Electronic Monitoring for control on fishing vessels

Authors: A.T.M van Helmond, R.W.T. Smith, I. H. T. Harkes

Wageningen University & Research
report C001/22

WAGENINGEN
UNIVERSITY & RESEARCH

Electronic Monitoring for control on fishing vessels

Authors: A.T.M van Helmond, R.W.T. Smith, I. H. T. Harkes

Wageningen Marine Research

This research project was carried out by Wageningen Marine Research and subsidized by the ministry of Agriculture, Nature and Food Quality for the purposes of Policy Support Research Theme 'Visserij Monitoring' (project no. BO-43-119.01-021).

Wageningen Marine Research
IJmuiden, December 2021

Wageningen Marine Research report C001/22

Client: The ministry of Agriculture, Nature and Food Quality
Attn.: mr. C.C. Nijenhuis
Bezuidenhoutseweg 73
2594 AC The Hague

This report can be downloaded for free from https://doi.org/10.18174/561838

Wageningen Marine Research provides no printed copies of reports

Wageningen Marine Research is ISO 9001:2015 certified.

Wageningen Marine Research, an institute within the legal entity Stichting Wageningen Research (a foundation under Dutch private law) represented by
Drs.ir. M.T. van Manen, Director Operations

KvK nr. 09098104,
WMR BTW nr. NL 8113.83.696.B16.
Code BIC/SWIFT address: RABONL2U
IBAN code: NL 73 RABO 0373599285

A_4_3_2 V32 (2021)

Contents

1 Summary

This study evaluates the potential of Electronic Monitoring (EM) to monitor compliance in the Dutch bottom trawl fishery, which, eventually, can be used as a guideline for further preparation of an EM pilot in Dutch fisheries. Within this context the feasibility of EM to monitor compliance of the landing obligation (LO) in Dutch bottom trawl fisheries is analysed considering technical, practical and financial requirements for control purposes and the ability of EM to completely document the catch, including discards, as stated on under the LO. In addition, the social aspects around the implementation of EM are described: the negative perception of EM by many fishers and the options that facilitate its uptake by the fishing industry.

A detailed review of the technical standards as described by the European Fisheries Control Agency (EFCA) and comparison with EM setups used during scientific trails points out that several technical standards can be considered as control specific. Technical applications on remote access, data back-up, data storage and transfer, camera positioning system diagnostics, drafting vessel monitoring plans and data exchange formats should be considered when implementing EM for LO control purposes. The estimated total budget needed for fleetwide implementation for EM on the current Dutch beam trawler fleet, approximately 105 vessels, is estimated at 1.2 million euro to set up an EM programme and 1.9 million euro for annual running costs.

The efficiency of EM to register catch very much depends on the type of fishery and catch, e.g. species and catch composition. EM preforms better when catches are processed in such a manner that it is easy to detect individual fish on video footage. This depends on the type of fisheries, e.g. hook and line fisheries, or the monitoring objectives, i.e. specimens of a particular species, are easily spotted in the catch. Results of previous studies showed that EM is less efficient in detecting smaller specimens, e.g. undersized and discarded fish. Occlusions of fish and other organic material on the sorting belt were the main reason for structural underestimation of the discarded catch. Manual review of EM video data is perceived as a highly labour intensive and time consuming task. Implementation of protocols to increase visibility of discards improves efficiency of EM, but it comes with a cost. The estimated extra time needed to conduct a protocol to better display discarded catch in front of the cameras would exceed 12 hours per fishing trip. Computer vision technology will reduce time and manual labour currently needed for EM video review and decreases the level of dependency in discard recording of fishers for control purposes.

In order to successfully implement EM, it is important that the fishing industry supports and accepts the tool as beneficial. Currently there is a sense of distrust and resistance on behalf of a large part of the fishing fleet. The incentives offered for fishers to participate in previous, more scientific orientated, EM trials were direct and consisted of individual quota uplifts, direct payments, increased days at sea, access to closed areas and increased flexibility in gear choice. However, in order to roll out EM over the entire Dutch (and European) fleet, a more intrinsic motivation is required. This can be fuelled by indirect incentives, such as increased market access though eco-labelling, but also by experiencing the advantages in terms of better fishing opportunities or healthy fisheries, because, EM provides better data for improved fisheries management. A first step in creating support is to involve the fishers in the process of planning and implementation. Managers, fishers, scientists, IT specialists and other relevant parties need to discuss the concerns of the parties involved, such as privacy, data security, data ownership, and information provision. The discussions are also an opportunity to manage expectations and to help build trust and confidence. The establishment of a multi-stakeholder group including industry representatives and experts could facilitate this process.

Implementation of EM on a large scale requires a substantial investment. EM generates a significant amount of (video) data, and needs an infrastructure that supports data transfer, storage, and review facilities. Development of computer vision technology to support the EM implementation process is recommended, the technology reduces time, costs and manual review needed and enhances the recording of discards under the LO.

2 Introduction

In January 2019, the phased implementation of the landing obligation (LO), part of the reformed Common Fisheries Policy (CFP), was completed for all European fisheries. Implementing the LO requires that the complete catch (landings and discards) of species under quota regulations needs to be landed, reported and deducted from the available quota. Without accurate methods to register all catches, sustainability of fisheries may be hampered as unobserved catches cause fishing mortality to exceed limits set by quotas (Daan, 1997; Crowder & Murawski, 1998; Batsleer et al., 2015). Therefore, reliable methods to accurately record catches on board commercial fishing vessels are of crucial importance for the implementation of the LO.

Article 15 of the 2013 CFP states that: For the purpose of monitoring compliance with the LO, EU Member States shall ensure detailed and accurate documentation of all fishing trips and adequate capacity and means. In doing so, Member States shall respect the principle of efficiency and proportionality (EU Regulation No 1380/2013). However, the conventional control methods, such as at-sea surveillance and dock side monitoring, are not considered sufficient tools to create the constant surveillance necessary to monitor compliance under the LO, certainly not with respect to the principle of efficiency and proportionality. Monitoring all fishing activity and catch with onboard observers will lead to exorbitant costs (Needle et al., 2015; van Helmond et al., 2020)

Electronic monitoring (EM) is often presented as one of the solutions to monitor fisheries in the context of the implementation of the LO (Kindt-Larsen et al., 2011; Mangi et al., 2013; Msomphora and Aanesen, 2015; Needle et al., 2015; Ulrich et al., 2015; van Helmond et al., 2015). A computer system on board of a vessel provides the ability to fully document fishing operations and catches, through automated recording of fishing activity by sensors and complete catch registration by a digital camera system. Within this context, the Scheveningen Control Expert Group (CEG) presented a template for a possible regional EM pilot project in the North Sea to the Scheveningen High Level Group (HLG). The Scheveningen HLG endorsed this template and mandated the Scheveningen CEG supported by EFCA to continue preparing the joint regional pilot project on EM. The overall aim of the pilot project is to develop a draft operational plan and gaining experience when monitoring compliance with the LO in EU fisheries in the North Sea.

In the Netherlands, a feasibility study was conducted on the Dutch pelagic fisheries in 2015. This study demonstrates that EM was successful in cost-effectively monitoring large amounts of fishing activity (Bryan, 2015). However, several EM pilot studies on demersal mixed fisheries (bottom trawl) indicated a limited efficiency of EM to accurately register smaller juvenile individuals, e.g. discarded and/or unwanted catch (van Helmond et al., 2015; Ulrich et al. 2015; Mortensen et al., 2017; van Helmond et al., 2017). Therefore, the efficiency of EM in the context of control purposes, i.e. to monitor fleet wide compliance under the LO for the wide variety of fisheries in European waters, remains unclear. Also, in case EM should be implemented on a larger scale, i.e. national, regional or European level, more detail on the practical and financial requirements is needed, e.g. data transfer, data storage, IT infrastructure. In addition, the low level of acceptance of the fishing industry to introduce EM as control measure could severely hinder the implementation process of EM.

To accommodate these queries and to prepare formulating a draft operational plan for monitoring compliance with the LO for the Netherlands, the Ministry of Agriculture, Nature and Food Quality (LNV), requested Wageningen Marine Research (WMR) to conduct a feasibility study on the proposed joint regional pilot project on EM as endorsed by the Scheveningen HLG.

This study evaluates the potential of EM to monitor compliance in demersal mixed fisheries, which, eventually, can be used as a guideline for further preparation of an EM pilot in Dutch bottom trawl fisheries.

The objective of this study **is to estimate the feasibility of EM to monitor compliance of the LO in Dutch bottom trawl fisheries.**

The following sub-questions were defined:

- What technical requirements are needed to use EM as a control tool under the LO?

It can be assumed that all technical requirements can be met by standard EM systems. However, several technical applications and standards can be considered as control specific and should be taken into account when implementing EM for control purposes of the LO. The detailed specifications are described in **chapter 3**.

- What are the practical and financial requirements for a fleet wide implementation?

Chapter 4 provides an overview on practical and financial requirements such as start-up costs, running costs, implementation of data review, data storage and transfer. This includes an estimation of costs for a fleet wide implementation of EM.

- How efficient is EM in monitoring the complete catch under the LO?

The efficiency of EM to register catch very much depends on the type of fishery and catch composition, e.g. species and length composition. EM performs better when catches are processed in such a manner that it is easy to detect individual fish on video footage. **Chapter 5** describes the effectiveness of EM for the Dutch demersal fisheries and possibilities to improve the EM efficiency.

- How can the uptake of EM by the fishing industry be facilitated?

In general, EM is a government driven introduction to improve accountability of catches, often for control purposes. Frequently this is met with a sense of distrust and resistance of fishers against EM. **Chapter 6** discusses the potential to facilitate the uptake of EM by the fishing industry.

3 Technical requirements

KEY FINDINGS

- EM is a cost-efficient monitoring tool, that allows for 100% coverage of a vessel’s fishing activity and the monitoring of all catches using (digital) video recording.
- Several technical applications and standards can be considered as control specific and should be taken into account when implementing EM for control purposes of the LO: remote access; data back-up, storage and transfer; camera positioning; system diagnostics; vessel monitoring plan; and data exchange formats.

3.1 The Electronic Monitoring system

Since the beginning of the 21st century, electronic monitoring (EM), also commonly referred to as remote electronic monitoring (REM), has emerged as a cost-efficient monitoring tool for commercial fisheries.EM systems typically consist of GPS, cameras, and sensors for measuring force on the tow cables or net drum rotation, all connected to a control box (Figure 1) (McElderry et al., 2003). These systems allow 100% coverage of a vessel’s fishing activity and the monitoring of all catches using (digital) video recording (Ames et al., 2007; Kindt-Larsen et al., 2011; Stanley et al., 2011).

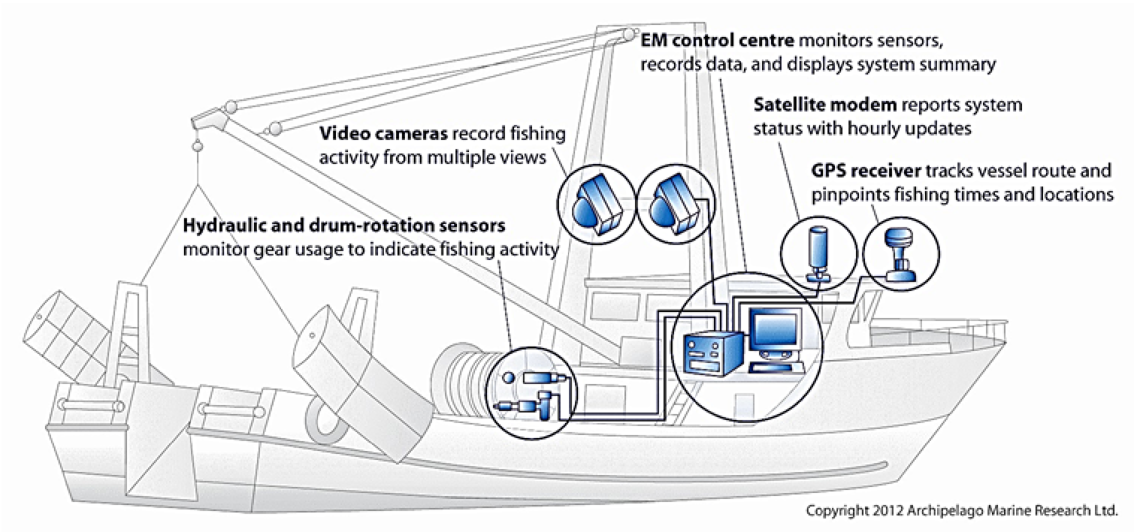

Figure 1. *Overview of a standard electronic monitoring system set-up.*

3.2 Requirements for control purposes

The Technical guidelines and specifications for the implementation of Remote Electronic Monitoring (REM) in EU fisheries (EFCA, 2019) describes the minimal requirements and standards needed for EM systems to be used for monitoring compliance with the LO under the CFP. The document is meant as a guidance for Member States authorities, i.e. control agencies, to implement EM on vessels for monitoring and controlling LO provisions.
In general, the European Fisheries Control Agency (EFCA) describes a similar system set up used on vessels during the EM pilot in European fisheries as described in van Helmond et al. (2020). An EM system should consist of a control box (modified computer) connected to a number of sensors to detect fishing activity, and cameras to record video footage of the catch. Data storage is embedded in the system and all information should be displayed on a screen on board the vessel.

Seemingly, all technical requirements can be met by standard EM systems produced by the common EM providers (www.EM4fish.com). However, several technical applications and standards, as described by EFCA (2019), can be considered as control specific and should be taken into account when implementing EM for control purposes of the LO:

- Remote access. Remote access of EM systems is considered to be an important requirement for control purposes. EM systems should allow distant access through utilization of on-board satellite connection for system configuration, verification of system health and data transmission if required. In case of video recording, the system should allow for remote configuration of frames per second, image resolution, image quality, digital and optical zoom. In addition, on board configuration should be secured and any changes should be logged/registered.

- Data back-up, transfer and storage. Uninterruptible power supply of controlled shut down and continuation of recording of a relevant time span (e.g. 10 minutes). Information on any power failure should be automatically recorded. Use of existing onboard satellite connection for data transfer should be facilitated. For vessels only fishing within cell phone range, e.g. small-scale coastal fisheries, 4G can be used for data transmission. In addition, there should be the possibility to have a wireless option for uploading data from vessel to land-based system, e.g. via WIFI points in harbour. Sensor data and video footage should be properly encrypted and compressed before sending. In addition, transferred data should contain a digital signature describing data and time, vessel name, vessel registration code and GPS coordinates. If data transmission is temporally not possible, the request should be stored onboard and the requested data shall be secured to prevent possible deletion or tampering. Manual retrieving of data from vessels, e.g. collecting hard drives from all vessels at regular intervals, is not considered a sustainable solution. Privacy and data protection legislation should need to comply with the EU General Data Protection Regulation standards. Furthermore, a minimum and maximum period for data storage, both sensor and video, should be specified by the flag state competent authority.

- Camera positioning to ensure an optimal view on the complete catch. Cameras (and housing) should resist the harsh environment on board fishing vessels. e.g. saltwater, moving environment. To guarantee good quality footage, high-resolution cameras should be prioritized. The prescribed camera setup should capture the following views, requiring one or more cameras for each view depending on the vessel: 1) the fishing deck, 2) general overview of the fish handling/processing area, 3) sorting belt/table, 4) discard area(s), 5) view on the hauling of the net. When installing the camera, the following parameters should be considered: 1) distance of the camera to the object/ focus area, 2) aperture and focal length of the lens, and 3) the resolution. For the deck overview and discard area, the setup should facilitate the identification of the legality of a discard activity, also in low natural light conditions, possibly achieved by infrared lighting or automated illumination of viewed areas, e.g. motion sensor triggered.

- System diagnostics. A self-test function should be incorporated in the EM system to ensure complete functionality before leaving the port. A standard test should include a position check, memory status check, camera check and sensor check. The system must record and store test results and alert skipper/fishers in case of malfunction. Rules and protocol need to be established is case of EM system impairment.

- Vessel Monitoring Plan (VMP). To ensure all monitoring requirements are covered and to optimize the quality of the data a VMP should be made for all vessels. The VMP should contain a layout of the EM system on board, including camera positions, prioritizing an optimal view of the discard area. Some areas require continuous recording during the fishing trip, e.g. designated discard areas and other identified infringement prone areas on the vessel. Other cameras only record during certain processes, e.g. net hauling. When the EM system is installed the flag state competent authority shall approve the VMP (and EM system) before the vessel is authorized to start its fishing activities. Any physical changes of the EM setup should be recorded in the updated VMP and the competent authority need to be notified.

- Data formats. EM systems have to facilitate data distribution, both sensor and video information, in a specified common format. All information should be able to be analysed by any EM analyser software, i.e. data received from the different EM systems need to be processed using EM analyser software from a provider even though the data are collected by a system from another provider.

4 Practical and financial requirements

KEY FINDINGS

- EM costs consists of different elements: onboard hard- software, maintenance, IT facilities (e.g. data transfer and storage) and data review.
- Regular rewinding and pausing the video footage during manual video review when identifying all the individual fish, makes video review a labour intensive and time consuming task.
- Total costs for fleetwide implementation for Dutch beam trawlers are estimated at, ~1.2 million euro for implementation and ~1.9 million for annual running expenses.

4.1 EM costs

Depending on different factors, e.g. minimum audit coverage, method used for video review, vessel specifications, fishing operations, fishing area, video quality, how- and how long data is stored, the costs for EM can vary considerately (Plet-Hansen et al., 2019). To get an overview of the costs for this study, EM is divided in four different components: the EM-system on board, the hard- and software used for the video review, data storage and data transfer and salaries (e.g. review, support, management and communication).

4.1.1 EM-system

The general set-up used during scientific EM trials, including the ongoing Fully Documented Fisheries project on Dutch beam trawlers, consists of: 5 cameras (2 megapixel), winch or hopper sensor(s), GPS and GSM antennas, control unit (onboard computer) and a touch screen with keyboard. For the use of the system an annual license is required. In addition to the costs for the EM-system there are costs for the installation and maintenance of the EM-system on board.

4.1.2 Hard- and software

Specific analyzer software is required for the purpose of reviewing video data on a video audit computer. For the use of the analyzer software a user license is required. A license is initially for one user only but can be expended to multiple users for additional costs. Some EM providers provide the option for an unlimited amount of users (EFCA, 2019). For the use of the analyzer software specific training is required.

4.1.3 Data storage and transfer

The transfer of the collected video and sensor data on board to a server for data storage is done by using a 3G/4G network. As soon as a vessel is within coverage of a mobile network data can be downloaded on to the server. The mobile data required for downloading video data can be used via a sim card provided by a standard 3G/4G network provider. The time it takes to download video footage can vary depending on network coverage in the port where a vessel is docked. Experience with EM-equipped Dutch vessels demonstrate that the time between two consecutive fishing trips, usually around 3 days but can be as short as 5 hours, is enough to download the video footage of the sorting process of six hauls.

Besides using a 3G/4G network there is the possibility of using a satellite connection for data transfer, as recommended by EFCA (2019). A satellite connection is not dependent on network coverage. However, using a satellite connection for data transfer is a more expensive.
Storage of downloaded data requires a server. Storage capacity depends on the quality requirements of the video data for video review (Plet Hansen et al., 2019). Server space can be hired for the necessary amount of data storage by the usual IT service providers.
When a vessel is within network coverage, e.g. in the harbour, video data can be downloaded onto a server. If 4G roaming is enabled on the system on board and with the sim card provider, downloading data is possible within the EU. Downloading video data outside of the EU is dependent on the sim card provider and the settings for the use of the mobile data. A limiting factor for the transmission of video data is the quality of the network coverage, which in some ports can be poor (e.g. Eemshaven). Another limiting factor is the time vessels spend within network coverage (port time) (Plet-Hansen et al., 2019). Alternatively, but more time consuming and, therefore, expensive, manual replacement of removeable hard drives is used when vessels are in the harbour. Still used in areas with poor network coverage (van Helmond et al., 2020).

Table 1. *Financial specifications of EM.*

Costs	Once	Annually
Vessel		
Complete EM-system incl. one year license and firmware updates	7000	
Installation	4027	
Maintenance		1119
EM software license		250
Video review		
Blackbox Analyzer Software Service Package incl. 1x server license, 1x machine analyzer, 1x personal license		6750
Additional user license		4000
Unlimited users license		20000
Consultancy 25 hours		2500
Video audit computer	1074	
Training (one reviewer)	902	
Data transfer and data storage		
Video and sensor data transfer (3G/4G)		300
Satellite connection		9600
Video data storage		
Installation Windows and SQL server	446	
License Microsoft SQL and virtual server (5 TB)		4752
Optional extra 1 TB capacity		168

Sources: *AnchorLab (EM provider); Plet Hansen et al., 2019; EFCA, 2019; VisNed (National Fishers Organisation), Fully Documented Fisheries project Wageningen Marine Research.*

4.1.4 Data review

In general, the video of the complete sorting process of a haul is reviewed. The analysis is aided by dedicated review software that merges the multiple data formats in EM (GPS, sensors, time, video, etc.), so that all can be visualized together. When inspecting EM data sets, users can fast forward, rewind or pause with synchronous views of all active cameras, along with normal video viewing tools such as zoom. Prior to the video analysis the video data is inspected on image quality (e.g. clean lenses, technical malfunctions and moment of recording). The quality of the video is recorded and feedback to the skippers is provided. Video records with low quality images can/will not be reviewed. The time spent on review varies greatly and mainly depends on the focal species.

Based on experience from EM trials on the Dutch demersal fisheries the difference of review-time needed can be considerable. Some species such as turbot (*Scophthalmus maximus*), brill (*Scophthalmus rhombus*) and rays (Rajidae spp.) have specific morphology (i.e. body shape and size) by which they stand out from more common smaller species such as plaice (*Pleuronectes platessa*), sole (*Solea solea*) and dab (*Limanda limanda*). In general, the review is done by one person, consequently, when a vessel operates two sorting belts, the review time doubles. The time spent reviewing a haul for turbot and brill is on average double the actual sorting time needed on board by the crew. This includes measuring the length of each individual fish. Review time for rays is more variable, similarities between different ray species, i.e. dorsal (brown and black spots) and ventral (white belly) patterns, which complicates the identification process. Regular, rewinding and pausing the video footage, when identifying all the individual fish, makes video review a labour intensive and time consuming task. Video review of more common species, e.g. plaice, which are, in general, more abundant in the catch, is more time consuming. Video review becomes more complicated when fishermen move around the catch on the sorting belt to grab the covered individuals. On average a review of a single haul for plaice takes 2.5 hours per sorting belt, so in total 5 hours to analyse one complete haul. An overview of the review times for different species is shown in Table 2. Methods to reduce reviewing time, i.e. only reviewing a random selection of smaller, but representative, sub-set of the total video, are currently investigated on Dutch beam trawlers in the project Fully Documented Fisheries.

Table 2. *Average review time of EM video data for the catch of different species for a bottom trawl vessel.*

Species	**Average estimated review time for a single haul (in minutes)**
Turbot and Brill (including length measurements)	120
Rays	120
Plaice	300
Sole	240
Whiting	90

4.2 Salaries

The salary costs for EM can be divided in costs for video reviewers and costs for support and management. The total budget needed for review salary costs are dependent on many factors such as percentage of hauls reviewed, review method, target species and number of vessels equipped with cameras (Plet-Hansen et al., 2019). Support and management costs are more variable and, therefore, difficult to predict beforehand. During the implementation phase of a programme/project costs on support and management will likely be higher, during this phase budget is needed for setting up the data collection, storage and review process, training of staff, communication with participating fishers, informing stakeholders, etc. Based on previous EM trials, support and management is estimated at 10% of the total project costs. It should be noted, however, that this estimate is based on experiences in scientific EM trials, with a limited number of participants, between 8 to 14 vessels.

4.3 Fleetwide implementation

For the estimation of costs on fleet level a scenario was used of 105 Dutch beam trawlers: 75 large beam trawl cutters and 30 euro cutters (Quirijns et al., 2019). The financial specifications are presented in table 3 and includes programme setup (initial costs) and annual running cost.
The calculation for the salary costs of the video audit, support and management, video audit computers, training and extra data storage capacity is based on the following information:

- 200 days at sea
- 105 vessels
- 10 hauls per day
- 10% of hauls audited
- 120 minutes audit time per haul
- €30,- hourly wages
- 1 hour video length average per haul
- 5 GB per hour storage (depending on video quality)
- 5 cameras

105 vessels spend a total of 21.000 days at sea and during that period 210.000 hauls are made.
A total of 21.000 (10%) hauls will be used for video audit. At an average of 120 minutes of audit time per haul a total of 42.000 hours is spent on video auditing. With an hourly rate of €30.- the cost for the video audit comes to €1.260.000.-. The costs for support and management are estimated to be made up of 10% of the costs for the video audit.
42.000 hours of work in a year roughly translates to 21 fte (1 fte = 2040 hours). Assuming that the video auditors will work full time, 21 video audit computers are needed and all 21 video auditors need training. Working full time on video audit is however not recommended (Plet-Hansen et al., 2019).

With 5 cameras on board and 21000 hauls to audit a total of 105.000 hours of video will be recorded.

At 5 GB per hour this comes to a total of 525.000 GB (525 TB) of data annually.

Table 3. *Overview initial and yearly costs EM for Dutch beam trawl fleet (105 vessels*).*

	Initial costs	**Annual costs**
EM-system		
Onboard EM-system	735.000	
Installation	422.835	
Maintenance		117.495
EM software license		26.250
Video review		
Analyzer Software Incl. Unlimited user account		26.750
Consultancy (250 hours)		210.000
Video audit computer (x21)	22.554	
Training (x21)	18.942	
Data transfer and data storage		
Video and sensor data transfer (3G/4G)		31.500
Satellite connection (optional)		1.008.000
Video data storage		
Installation Windows and SQL server	446	
License Microsoft SQL and virtual server (5 TB)		4752
Extra TB capacity		87360
Salary		
Video audit		1.260.000
Support and management		126.000
Total	**1.199.777**	**1.890.107** (2.898.107 including satellite connection)

**) Quirijns et al., 2019, see also section 4.3.*

5 Feasibility of EM to register catch

KEY FINDINGS

- EM performs better when catches are processed in such a manner that it is easy to detect individual fish on video footage.
- EM is less efficient in detecting discarded fish, in mixed catches of bottom trawl fisheries.
- Implementation of protocols to improve efficiency of EM shifts the burden of monitoring discards to the fishing crew.
- Computer vision technology will reduce time and manual labour currently needed for EM video review and decreases the level of dependency in discard recording of fishers for control purposes.

The efficiency of EM to register catch very much depends on the type of fishery and catch composition, e.g. species and size. EM performs better when catches are processed in such a manner that it is easy to detect individual fish on video footage. This depends on the type of fisheries, e.g. hook and line fisheries, the monitoring objectives, e.g. specimens of a particular species, and recognizability of the species in the catch, e.g. bycatch of cetaceans (van Helmond et al., 2015).

5.1 Experiences from previous EM trials

Preliminary results of ongoing Dutch EM studies showed an excellent performance of EM in recording turbot in the Dutch beam trawl fishery. Turbot is a relatively large species, compared to the other targeted flat fish species, and caught in lower abundance, which makes it easy to spot during video view (Figure 2).

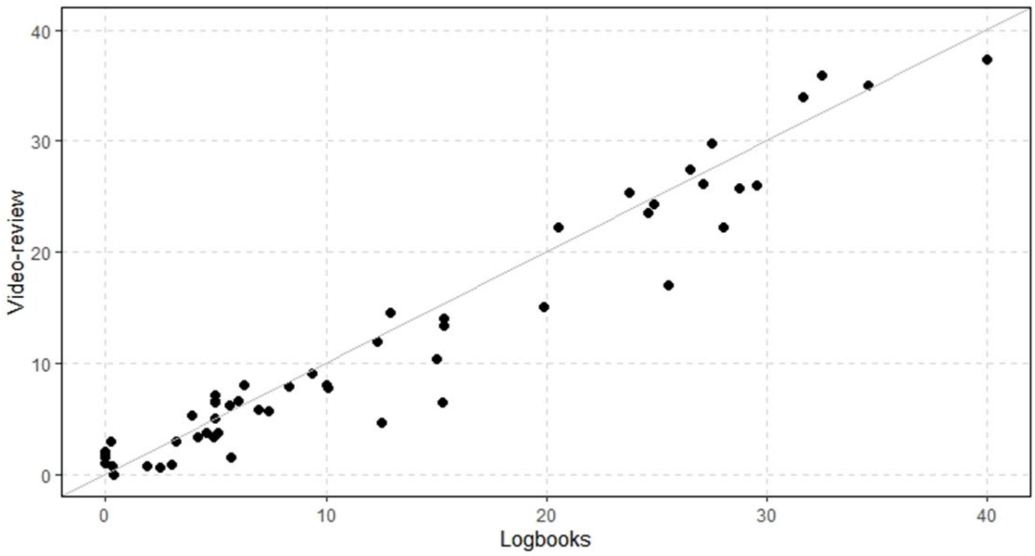

Figure 2. *Comparison between estimations in weights (kg) per haul from video review vs. observations on board for Turbot (Scophthalmus maximus). The scatterplot indicate a high agreement between the estimates based on video and the actual observations on board. The diagonal line represents the identity line, y=x.*

These studies also indicated that EM is less efficient in detecting smaller individuals, e.g. undersized and discarded fish, in mixed catches of bottom trawl fisheries (van Helmond et al., 2020). Van Helmond et al. (2017) showed an underestimation of EM for undersized sole, < 24 cm, compared to on board observations (Figure 3). Because of occlusions on the sorting belt, caused by overlapping (flat) fish mixed with other (organic) material on the soring belt, not all undersized sole was visible during video review, which resulted in a structural underestimation. Similarly, underestimation of discards was observed during EM trials in Denmark, where video review tended to underestimate discards by 32% compared to fisher's discard recordings (Mortensen et al., 2017). Furthermore, in the Danish EM trial to fully document catches of cod, uncertainties around the absolute estimates of discard quantities were observed (Ulrich et al., 2015).

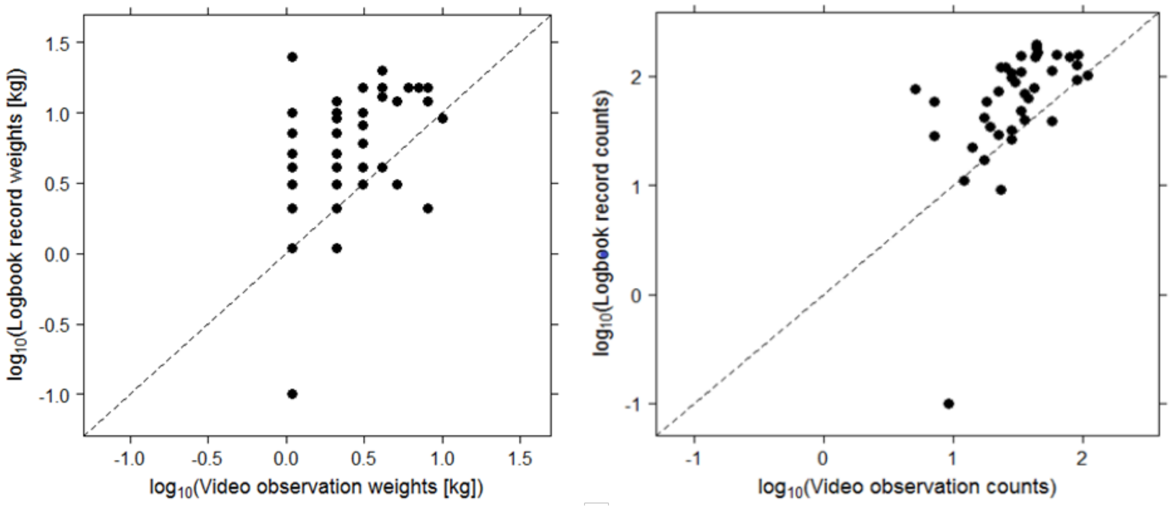

Figure 3. *Scatterplot of EM video estimations vs. logbook records for undersized sole (< 24 cm) based on (a) weights (kg) and (b) counts, both presented in logscale. The dotted line represents the identity line, y=x. The plot shows a structural underestimation of undersized sole based on video review, both for weights and counts, indicating not all undersized sole was identified and recorded during video review. (van Helmond et al., 2017).*

In general, the accuracy of EM recordings, and time spent on video review, depends on the factors, as described in Table 4.

Table 4. *Main factors that influence the efficiency of the (manual) review process of EM video data.*

1. Duration of the sorting process on board	- The length of the video analysis is related to the length of the sorting process on board of a vessel. Longer sorting times therefore lead to longer review times.
2. Targeted species for reviewing, e.g. species identification and catch volume.	- In order to annotate a fish the video is paused. A species which is caught in larger quantities requires more annotating (pausing) during a video analysis which is time consuming. A large amount of fish on the conveyor belt as can be seen in Figure 4 makes annotating a labour intensive process - The degree in difficulty of identifying different species during a video analysis contributes to the difference between the length of the video analysis. In Figure 5 the difference can be seen between identifying a turbot, large fish in the middle, which is easier identified with a higher level of accuracy compared to identifying smaller plaice, sole and dab in the same image.
3. Image quality	- Image quality determines partly the difficulty of identifying fish. Lower image quality increases the difficulty of identifying fish and consequently decreases the level of accuracy of the recordings. Also the time spent on a video analysis increases because of low image quality. By comparing Figure

	4 and 5 a difference in quality can be seen. The quality in the first image is better and therefore displays a higher level of detail, which enables a faster and more accurate identification and recording process.
4. Catch composition	- Benthos and other items in the catch besides fish can obstruct views. As seen in Figure 6 bryozoans can for example lead to difficulties in identification and accurate recording. Also, reduced visibility increases identification difficulty which leads to longer review times. - Larger quantities of fish also lead to longer review times (see point 2).
5. Annotation method e.g. count only, length measurements or drawing a fish shape specific identification 'box'. (The different annotation methods are made available in analyser software packages of EM providers)	- Counting fish is the least time consuming annotation method. The only 'handling' required is marking a counted fish with an annotation mark, e.g. dot. - More time consuming is measuring lengths of every single fish individually. This requires drawing a line over the complete length of the fish. - Drawing fish specific shapes around every fish is the most time consuming method.
6. Sorting process on board e.g. amount of conveyor/sorting belts on a vessel, conveyor belt speed and fishermen behavior.	- Vessels are equipped with one or more sorting belts. Each sorting belt has one or more separate cameras. The footage is analyzed by watching the footage of one camera at a time. The vessel layout determine the number of cameras needed. More cameras require the same sorting process to be viewed more than once. - The speed of the sorting belt varies between vessels and can even vary between hauls. A relatively high speed of the sorting belt has a negative effect on the image quality and species identification becomes increasingly difficult. The difference between a slow moving conveyor belt and a conveyor belt at medium speed can be seen when comparing Figures 4 and 5. - When a conveyor belt moves too fast to identify fish. Video can be viewed at ½ or ¼ of the actual recorded speed. This automatically increases the length of the video which leads to longer review times. - When large quantities of catch are on the sorting belt, e.g. occlusions of fish, fishermen often spread the catch over the sorting belt. Usually they move the catch back on the conveyor belt to grab fish which they missed the first time. Moving the fish back and forth over the sorting belt results in a continuous mix of the catch. It requires skill, effort and time for the reviewer to identify and count fish which is moved around on the conveyor belt by fishermen.

Figure 4. *Large amount of different species of fish on a slow moving sorting belt. Example of higher quality footage.*

Figure 5. *Identifying turbot (large fish in the middle) compared to identifying sole, plaice and dab in the same image. Example of a sorting belt moving at medium speed.*

Figure 6. *Bryozoans obstructing count and identification of fish on a sorting belt.*

An overview of recognized analytical errors made during review of EM video data and possible improvements is given in Table 5.

Table 5. *Overview of error types potentially generated during review of EM video data.*

Error type	Possible cause	Improvement
Measurement error	• Fish overlap • Occlusion • Incorrect species identification • Low video quality • Unfavorable camera position	• Involvement of crew: increase visibility to better display catch, clean lenses. • Training of video reviewers, e.g. species recognition. • Repositioning of camera(s)
Estimation error	• These are the error introduced by an estimator, e.g. length estimation, length-weight conversion.	• Improved video recording and review methods, e.g. computer vison technology, increases estimation accuracy and reduces the estimation error.

5.2 Improve EM efficiency

To improve efficiency of EM protocols were implemented during several studies. For example, to improve the detection of smaller individuals of under sized sole the crew was requested to display all individuals below 24 cm on the soring belt in front of the cameras after the regular sorting process (Figure 7). This protocol substantially improved the efficiency of EM to record the complete sole catch. However, the protocol added additional time to the sorting process on board and was perceived as a burden to the crew. Particularly, for a mixed fishery in the context of the LO, and the large number of different species affected, implementation of such protocols would come with a cost. The estimated extra time needed to conduct this protocol for a beam trawl vessel under the LO would exceed 12 h per fishing trip (van Helmond et al., 2017).

Figure 7. *Implementing a protocol to display undersized sole, < 24 cm, after the catch sorting process. Implementation of the protocol, with the support of the fishing crew, was essential to increase the level of estimation accuracy of EM in detecting undersized sole in this fishery (van Helmond et al., 2017).*

5.3 Review intensity and the audit-approach

When monitoring for rare and highly visible catch events, such as by-catch events of cetaceans, all video footage can be reviewed, a so-called 'census review'. Under these circumstances video can even be replayed at a higher rate than real time (Kindt-Larsen et al., 2012). The same method can be applied for species that are less abundant and easily spotted in the catch, like turbot (Figure 2). Monitoring smaller and more abundant species, e.g. plaice in a catch of a Dutch beam trawler, is generally time consuming, review is done at a much slower rate than real time (Table 2). In response to the intensity of video review, strategies are developed where only a random selection of 10%-20% of the collected video data is validated against self-recorded catch data from logbooks, a so-called audit approach (Stanley et al., 2015). Even though only a minority of the logbooks are audited with video, the fishers do not know which hauls will be audited and when, which creates an incentive to report all catches accurately. However, the audit approach introduces a burden of monitoring discards to the fishing crew, since sorting, weighing and recording of discards by species will be an additional labour intensive task. A method to document all discards solely based on video review, i.e. estimate total discards quantities by reviewing a random selected smaller sub-set of the total video, is currently investigated on Dutch beam trawlers in the project Fully Documented Fisheries.

5.4 Computer vision technology

The on-going development of automated species recording systems in combination with EM foresees improved implementation of video-based monitoring in the near future (Figure 8). The implementation of computer vision technology will reduce time and manual labour currently needed for EM video review. This technology will facilitate processing large amounts of EM data and, potentially, allows for direct automated image review on board. Immediate automated registration onboard may only generate catch descriptions as output, e.g. list of species and quantities, making transmission of large amounts of video data from vessel to servers ashore to allow for further (manual) analysis redundant (Michelin et al., 2018; van Helmond, 2021).
In the context of control and enforcement, computer vision technology will also enhance recording of discards under the LO, reduces the burden on the fishing crew to record discards, and decreases the level of dependency in discard recording for control purposes.

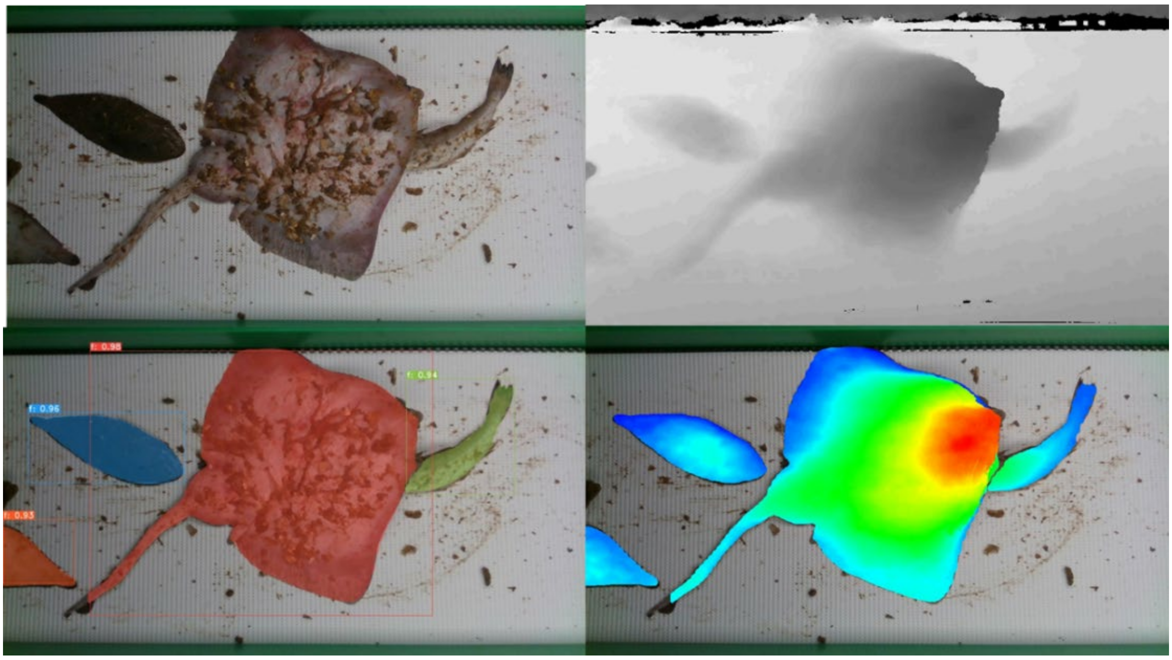

Figure 8. *Computer vision technology in practice: Automated classification of fish species and volume computation of the sorting belt of a bottom trawl vessel.*

6 Supporting the uptake of EM

KEY FINDINGS

- Currently there is a sense of distrust and resistance against EM on behalf of a large part of the fishing fleet.
- Aside from the general resistance of the fishing industry to the LO, the main objections to EM from the perspective of fishers are potential misuse of data and the invasion of privacy on board the fishing vessel.
- In order to roll out EM over the entire Dutch (and European) fleet a more intrinsic motivation is required. This can be can fueled by indirect incentives, such as increased market access, traceability and transparency, support of sustainability labels, providing proof of good practices.
- Without fisheries consultation and involvement, it can be expected that fishers will keep on resisting EM and circumvent the system.
- The establishment of a multi-stakeholder group including experts, as well as platforms on which users can exchange knowledge and experiences can help in laying out potential advantages and eventually create a positive experience in support for EM as a tool for sustainable fisheries management.

6.1 Different roads to implement EM

EM can be implement using either a top down or bottom up approach. The latter is exemplified by the British Columbia Crab Fishery in which, as a means to counter a significant increase in fishing effort, trap limits were proposed. While the industry recognised there was no means to enforce this, they have themselves proposed an EM programme to ensure overall compliance (Michelin and Zimring, 2020). In case of a top down approach, EM is a government driven introduction to improve accountability and reduce unreported discarding of choke species. An example is the Canadian groundfish fishery (Box 1).

BOX1: "Fix-it or lose-it"

In the Canadian groundfish fishery measures needed to be taken to reduce discards in the (mixed) fisheries and derive proper stock assessments. The monitoring programme consists of three integral components: Fishers' log books, third-party dockside-monitoring, vessel monitoring and full video capture (EM) of fishing events at sea.

The government applied a carrot-and-stick approach in which the incentive to participate consisted of an introduction of individual vessel quotas (ITQs) whereas in case of no commitment of the fishery the government would not support ITQs and close the fishery until monitoring was improved. The fishing industry realised they needed to work together and agree to collaborate as the alternative (government control or closures) would be worse.

In 2006 a pilot project was developed. The basis was a shared understanding of the principles of sustainable management and the willingness of the fishing industry to be accountable for their catches. Parties committed to a long term effort and an investment in time and funds. An industry led committee was in charge of formulating a management plan for groundfish.

The improved catch monitoring system consisted of:

1. A system that enabled harvesters to temporarily reallocate species among license types so that each fleet could execute their fishery while reducing the need to discard.
2. A catch monitoring system for all fleets to account for all catches through 100% at-sea and dockside monitoring.
3. An ITQ system for all commercial groundfish fisheries.

The system also contained two co-management arrangements.
The Provincial Government and the Department of Fisheries formed an Advisory Committee including all relevant stakeholders who developed a strategic approach for the catch monitoring system. An Electronic Monitoring Subcommittee composed of fishers, the Department of Fisheries, managers, scientists, IT specialists and enforcement groups worked on fine tuning the system. Subsequently a pilot project was developed where all vessels were furnished with EM.
All information was collected at an Information Management System (at the Department of Fisheries) that within days provided the status of each vessel's catch relative to its various species ITQs. Credible discard data allowed for better (and higher) catch quota as there was no need to be over precautionary to compensate for unknown catches. As a result the assessment discussions also took less time. In 2010, the pilot was permanently implemented.
Summarized, the government indicated that in order to achieve sustainable fishing, a reduction of discards was required. In order to come to fisheries measures and catch limits based on proper data, these discards needed to be assessed. The industry got the option to organise themselves and work towards improved monitoring, or leave it to the state who would consequently close the fishery if monitoring of catches did not improve. The fishers took action and organised themselves to what is now an ITQ based fishery with full monitoring of catches.

Box 1. *Canadian Groundfish case (Mawani, 2009, Stanley et al., 2015, Canadian Government, 2021)*

In Europe the introduction of the LO meets strong resistance from the industry as it is perceived to undermine fishing operations. At the same time, the governments of the Member States (regulators) have the obligation to enforce the LO with full at-sea monitoring (EM) as a mechanism to ensure compliance. Michelin and Zimring (2020) have drafted three general scenarios for how this could play out:

1. The industry continues to fend off implementation of the LO resulting in negative impacts on the fish stocks and the long-term economic prospects. This will also increase the probability that several fisheries lose their MSC certification.
2. The government mandates the implementation of EM to enforce the LO with no concessions made to industry. This causes significant near-term economic pain for industry and serious implementation and political challenges.
3. The industry and government reach an agreement in which both sides make concessions. The result is a compromise that includes a means to control unreported discards to ensure fisheries are managed sustainably while addressing the economic concerns of the industry.

6.2 Carrot or stick

In order to successfully implement EM, it is important that the fishing industry supports and accepts the tool as beneficial. Currently there is a sense of distrust and resistance on behalf of a large part of the fishing fleet. Pilots have laid out the difficulties, but also revealed opportunities that effective use of EM offers. Even though the fisheries in the wider North Sea area (North Sea, English Channel, Skagerrak, and Kattegat) are diverse, a coordinated approach among the member states and third countries will help to address these issues and formulate an appropriate approach to roll out EM.
For the Netherlands, in order to roll out EM, a carrot-and-stick approach may lead to the creation of willingness to adopt EM. The carrot might be the introduction of more flexible management measures enabled by EM that may lead to more appropriate catch quota, a stronger market position, more stability, and potentially higher economic returns. With 100% at-sea monitoring, the data derived from EM can be used as input for management measures. Examples are individual quotas, flexible time- and area closures, but also the reduction of the uncertainty buffers that are currently used in setting the TAC because of uncertain catch data. These types of measures could be considered in discussions on the level of the EU in order to enhance the link between EM and improved economic outcomes for fishing industry.
EM is a regulatory-driven tool and the Dutch government is required to establish a monitoring system in their fisheries. The stick is that if the industry does not cooperate on a voluntary basis, the government is in a position to implement at-sea monitoring (EM) as a compulsory measure to secure compliance. The sector then will lose a voice in the development and execution of an improved monitoring and control programme.

6.3 Fishers’ attitudes towards EM

The main objections to EM from the perspective of the fishing industry are potential misuse of data and the invasion of privacy on board the fishing vessel - the so called “big brother” effect (Mangi et al., 2013). There are also concerns around the costs of the system including installation, maintenance and running costs on the long term (NOAA, 2017, van Helmond et al., 2019). Another issue, particularly on small vessels is the space required for the cameras in the work space. Combined with automated image recognition the system restricts movement of the crew and requires a different way of handling the catch on the sorting belt, which hinders the work flow. A Danish study shows that reluctance against EM is strongest for the proportion of the fishing industry without experience with EM (9 out of 10), (Plet-Hansen et al., 2017).

Fishers who had participated in EM trials developed a different, more positive experience; 7 out of 10 could see the benefits when the pilot was over (Michelin et al., 2020; Plet-Hansen et al., 2017). Most valued the cooperation and exchange with scientists on fisheries data and information. For a number of fishers it is also an incentive to know that the up-to-date data they are collecting helps to improve fisheries management. Moreover, EM can serve as a means to prove their sustainability claims and as a result create a more positive image. From a practical point of view, it was mentioned that EM is preferred to observers on-board as the latter requires more planning of the fishing trip, and once they got used to it, the fishers felt that the presence of cameras was actually perceived as less intrusive than an observer on board (McElderry, 2006; van Helmond et al., 2019).

6.4 Incentives

Direct incentives offered to fishers to participate in EM trials consisted of individual quota uplifts, direct payments, increased days at sea, access to closed areas and increased flexibility in gear choice (Kindt-Larsen et al., 2011; Needle et al., 2015; van Helmond et al., 2016; van Helmond et al., 2019). However, in order to roll out EM over the entire Dutch (and European) fleet a more intrinsic motivation is required. This can be can fueled by indirect incentives, such as increased market access through eco-labeling, but also by experiencing advantages in terms of better fishing opportunities or healthy fisheries, because, EM provides better data for improved fisheries management.

One advantage of EM is improved traceability and transparency, two aspects that are becoming increasingly relevant now given consumers show an increased interest in sustainably produced fish. To service this growing market an increasing number of seafood retailers are supporting sustainability labels such as MSC. Systems such as EM can help to provide a complete “net-to-plate” overview (Michelin et al., 2020) thus supporting increased market access and potential economic benefits.

A second important advantage is that the real-time data derived by EM enables fishers to benefit from better fishing opportunities (Mangi, 2013; Needle et al., 2015). Information on the spatial distribution of unwanted catches (choking species) can stimulate discard avoidance. Fishers can also improve selectivity by changing the timing of fishing trips or adapt the target species (Condie et al., 2014; van Helmond et al., 2019). The aggregation of data at a central point for analysis will allow for accurate and up to date recommendations on TACs and quota. In this way the use of EM data can lead to more efficiency in economic terms whilst enhancing compliance with the LO.

A study by Plet-Hansen (2017) shows that there is still confusion on the exact content and reasoning behind the LO. Fishers are not entirely sure what to land and what to release and hence are afraid of repercussions, particularly when cameras on board would monitor their behaviour. Therefore it is important to ensure that fishers have clarity on LO regulations (van Hoof et al., 2019).

6.5 Compliance and legitimacy

Compliance behaviour among fishers is influenced by whether regulations are seen as meaningful and legitimate (Plet-hansen et al., 2017). Since the real-time data that EM provides helps fishers to avoid catching undersized fish, and may reduce high-grading, i.e. the decision by fishers to discard fish of low value that allows them to land more valuable fish (Kindt-Larsen et al., 2011; Batsleer et al. 2015; van Helmond et al., 2016). Reduced discarding of quota species translates into healthier stocks and consequently higher revenues. This may give fishers the motivation to comply with recording discards (Ulrich et al., 2015). The analysis of the data can be used to assess the outcome of management measures and if these are positive, compliance can be expected to increase further. Long term profitability of the fisheries will be improved rendering the additional monitoring costs as an investment that supports sustainable fishing and economic stability (Mawani, 2009).

The creation of an equal level playing field, where all vessels fishing in the wider North Sea area are all subject to the same rules where it comes to EM, will increase legitimacy of the system. This requires collaboration and harmonization of rules and regulations concerning EM by all the member states and third countries such as the United Kingdom. With this view in mind, it is stipulated that the EU Member States concerned will need to start simultaneously as to allow for the exchange of experience with EM (EFCA/Scheveningen Group 2021).

6.6 Data ownership

Turning the perceived threat of EM into an opportunity is a big challenge. It requires shifting fishers' perception that EM is only used for control and enforcement, to a perspective that EM is a means that can be used to actively support sustainable fisheries. An alternative to explore is to provide fishers ownership of the video footage recorded on board (Plet-Hansen et al., 2017). Established rules underlining fishers' ownership of the data would minimize the risk of third parties getting hold of video footage and use it to discredit the fishing industry. For monitoring and control and surveillance (MCS) purposes and in cases where non-compliance is suspected, the fisheries control authorities could ask the fisher in question for video documentation, thus reversing the burden of proof and bringing the responsibility back to the fishers (Plet-Hansen et al., 2017). By giving the responsibility back to the fishing industry the association of EM from "big Brother" may change to one of "agency" (van Helmond et al., 2019).

In order to build trust and work towards a greater degree of self-management by the fishing industry, they can document their activities and demonstrate compliance with the management measures (Gray and Hatchard, 2003; van Ginkel, 2005). A results-based approach could be envisaged where fishers are accountable for the impact they create on the marine environment and EM could be used to prove the reliability of fishers' documentation of fishing activities and catches.

6.7 Support EM uptake by the fishing industry

With a top-down approach, without consultation and involvement from the fishing sector, it can be expected that fishers will keep on resisting EM and circumvent the system. Widespread implementation will be difficult and probably fail.

Voluntary participation can be induced by the government offering the fishing industry and other stakeholders the opportunity to be involved. They also need to have a clear stake (Mawani, 2009). Therefore it is important to create the incentives that will help the fishing sector to adopt EM as a tool that enhances fisheries management and has long-term benefits.

6.8 Involvement in the process/design

A first step in creating support is to involve the fishers in the process of planning and implementation (Stanley et al., 2015). Managers, fishers, scientists, IT specialists and other relevant parties need to discuss the concerns of the parties involved, such as privacy, data security, data ownership, and information provision (Mangi et al., 2013). The discussions are also an opportunity to manage expectations and to help build trust and confidence.
Bringing private-sector partners to the table will help to shape EM implementation in a way that will reduce political and practical friction. There may be possibilities for the industry to fulfil a more prominent role in fisheries management and research. Participation then provides an opportunity for leading industry members to shape the EM program and benefit from incentives such as quota top-ups, which will give them an advantage over less cooperative industry peers.

6.9 Collaborative effort

The industry can be invited to draft recommendations for better fishing practices, security of access, a year-round fishery, economic viability and efficiency. A feeling of 'agency' will create an important incentive for the fishing sector to adopt EM and actively contribute to its success. The design of a route that allows for these aspects to become a reality is the task now at hand for the governments responsible for rolling out of EM in their fishing fleets.
The government needs to set the boundaries, lay out the process and provide the guiding principles that form the basis for a strategic approach. These principles could include for example individual catch accountability of fishers, monitoring standards that support this, and management decisions consistent with the precautionary approach (Stanley, 2015).
In Europe the North Sea Advisory Council could provide a useful platform for collaborative efforts towards developing a catch monitoring system in line with EU requirements. Establishing a equal level-playing field among Member States would be an important element. Differences between neighbouring countries in EM approaches will not easily accepted by the fishing industry For EM program development in the Netherlands a multi-stakeholder working group consisting of government representatives, fishers, NGOs, EM service providers, and scientists could provide guidance. In addition, on specific issues and programme design experts are needed who can provide the government and other parties with detailed, high-quality, on-demand information (Michelin and Zimring, 2020). The International Council for the Exploration of the Seas (ICES) formed the Working Group on Technology Integration for Fishery-Dependent Data (WGTIFD) for the North Atlantic. This body can be of help in the implementation of EM.

6.10 Market mechanisms

Government efforts can be supplemented by market driven incentives to stimulate the use of EM. There is pressure from the market to improve data and accountability for the operations of the fishing industry. The increasing demand for products from fisheries with proven sustainably standards and that meet the criteria of traceability and transparency can be a strong incentive to adopt EM.
At the same time, for the part of the fleet that already is MSC certified there is the threat of decertification if fishing practices are not meeting the sustainability standards. If environmental organisations or other parties will push for stronger risk-based data requirements in the MSC standard, pressure will be added to advance EM and reach a broader agreement on the LO (Michelin and Zimring, 2020). A large portion of MSC certified fish comes from Europe and if the LO is not properly implemented, some of this supply could be at risk of losing certification (Michelin and Zimring, 2020).

6.11 Data analysis and sharing results

Another step is the creation of knowledge sharing platforms where the results of the analyses are shared with the fishers. This not only creates more insight and understanding of management measures, it may also stimulate a sense of responsibility and accountability with the fishers (Needle et al., 2015; Bergsson & Plet-Hansen, 2016; Bergsson et al., 2017; Plet-Hansen, 2017). As shown in the pilot studies, experience with EM generally leads to a more positive attitude towards the tool and its usefulness. Showing fishers on board vessels what EM entails, the video footage and what can be done with the results of the data is important, also where it comes to the potential benefits of EM. Internal motivation of fishers fed by trust, legitimacy, and a belief that EM has true benefits for them, will support adoption of EM by at least a substantial part of the fishing fleet. The careful design of a process that involves the fishing sector will help to enhance trust and find solutions for the issues that have been raised.

Once this has been realized, the widespread implementation of EM and the availability of high quality real-time data offers the potential for more flexible and cost-effective fisheries management. Real-time closures and flexible TACs for a number of commercial stocks can lead to improved financial performance for the fishing industry.

6.12 Role of the government

Within the context of the Common Fisheries Policy, each Member State has the task to provide the legislative framework for the introduction of EM. The government also has a pivotal role in providing the incentives to the fishing industry to participate and in providing the opportunity for substantial industry input in program design, this includes the establishment of an equal level-playing field among Members States. Regulators need to guide the process, provide the boundaries and formulate the principles to which all stakeholder parties need to agree in order to bring the process forward. Regulators may seek assistance in program design and in working out the practical and financial aspects of EM, including data modernization.

A number of tools are available to regulators:

- Best-practice toolkits.
- Conventions where regulators can interact.
- Pilots and trials that provide insight in the process and provide guidance.
- Studies and reviews on the implementation of EM worldwide.
- Cases that demonstrate the functionality of EM.

6.13 Current foreseen approach

At the moment, the process foreseen by EFCA and the Scheveningen Group (2021) includes the establishment of two cooperation groups to stimulate the exchange of experiences and plan the activities:

1. An EM Steering Group coordinated by EFCA involves national project leaders. The group will establish the Terms of Reference for both groups.
2. An EM project group coordinated by EFCA and/or group members will be set up for Member State representatives in charge of national coordination of activities and securing common reviewing standards. This group includes scientific data experts from the National Fisheries Research Institutes. They will report to the Steering Group.

Other member states not participating in the trial may participate in the two groups as observers. Activities of the EM project group include:

- Preparation of Vessel Monitoring Plans by the vessel owner, a provider, plus the national competent authority.
- Installation of the EM systems on board, also test EM equipment.
- Maintenance of EM systems.
- Video footage reviews.
- Data analysis.
- Organisation of workshops on video footage review (for reviewers and to standardize the approach).

The Competent National Authority has a central role in the roll-out, data handling and control of EM. This responsibility and particularly the work load resulting from the need to review (a part of) the video footage could be diminished if the system was perceived as supporting the fishery rather than a means to control it. Support could be created for the system by the sector by laying out advantages, particularly if automated image review would take away the burden of logging data and would lead to real-time data useful in flexible fisheries management. Working communally on the implementation of EM system where all parties have benefits from this technological innovation offers clear advantages.

6.14 Suggestions for a multi-stakeholder Working-Group

Regulatory changes in fisheries are often long processes which require the support of many different stakeholders. This has been confirmed by a number of studies. Although growth of EM has historically been quite slow, the tool appears to be at a critical point in its development and suitable for much wider adoption. EU regulations require Member States to push ahead with the introduction of EM. However, to enhance successful implementation within the Dutch context, it is important to roll out EM as a tool that will serve both the industry and control purposes. The establishment of a multi-stakeholder group including industry representative and experts in addition to the above, as well as platforms on which knowledge and experiences can be exchanged on the level of the users, can help in laying out potential advantages and eventually create a positive experience and economic benefits that will enhance compliance and support for EM as a tool for sustainable fisheries management.

7 Conclusions

Several technical applications and standards should be considered when implementing EM for control specific purposes in the context of the LO. Compared to EM setups used in previous (scientific) trials additional elements should be included:

1. Remote access is considered to be an important element for control, distant access for system configuration, verification of system health and data transmission is required.
2. Controlled shut down and continuation of recording of a relevant time span during power failure are mandatory to ensure data back-up, storage, transfer in a secured environment to prevent possible deletion or tampering.
3. Camera positioning is directed on complete coverage of activity and catch processing on board. High-resolution cameras should be prioritized for monitoring identified high-risk spots, such as designated discard areas.
4. A self-test function should be incorporated in the EM system to ensure complete functionality before leaving the port.
5. To ensure all monitoring needs are covered and to optimize the quality of the data a layout of the EM system on board (Vessel Monitoring Plan) should be made for all vessels.
6. To support data distribution, both sensor- and video information, a specified common format is recommended.

Besides the costs on EM systems itself, a substantial investment in needed for a proper IT infrastructure and data review. Implementation of EM on a large scale requires a sufficient IT infrastructure. EM generates a significant amount of (video) data, such a infrastructure should support data transfer, storage, and review facilities. Manual video review is a labour intensive and time consuming task. This adds up when implementing EM on a fleetwide level, a sufficient amount of workforce should be made available for video review.
EM is less efficient in detecting smaller specimen, e.g. discards, in mixed catches of bottom trawl fisheries. This means that within mixed fisheries targeting flatfish, i.e. main Dutch demersal fishery, manual review of EM video data it is not possible to estimate exact quantities of discards, with high levels of certainty. In the context of monitoring compliance under the LO, this is a draw back for implementing EM for control purposes in the bottom trawl fisheries. However, the efficiency of detecting discards from video review can be significantly improved by implementation protocols to display discards in front of the cameras. But this shifts the burden of monitoring discards to the fishing crew, since sorting, weighing and recording of discards by species will be an additional labour intensive task.

Figure 9. *Fishers need to conform to the operational practices required on board to facilitate the success of EM, this includes cleaning lenses. Figure shows video shot from the same camera clean, useful data (left panel), and murky, useless data (right panel).*

An important lesson learnt from previous EM studies is that involvement of fishers in EM has a direct effect on data quality, and consequently, the efficiency of EM. Fishers need to conform to the operational practices required on board to facilitate the success of EM. Footage collected from cameras with dirty lenses is useless, therefore camera lenses need to cleaned on regular intervals (Figure 9).

Computer vision technology will reduce time and manual labour currently needed for manual review of EM video data. Ongoing developments and applications of machine learning technology, e.g. deep learning, convolutional neural networks, will make EM implementation on a larger scale possible. Automated recording of all catches, including discards, releases the fishers of the burden of catch recording under the LO and creates incentives to make use of EM on their vessels.
Without consultation and involvement of the fishing industry, it can be expected that fishers will keep on resisting EM and circumvent the system. Intrinsic motivation of the fishers fuelled by both direct and indirect incentives, such as increased market access, traceability and transparency, support of sustainability labels, providing proof of good practices, is believed to be the best possible way forward to support uptake of EM by the fishers community. Implementation of knowledge sharing platforms and establishment of a multi-stakeholder group should be considered. Results of EM analyses and experiences can shared with fishers and between other stakeholders. This not only creates more insight and understanding of management measures, it may also stimulate a sense of responsibility with the fishers.

8 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. The organisation has been certified since 27 February 2001. The certification was issued by DNV.

On the basis of this accreditation, the quality characteristic Q is awarded to the results of those components which are incorporated in the scope, provided they comply with all quality requirements. The quality characteristic Q is stated in the tables with the original research results.

The quality of the test methods is ensured in various ways. The accuracy of the analysis is regularly assessed by participation in proficiency tests.
In addition, a first-level control is performed for each series of measurements.

If desired, information regarding the performance characteristics of the analytical methods is available.

If the quality cannot be guaranteed, appropriate measures are taken.

9 References

Ames, R.T., Leaman, B.M. and Ames, K.L. 2007. Evaluation of Video Technology for Monitoring of Multispecies Longline Catches. North American Journal of Fisheries Management 27, 955–964.

Batsleer, J., Hamon, K.G., van Overzee, H.M.J., Rijnsdorp, A.D. and Poos, J.J. 2015. High-grading and over-quota discardingin mixed fisheries. Reviews in Fish Biology and Fisheries, 25: 715-736.

Bergsson, H., Plet-Hansen, K. 2016. Final Report on Development and usage of Electronic Monitoring Systems as a measure to monitor compliance with the Landing Obligation - 2015. 10.13140/RG.2.2.13561.67683.

Bergsson, H., Plet-Hansen, K., Nyholm, L. Jensen, P. Bahlke, S. 2017. Final Report on Development and usage of REM systems along with electronic data transfer as a measure to monitor compliance with the Landing Obligation. 10.13140/RG.2.2.23628.00645.

Canadian Government. 2021. Integrated fisheries management plan summary: Groundfish - Pacific Region. https://www.pac.dfo-mpo.gc.ca/fm-gp/mplans/ground-fond-ifmp-pgip-sm-eng.html

Condie, H.M., Catchpole, T.L., Grant, A. 2014. ICES Journal of Marine Science. Volume 71, Issue 5, July-August 2014, Pages 1266-1276.

Crowder, L.B., Murawski, S.A. 1998. Fisheries bycatch: implications for management. Fisheries, 23: 8-17.

Daan, N. 1997. TAC management in the North Sea flatfish fisheries. Netherlands Journal of Sea Research, 37: 321-341.

EFCA. 2019.Technical guidelines and specifications for the implementation of Remote Electronic Monitoring (REM) in EU fisheries. Vigo, Spain. 43 pp.

EFCA/Scheveningen Group. 2021. Design and implementation of a Remote Electronic Monitoring (REM) pilot project for selected fisheries in the North Sea.

Gray, T. Hatchard, J. 2003. The 2002 reform of the Common Fisheries Policy’s system of governance - rhetoric or reality? Marine Policy 27, 545–554.

van Ginkel, R. 2005. Between top-down and bottom-up governance: Dutch beam trawl fishermen’s engagement with fisheries management. Methods and Technologies in Fish Biology and Fisheries, 4, 119–139.

van Helmond, A.T.M., Chen, C., and Poos, J.J. 2015. How effective is electronic monitoring in mixed bottom-trawl fisheries? ICES Journal of Marine Science, 72: 1192-1200.

van Helmond A.T.M., Chen, C., Trapman, B.K., Kraan, M., Poos, J.J. 2016. Changes in fishing behaviour of two fleets under fully documented catch quota management: Same rules, different outcomes. Marine Policy, Vol. 67, Pages 118-129.

van Helmond, A.T.M., Chen, C. and Poos, J.J. 2017. Using electronic monitoring to record catches of sole (Solea solea) in a bottom trawl fishery. ICES Journal of Marine Science 74, 1421-1427.

van Helmond, A.T.M., Mortensen L., Plet-Hansen K., Ulrich C., Needle C., Oesterwind D., et al. 2020. Electronic monitoring in fisheries: Lessons from global experiences and future opportunities. Fish and Fisheries 21, 162-189.

van Helmond, A.T.M. 2021. Research for PECH Committee – Workshop on electronic technologies for fisheries – Part II: Electronic monitoring systems, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels

van Hoof, L., Kraan, M., Visser, N.M., Avoyan, E., Batsleer, J., Trapman, B. 2019. Muddying the Waters of the Landing Obligation: How Multi-level Governance Structures Can Obscure Policy Implementation. The European Landing Obligation: Reducing Discards in Complex, Multi-Species and Multi-Jurisdictional Fisheries. S. S. Uhlmann, C. Ulrich and S. J. Kennelly. Cham, Springer International Publishing: 179-196.

Mawani, T. 2009. Evaluation of the Commercial Groundfish Integration Pilot Program in British Columbia (collectionscanada.gc.ca). Master’s Thesis.

Mangi, S.C., Dolder, P.J., Catchpole, T.L., Rodmell, D. and de Rozarieux, N. 2013. Approaches to fully documented fisheries: practical issues and stakeholder perceptions. Fish Fish, 16: 426-452.

Mortensen, L.O., Ulrich, C., Eliasen, S.Q. and Olesen, H.J. 2017. Reducing discards without reducing profit: Free gear choice in a Danish result-based management trial. ICES Journal of Marine Science 74, 1469-1479.

Msomphora, M., Aanesen, M. 2015. Is the catch quota management (CQM) mechanism attractive to fishers? A preliminary analysis of the Danish 2011 CQM trial project management (CQM) mechanism Landing quota (LQ) Incentive compatibility Participation constraint Principal–agent model Total allowable catch (TAC). Marine Policy. 58. 78-87.

Kindt-Larsen, L., Kirkegaard, E., Dalskov, J. 2011. Fully documented fishery: a tool to support a catch quota management system, ICES Journal of Marine Science, Volume 68, Issue 8, Pages 1606–1610.

Kindt-Larsen, L., Dalskov, J., Stage, B. and Larsen, F. 2012. Observing incidental harbour porpoise Phocoena phocoena bycatch by remote electronic monitoring. Endangered Species Research 19, 75–83.

McElderry, H., Schrader, J. and Illingworth, J. 2003. The Efficacy of Video-Based Monitoring for the Halibut Longline. Victoria, Canada. Canadian Research Advisory Secretariat Research Document 2003/042. 80 pp.

McElderry H. 2006. At-Sea Observing Using Video-Based Electronic Monitoring Prepared for ICES Annual Science Conference 2006 Session CM 2006/N:14.

Michelin, M., Elliott,M., Bucher, M., Zimring,M., Sweeney, M. 2018. “Catalyzing the Growth of Electronic Monitoring in Fisheries.” California Environmental Associates, September 10. 63pp. https://www.ceaconsulting.com/wp-content/uploads/CEA-EM-Report-9-10-18-download.pdf

Michelin, M., Zimring, M. 2020. Catalyzing the growth of electronic monitoring in fisheries. California Environmental Associates (CEA) Consulting, The Nature Conservancy. https://www.fisheriesem.com/pdf/Catalyzing-EM-2020report.pdf

Needle, C. L., Dinsdale, R., Buch, T. B., Catarino, R. M. D., Drewery, J., Butler, N. 2015. Scottish science applications of Remote Electronic Monitoring. ICES Journal of Marine Science, 72, 1214–1229.

NOAA. 2017. Electronic monitoring and reporting implementation plan – Alaska region spring 2017. https://media.fisheries.noaa.gov/dam-migration/ak_et_regional_implementation_plan_2017-05_update.pdf

NSAC. 2021. https://thefishingdaily.com/eu-fishing-industry-news/nsac-advice-to-the-scheveningen-group-on-the-discard-plan/

Plet-Hansen, K., Eliasen, S.Q. Mortensen, L.O., Bergsson, H., Olesen, H.J., Ulrich, C. 2017. Remote electronic monitoring and the landing obligation – some insights into fishers’ and fishery inspectors’ opinions, Marine Policy, Volume 76, Pages 98-106.

Plet-Hansen, K.S., Bergsson, H., Ulrich, C. 2019. More for the money: Improvements in design and cost efficiency of Electronic Monitoring in the Danish Cod Catch Quota Management trial. Fisheries Research 215, 114-122.

Quirijns, F.J., Steins N.A., Zaalmink, B.W., Mol, A., Kraan, M., Strietman, W.J., van Asseldonk, M.A.P.M., Molenaar, P., van Oostenbrugge, J.A.E., Baltussen, W.H.M. 2019. Duurzame Noordzee kottervisserij in ontwikkeling. Ervaringen, lessen en bouwstenen. Wageningen Marine Research rapport, C085/19. 126 pp.

Stanley, R.D., McElderry, H.I., Mawani, T. and Koolman, J. 2011. The advantages of an audit over a census approach to the review of video imagery in fishery monitoring. ICES Journal of Marine Science 68, 1621–1627.

Stanley, R.D., Karim, T., Koolman, J., McElderry, H. 2015. Design and implementation of electronic monitoring in the British Columbia groundfish hook and line fishery: a retrospective view of the ingredients of success. ICES journal of Marine Science, 72(4), pp 1230-1236.

STECF. 2020. 65th Plenary Report (PLEN-20-03), Ulrich, C. and Doerner, H. editor(s), EUR 28359 EN, Publications Office of the European Union, Luxembourg, 2020, Scientific, Technical and Economic Committee for Fisheries.

Ulrich, C., Olesen, H., Bergsson, H., Egekvist, J. Hakansson, K., Dalskov, J. Kindt-Larsen, L. and Storr-Paulsen, M. 2015. Discarding of cod in the Danish Fully Documented Fisheries trials. ICES Journal of Marine Science. 72. 10.1093/icesjms/fsv028.

10 Justification

Report C001/22
Project Number: 4313100168/ BO-43-119.01-021

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved:	Dr. J. Batsleer Researcher
Signature:	
Date:	13 Januari 2022

Approved:	Drs. J. Asjes MT Member Integration
Signature:	
Date:	13 Januari 2022

Wageningen Marine Research
T +31 (0)317 48 7000
E: marine-research@wur.nl
www.wur.eu/marine-research

Visitors’ address

- Ankerpark 27, 1781 AG Den Helder
- Korringaweg 7, 4401 NT Yerseke
- Haringkade 1, 1976 CP IJmuiden

With knowledge, independent scientific research and advice, **Wageningen Marine Research** substantially contributes to more sustainable and more careful management, use and protection of natural riches in marine, coastal and freshwater areas.

Wageningen Marine Research is part of Wageningen University & Research. Wageningen University & Research is the collaboration between Wageningen University and the Wageningen Research Foundation and its mission is: 'To explore the potential for improving the quality of life'