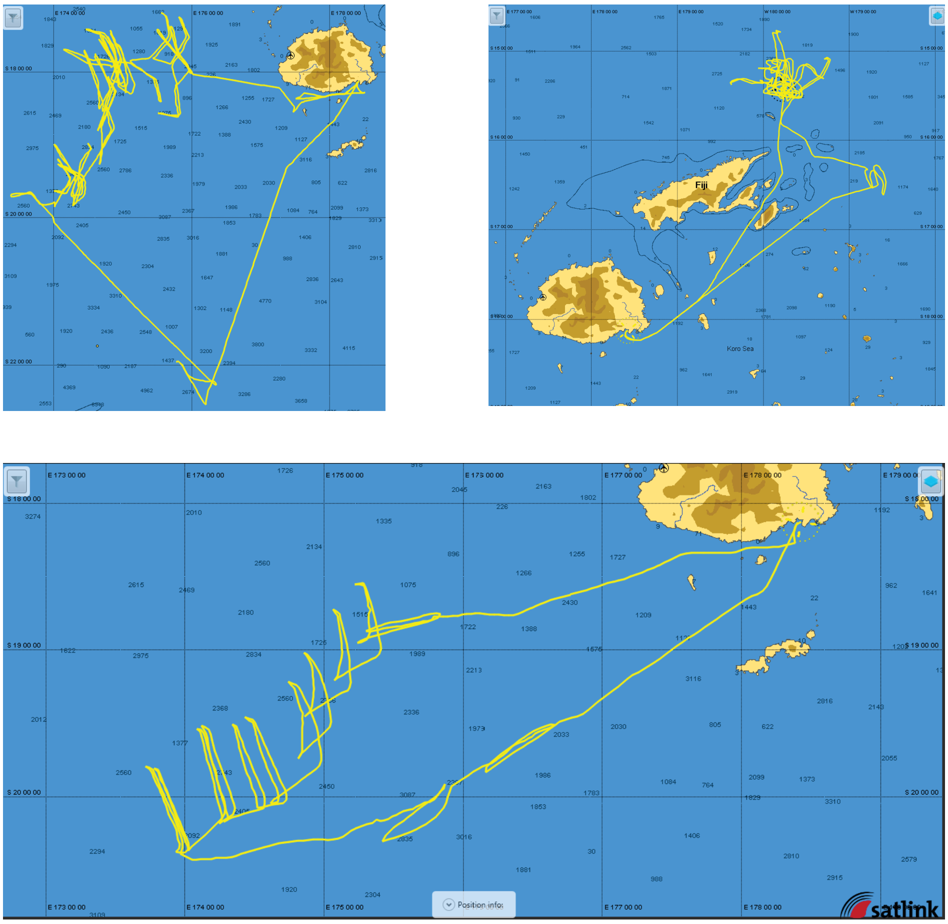
Figure A2.5 shows examples of trajectories of longliners during the trial carried out in Fiji. Based on the description above, it becomes straightforward to identify when the vessels are setting or hauling the line. This is observed when the vessel backtracks on its course, or when it takes a different course and then backtracks.

Introducing the Satlink View Manager

Satlink View Manager (SVM) is the proprietary software developed by Satlink for the review and analysis of electronic monitoring data obtained through its SeaTube system (Figure A2.6). The SVM software is a set of tools that includes:

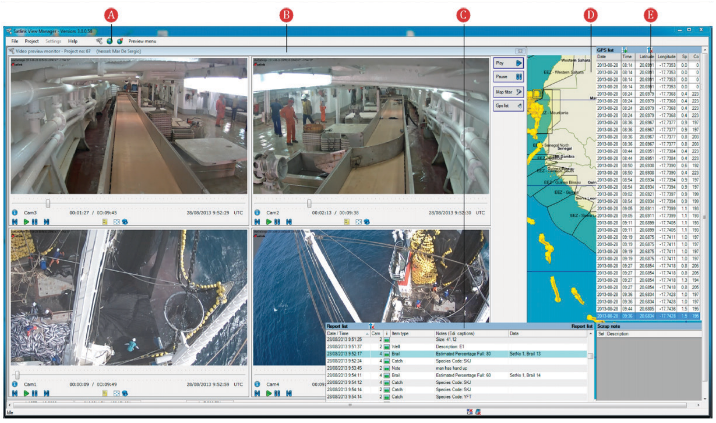
- global maritime charts integrated with exclusive economic zones (EEZs);
- mapping of vessel trajectories based on GPS data;
- video players showing all cameras simultaneously with the possibility of taking pictures, zooming, creating notes, etc.;
- resources for creating reports on fishing trips with relevant data such as species caught and other details with the possibility of adding pictures/video.

FIGURE A2.5
Examples of trajectories of Fijian longliners from the electronic monitoring trial 2015–19



Source: Ministry of Fisheries (Fiji).

FIGURE A2.6
Satlink View Manager screen layout



A: project menu bar; B: project video pane; C: project report list and scrap notes; D: project map pane; E: project GPS pane.
Source: Ministry of Fisheries (Fiji).

Satlink View Manager includes a number of panes that together form the screen layout of the programme:

- Map pane: the map pane will show the latitude and longitude of the vessel position as per information in the metadata of the video.
- GPS list: this includes a list of the latitude and longitude of vessel positions as per information in the metadata of the video.
- Filter: the filter pane exists in both the wizard mode and project mode. It allows the user to apply different filters, with the result being shown in the map pane in different colours.
- Video panes: this shows the videos from the first four cameras, out of a total maximum of eight cameras supported by Satlink SeaTube. In Ghana, a total of six cameras were installed on each vessel. In the case of Satlink SeaTube Lite used in Fiji, a total of three cameras were installed (out of a maximum of four cameras). There is synchronization of the videos and editing in project mode.

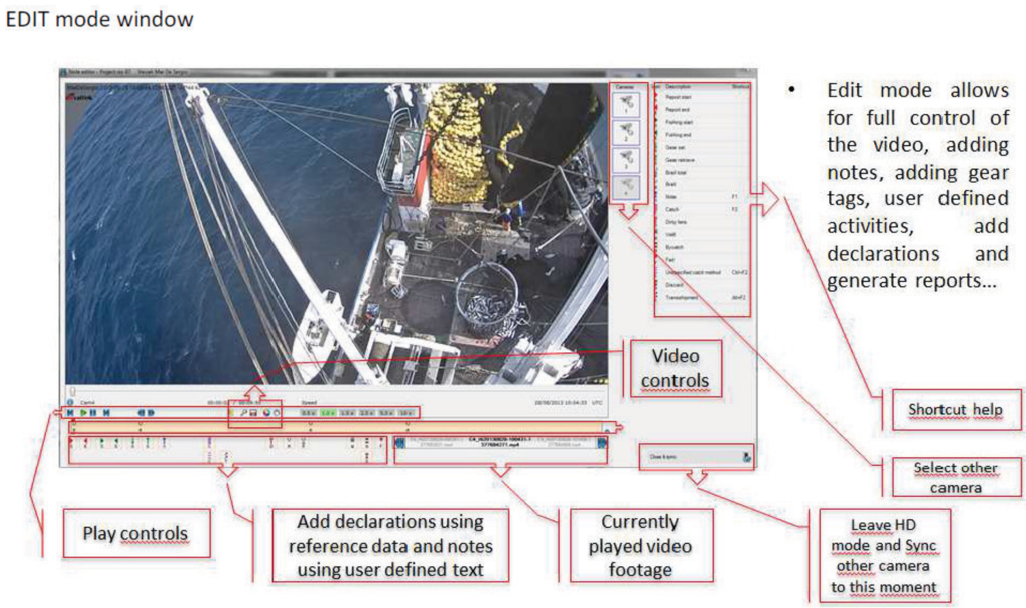
Satlink View Manager functions in two distinct modes. Wizard mode is used to scan through videos and identify periods of interest, using, for example, a filter based on GPS data. The purpose is to quickly identify "projects" for later detailed analysis in project mode. Project mode is used for detailed analysis of the videos, and for adding notes, declarations and other markers to generate inspection reports.

The filter feature can be applied to:

- select specific EEZ;
- select videos with vessel speeds (based on GPS data) within a specific range;
- select a specific time interval;
- manually select points.

Figure A2.7 illustrates how a report is generated as part of the video review process. There are controls for viewing the footage, buttons to add specific declarations, and shortcuts to define the report and its content in chronological order (Figure A2.8), and the possibility to generate inspection reports (Figure A2.9).

FIGURE A2.7
Overview of controls and functions to generate reports



Source: Satlink.

FIGURE A2.8
Example of a report list showing various declarations

Report list | **Report list**

Date / Time	Cam	i	Item type	Notes (Edi captions)	Data
				Size Of Fish Number Of Fish Sex Of Species Weight Of Fish Note:	
28/08/2013 9:46:12	4		Brail	Estimated Percentage Full: 60 Estimated Tonnage: 5 Note:	SetNo 1, Brail 11
28/08/2013 9:47:46	4		Catch	Species Code: SKJ Size Of Fish: 0,5 Number Of Fish Sex Of Species Weight Of Fish Note:	
28/08/2013 9:47:46	4		Brail	Estimated Percentage Full: 90 Estimated Tonnage: 7 Note:	SetNo 1, Brail 12
28/08/2013 9:51:25	2		Catch	Species Code: SKJ Size Of Fish: 41,12 Number Of Fish: 21 Sex Of Species: M Weight Of Fish: 10 Note:	
28/08/2013 9:51:25	2			21 Number of fish	
28/08/2013 9:51:25	2			Size: 41,12	
28/08/2013 9:52:17	4		Brail	Estimated Percentage Full: 80 Estimated Tonnage: 6 Note:	SetNo 1, Brail 13
28/08/2013 9:52:24	4		Catch	Species Code: SKJ Size Of Fish Number Of Fish Sex Of Species Weight Of Fish Note:	
28/08/2013 9:53:45	2		Note	man has hand up	
28/08/2013 9:54:11	4		Brail	Estimated Percentage Full: 60	SetNo 1, Brail 14

Note: Double-clicking on a note opens the corresponding video evidence.
Source: Satlink.

FIGURE A2.9
Example of a printable SVM inspection report

Satlink View Manager Report | Página 1 de 1

Inspection report | **JHE // Y // TST // DOMO // 18SEP**

Project no: 62 | Vessel: xxx xxx | External marking: xxx | IRCS: xxx | CFR no: | 2013-11-27 20:08:11

Project date interval: 2013-09-18 - 2013-09-18
Date/time filter: All dates/times
Zone filter: All zones
Speed filter: All speeds
Image filter: Showing date/time watermark and showing mini image

Report

Date (file)	UTC time (file)	Lat (dec)	Long (dec)	Speed	Course	File
2013-09-18	09:40:14	20,2094	-18,6959	0,3	0	Y:\C3_Hi\20130918AM\C3_Hi20130918-093653-1379497013.mp4

<Vesselname> 2013-09-18 09:42:48 20°12'34" -18°41'45"
(Camera watermark)

Normal Camera showing sorting of skipjack tuna

Date (file)	UTC time (file)	Lat (dec)	Long (dec)	Speed	Course	File
2013-09-18	09:40:59	20,2094	-18,6959	0	270	Y:\C1_Hi\20130918AM\C1_Hi20130918-093828-1379497108.mp4

<Vesselname> 2013-09-18 09:44:25 20°12'34" -18°41'45"
(Camera watermark)

Mast Camera showing unloading of fish

Date (file)	UTC time (file)	Lat (dec)	Long (dec)	Speed	Course	File
2013-09-18	09:42:44					Y:\C2_Hi\20130918AM\C2_Hi20130918-094207-1379497013.mp4

Source: Satlink.

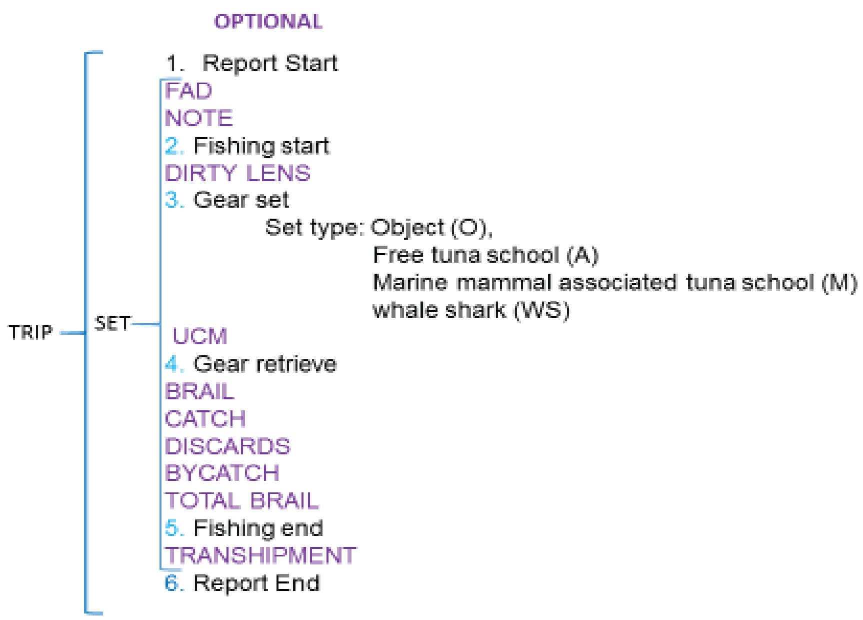
ANALYSIS PROTOCOLS

Report templates were developed for the trials in Ghana (Annex 3) and Fiji (Annex 4). These show the type of information prepared from the review of electronic monitoring data. This includes data on the fishing and related activity as well as compliance with relevant regulations, presented in aggregate form for each fishing trip. However, the review of the video footage consists of detailed analysis of events. The following gives a general idea of what this entails, but it is important to bear in mind that this can be simplified or intensified, depending on the objectives of the electronic monitoring programme to be implemented.

In the case of purse seiners, Figure A2.10 specifies the data that are recorded. All gear setting and hauling events are identified, and the time and position are recorded. The type of set is identified: free-swimming school; FADs; or other kind of drifts. The catch by species is estimated by counting the number of brails, their fullness and estimated weight. Notes are taken on bycatch, identifying as much as possible to species level, and the fate of the individuals (discarded, retained, gutted, etc.). Discards of tuna, including species and weight estimates, are also recorded.

In the case longliners, this is different because of the nature of the fishery. The analysis of the fishing event consists of recording details concerning the setting and hauling of the line, which is a process that spans many hours, and the fish are hauled in individually. In many cases, record-taking is facilitated using buttons, bearing in mind that time and location are registered automatically (Figure A2.11).

FIGURE A2.10
Overview of analysis protocol used for purse seine fishing in Ghana



Source: Satlink.

Longline vessel behaviour and gear setting have been described above, which gives an understanding of the data that are recorded. However, it should be noted that the following data are also recorded during the setting of the line:

- Hook counts from a sample of the gear – count every hook in the first ten baskets, another ten in the middle, and the last ten baskets. The term "basket" is defined as all the accoutrements between two floats. The branchline interval is estimated by counting seconds between hooks, and the average for each basket is calculated.
- Recording the floats that go overboard. At the end of the set (last radio buoy recorded), the total number of floats, hooks and baskets (Figure A2.12) can be calculated by pressing a button.
- Bait box recording includes bait species used and estimated box weight (in kilograms), which is totalled at the end.

FIGURE A2.11
Overview of analysis protocol for setting the line on longliners in Fiji

RESUME of SET ANALYSIS

(In button-pressing order)

1. Report start
2. Fishing star → meaning →Setting start
3. Float (usually x2 before hooks start being thrown)
4. Bait box
5. Hook — As many times as we need (items 4–6)
6. Float
7. Bait box total
8. Float total
9. Text note containing: branch line interval and pollution information
10. Text note with the "Setting end"

Items 1–10: **SETTING**

Source: Satlink.

FIGURE A2.12
Example of a line setting event

Yellow circle: setting floats; red circle: crew on the left attaches branch line to mainline, crew on the right baits hook and casts out to sea; white circle: bait box (saury/pilchard).
Source: Ministry of Fisheries (Fiji).

Hauling of the line can occur in two different ways, as described above: the last radio buoy out is the first radio buoy in; or backtracking to the first float deployed. This is recorded in order to calculate the real soak time for each hook. Figures A2.13 and A2.14 show the steps to be followed in the analysis. Note that each time a catch or bycatch species appears, a catch or bycatch declaration is recorded for each individual fish, including a size measurement. Moreover, the hook number is recorded for each catch or bycatch, which is done by counting hooks from the nearest float (counting from the closest clicked float icon). This was implemented by the SPC to determine catch by fishing depth. Figure A2.15 provides some example pictures to illustrate how specific events can be documented.

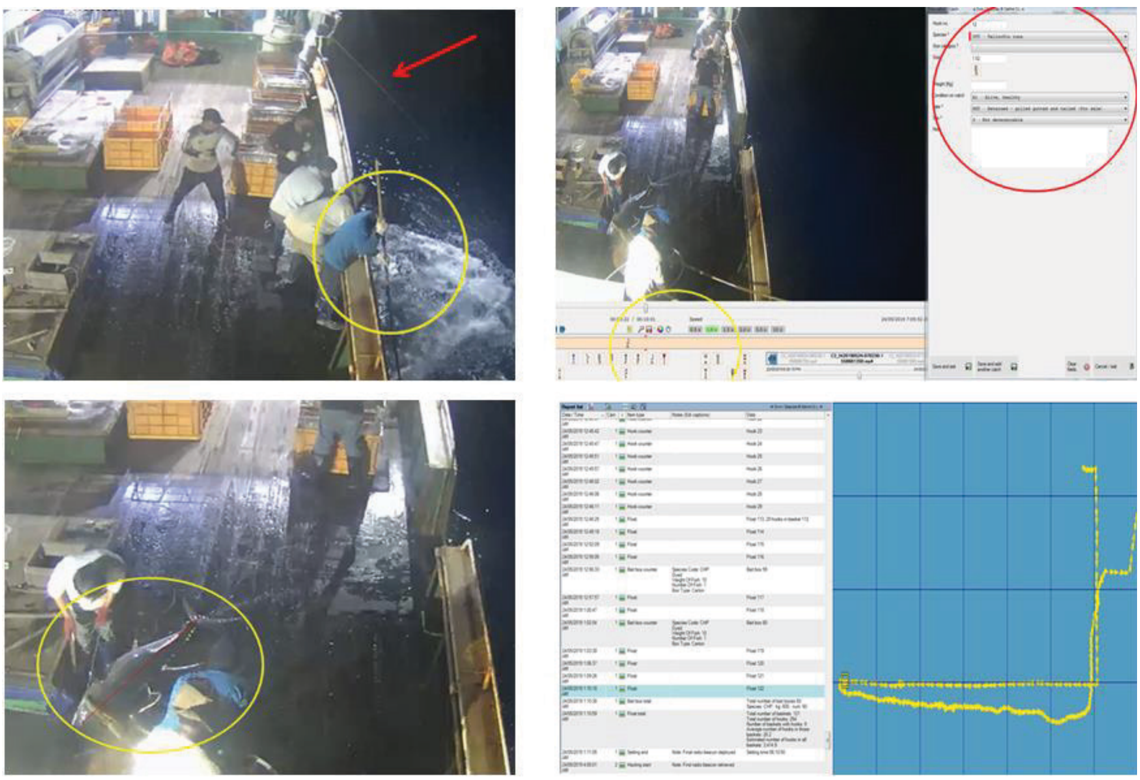
FIGURE A2.13
Overview of analysis protocol for hauling the line on longliners in Fiji

1. Gear set → meaning → Hauling start
2. Float
3. Catch / Bycatch
4. Text note declaring any strange maneuver or situation
5. Float total
6. Gear retrieve → meaning → Hauling End
7. Fishing end
8. Report end

HAULING

Source: Satlink.

FIGURE A2.14
Example of a hauling event: a) top left: hook counting (red line) and catch event (yellow circle); b) top right: hauling catch declaration (red circle); c) bottom left: catch measurement (yellow circle); and d) bottom right: report list and vessel track on set level



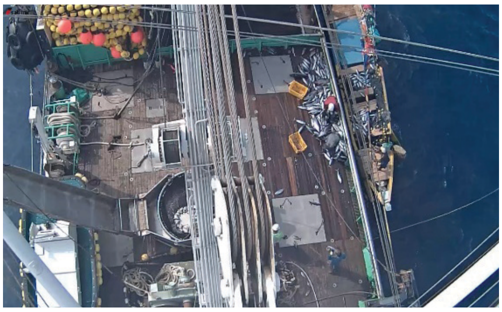
Source: Ministry of Fisheries (Fiji).

FIGURE A2.15
Example of photographs to document events – purse seiners


Bycatch of marlin being gutted, and some discards on deck
A whale shark was caught entangled in the net but was later released

Bycatch of a manta ray (dead)

Bycatch of a hammerhead shark



Offloading to a canoe

Discards of tuna

Source: Fisheries Commission (Ghana).

Annex 3 Report template developed for Ghana

EMS REVIEW – TRIP REPORT

Vessel name:	
Trip number:	
Reviewer:	

I. TRIP INFORMATION

Departure	date	
	port	
Arrival	date	
	port	

[Map of the trip]

II. REVIEW INFORMATION

HDD1	Serial number	
	Date loaded	
	Date retrieved	
HHD2	Serial number	
	Date loaded	
	Date retrieved	
HHD3	Serial number	
	Date loaded	
	Date retrieved	
HHD4	Serial number	
	Date loaded	
	Date retrieved	

Review	Starting date	
	End date	
	Land-based Observer	

III. EFFORT

a) Fishing days

Fishing days	
Non-fishing days	
Total days trip	

Comments:
if non fishing days, explain the reason (breakdown, bad weather, etc.)

b) Fishing sets

	Free School	FAD	Total
Positive Sets			
Null Sets			
TOTAL			

c) FADs

Nb. of FADs deployed	
Nb. Of FADs checked	
Nb. Of FADs collected	
Nb. Of FADs catch	
Nb. Of FADs catch & Collected	

IV. Estimated catch

a) Target species

	FS	FAD	TOTAL
SKJ			
YFT			
BET			
Other1			
Other2			
TOTAL			

b) Bycatch

Total bycatch species, retained or discarded)

	FS		FAD		TOTAL	
	Qtity	Unit (weight or number)	Qtity	Unit (weight or number)	Qtity	Unit (weight or number)
Species1						
Species2						
…						
TOTAL						

c) Discards

Quantities of target and bycatch species discarded

	Dead		Alive		Unknown	
	Qtity	Unit (weight or number)	Qtity	Unit (weight or number)	Qtity	Unit (weight or number)
Species1						
Species2						
…						
TOTAL						

V. Compliance with national and regional requirements

	Yes	No	Comments
ICCAT Rec. 04-10			
Full utilisation of sharks caught (excepting head, guts and skins)		√	
ICCAT Rec. 09-07			
Bigeye thresher caught		√	
Release of all bigeye thresher sharks caught unharmed			
Release of all other thresher sharks caught unharmed			
ICCAT Rec. 10-06 (*if Ghana is not reporting T1 data for shortfin mako*)			
Shortfin mako sharks (*Isurus oxyrinchus*) caught		√	
Release of all shortfin mako (*Isurus oxyrinchus*) caught unharmed			
ICCAT Rec. 10-07			
Oceanic whitetip sharks (*Carcharhinus longimanus*) caught		√	
Release of all oceanic whitetip (*Carcharhinus longimanus*) sharks caught unharmed			
ICCAT Rec. 10-08			
Hammerhead sharks (*Sphyrnidae*) caught		√	
Release of all harmmerhead sharks (*Sphyrnidae*) caught		√	
ICCAT Rec. 10-09			
Encirclement of marine turtles			
Release of marine turtles unharmed			
ICCAT Rec.10-10			
Observer on board during the trip	√		
ICCAT Rec. 11-08			
Silky sharks (*Carcharhinus falciformis*) caught	√		
Release of all silky sharks (*Carcharhinus falciformis*) caught unharmed	√		
ICCAT Rec. 12-06			
Transhipment at sea		√	
ICCAT Rec. 14-01			
– Activities in area/time closure		√	
– Launch of floating object in area/time closure		√	
– Fishing around object, including vessel in area/time closure		√	
– Fishing around logs, in area/time closure		√	
– Towing objects from inside to outside the area-time closure		√	
– Observer on-board when engaged in fishing activities during the time/area closure			
– Use of non-entangling FADs		√	
Fisheries ACT 625 (Amend.) ACT 2014 & Fisheries Regulations 2010 (L.I.1968)			
Fishing without licence, authorisation, permit		√	
Fishing in a closed area		√	
Use prohibited or non-compliant fishing gear		√	
Taken on board, transhipped or landed undersized fish		√	
Polluted fishing waters		√	
Dumped fish into the sea	√		
Endangered species caught	√		

Annex 4 Report template developed for Fiji

EMS REVIEW – TRIP REPORT

This report is prepared based on the review by the Department of Fisheries of data collected through electronic monitoring system.

Vessel name:	
Trip number:	
Reviewer:	

I. TRIP INFORMATION

	Date	Port
Trip start	*dd/mm/yyy*	
Trip end	*dd/mm/yyy*	
Trip duration (days)		

Insert Map of the trip

II. REVIEW INFORMATION

	S/N	Date loaded	Date retrieved
HDD1		*dd/mm/yyy*	*dd/mm/yyy*
HDD2		*dd/mm/yyy*	*dd/mm/yyy*

	Date
Review start	*dd/mm/yyy*
Review end	*dd/mm/yyy*
Review duration (days)	

Comments:

Please describe any issue with the electronic monitoring system identified during the review. For example, camera offline not allowing data to be recorded, camera out of focus, camera being covered, etc… Please list these events with the details of the date and time, and if possible location.

III. ESTIMATED FISHING EFFORT

a) Fishing days

Fishing days	
Non-fishing days	
Total days trip	

Comments:
If non fishing days, explain the reason (breakdown, bad weather, etc.)

b) Fishing sets

Total number of hooks is estimated by counting the number of hooks between floats for the first 3 baskets, 3 baskets in the middle and the last 3 baskets.

	Total
Number of sets	
Number of hooks	

IV. ESTIMATED CATCH

Catch estimation is done by monitoring the complete hauling of the line and counting individual animal caught.

a) Target species

	Quantity (Number)
ALB	
YFT	
BET	
Other 1	
Other 2	
…	

b) Bycatch (retained)

	RGG	RGT	RWW	RHG	RSD	RGO	ROR
Species 1							
Species 2							
…							

RGG: Retained gilled and gutted
RGT: Retained gilled, gutted and tailed
RWW: Retained whole
RHG: Retained headed and gutted (Billfish)
RSD: Retained by shark damaged
RGO: Retained gutted only
ROR: Retained other reason

c) Discards

	DPA	DPD	DPU	DSD	DWD	DUS	DDL	DSO	DCF	DTS
Species 1										
Species 2										
...										

DPA: Discarded alive
DPD: Discarded dead
DPU: Discarded unknown condition
DSD: Discarded shark damage
DWD: Discarded whale damage
DUS: Uneconomic species
DDL: Too difficult to land
DSO: Struck off close
DCF: Cut free or far
DTS: Too small

V. Compliance with national and regional requirements

Verify the below compliance issue. If non-compliance issues are identified provide precise date and time, and if possible positions in the Comments column

WCPFC CMM	Yes	No	Comments
2007-01 CMM for the Regional Observer Programme			
Observer onboard			Observer Name:
2008-03 CM of sea turtles			
Sea turtle caught			Details on number and species
Release of all sea turtles unharmed and following best practices (include used of line cutter and dehooker)			
2009-06 CMM on the regulation of transhipments			
Transhipment at sea			Provide details on transhipment activities (date, vessel, species, quantities) if any:
2011-04 CMM for oceanic whitetip shark			
Oceanic whitetip sharks (*Carcharhinus longimanus*) caught			Provide details on numbers
Release of all oceanic whitetip (*Carcharhinus longimanus*) sharks caught unharmed			
2013-08 CMM for oceanic whitetip shark			
Silky sharks (*Carcharhinus falciformis*) caught			Provide details on numbers
Release of all silky sharks (*Carcharhinus falciformis*) caught unharmed			
WCPFC 2014-05 CMM for sharks			
Vessel used wire trace as branch line or leaders			
Vessel used branch lines running directly off the longline floats or drop lines, known as shark lines			
WCPFC 2015-03 CMM to mitigate the impact of fishing for highly migratory fish stocks on seabirds			
Vessel fished South of 30°S			
Vessel used at least two of these three measures during all fishing sets: • weighted branch lines • night setting • tori lines during sets South of 30°S.			

Offshore Fisheries Decree			
Has the vessel fished in the fisheries waters of another State			
Has the vessel fished in the high seas			
Has the vessel used trace wire (shark lines)			
Transhipment at sea			
Bunkering at sea			
Provisioning at sea			

MARPOL Regulations			
Has the vessel discarded any form of plastics into the sea at anytime			
Has the vessel discarded any form of oil into the sea at anytime			
Has the vessel dump any form of rubbish into the sea within 12 nm of the seashore			

Illegal, unreported and unregulated (IUU) fishing is a serious threat to sustainable fisheries, marine ecosystems and the livelihoods of legitimate fishers globally. To address it, the Common Oceans ABNJ Tuna Project is exploring ways to strengthen and harmonize the use of monitoring, control and surveillance tools, and combat IUU fishing in tuna fisheries across the marine areas beyond national jurisdiction. One tool is the use of electronic monitoring systems to monitor individual vessel operations at sea. In a typical electronic monitoring application, cameras, recording video or still images, are deployed at key points on the vessel to allow a view of the fishing operation. The video footage is stored on hard drives that government officials can use to review compliance with regulations, as well as record detailed data on catch and effort. It was envisaged that industry would have access to these data for its own operational purposes. To test the best way to incorporate this technology as a complementary compliance tool, two pilot trials were set up: one in Ghana to cover the domestic tuna purse seine fleet fishing; and one in Fiji to cover the domestic longline fisheries. Close collaboration was established between national governments and industry for implementation. The overall aim of the pilots was to develop an effective implementation process at the national level, so that the information could be properly utilized for compliance purposes. This report documents the successful completion of these trials, and the lessons learned that could benefit electronic monitoring programmes elsewhere.

ISBN 978-92-5-133847-6 ISSN 2070-7010

9 789251 338476

CB2862EN/1/02.21