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Effectiveness of fully documented fisheries to estimate discards in a participatory research scheme

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ABSTRACT

A key challenge for fisheries science and management is the access to reliable and verifiable catch data. In science, the challenge is to collect reliable, precise and traceable data to provide sound advice. In management, the challenge is that catch documentation is necessary to enforce regulations. Currently, catch inspection at sea, self-reporting through e-log and on-board observers are the primary methods to document catches at sea. However, at-sea control and on-board observers are costly and have limited coverage, while self-reporting is susceptible to fraud and provides limited coverage. New cost-effective methods are currently emerging involving Remote Electronic Monitoring (REM) and on-board cameras. Previous studies have tested REM with promising results. However, evaluation of the potential biases of REM is needed before full benefits can be obtained. We deployed REM with on-board cameras on 14 fishing vessels and were able to inspect 56% of 1523 hauls made in the 6 month trial period, using an estimated 582 man-hours of video audit. The results showed an overall good agreement between the fishers self-reported discards and the video inspectors discard estimates. However, there was large variation in precision between individual vessels and species. Additionally, trial setup and process errors were shown to have a large effect on the precision of the video inspectors discard estimates. Nevertheless, despite challenges, REM was evaluated to have the potential to streamline monitoring and scientific documentation in a medium-size fishing fleet.

1. Introduction

In fisheries science, experiments are conducted on scientific vessels and/or using scientific observers on board commercial fisheries vessels. Both methods are costly, resulting in limitation in data collection that can challenge the reliability of quantitative estimates derived from the experiments. Additionally, monitoring the compliance with the Landing Obligation (LO) from the 2013 reform of the Common Fisheries Policy (CFP) (EU, 2013), to be implemented between 2015 and 2019, will require managers to ensure that all catches are documented. Finding ways of ensuring cost-effective high quality catch data is therefore a challenge for both the science and management.

Remote Electronic Monitoring (REM) has been suggested as a cost-effective solution to document the on-board activities on fishing vessels and to fully document catches (e.g. Dalskov and Kindt-Larsen, 2009; Kindt-Larsen et al., 2011; Mangi et al., 2015; Marine Management Organisation, 2013; McElderry et al., 2003; Needle et al., 2015; Ulrich et al., 2015; van Helmond et al., 2015). REM is a full documentation tool that uses closed-circuit-television (CCTV) cameras, GPS and sensors to monitor the fishing operations in-situ. Results from the REM can be used to verify logbook reports from the fishers, suggesting that REM can be used to scientifically verify participatory monitoring programs in the fisheries and as a control tool in fisheries management. However, it is necessary that REM has the sufficient precision and accuracy to verify the fishing activities.

Many previous studies have evaluated REM to be largely reliable and accurate (Ames et al., 2007; Kindt-Larsen et al., 2011; Needle et al., 2015; Stanley et al., 2009, 2011; Ulrich et al., 2015; van Helmond et al., 2015). However, most previous studies included fisheries (such as hook and line fisheries) where it was easy to identify individual fish in the catch (Ames et al., 2007; McElderry et al., 2003) or only focused on a single species in a mixed fishery, usually cod (*Gadus morhua*) (Kindt-Larsen et al., 2011; van Helmond et al., 2015). Within the EU, only the Scottish REM trials have focused

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on monitoring the discard of multiple species in a mixed demersal trawl fishery (Needle et al., 2015), along with unpublished trials at the Danish AgriFish Agency (HeiĐrikur Bergsson pers. com). We use the data collected during a Danish fisheries trial (Mortensen et al., 2016) to expand on the current understanding on the applicability of REM in mixed fisheries. We aim to evaluate the discard estimates made by REM video inspectors for several species and contrast the estimates with the reports of fishers and on-board observers to estimate precision and accuracy of the REM observations.

2. Materials and methods

Data for this study were obtained from the Danish project MINIDISC conducted in Danish and Norwegian waters (Mortensen et al., 2016). The aim of MINIDISC was to evaluate the effect of free gear selection in a catch quota management scheme and included 12 demersal trawlers and 2 Danish seiners. REM was used as a support tool to ensure compliance with the trial guidelines. Each vessel reported catches and discards on a haul by haul basis for seven commercial species, for the period from September 17th 2014 to July 15th 2015. The commercial species included were: cod, hake (*Merluccius merluccius*), haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*), saithe (*Pollachius virens*), plaice (*Pleuronectes platessa*) and Norway lobster (*Nephrops norvegicus*).

Catch and discard data were logged by the fishers on a haul-by-haul basis, either through the national eLog system administrated by the Danish AgriFish Agency or through the software interface of the REM system on-board the vessel. All vessels were equipped with REM, including cameras, GPS and gear sensors, all connected to a control box where data were stored on two mirrored hard-discs. Video recording started when the vessel left the harbour and automatically turned off when entering the harbour again, using the GPS signal to trace position. Cameras recorded activity on the trawl deck and in the catch-handling area, with at least one camera focused directly on the discard chute and the end of the conveyer belt, to the extent permitted by the layout of the handling area. Data from the REM were directly uploaded to local servers using the 4G network when vessels were within coverage, and consisted of video coverage of the entire fishing operation, vessel position and timing of gear deployment and retrieval. Fishers were instructed to sort all discard of the seven species into baskets and show the contents to the camera before discarding.

The REM system and software used to analyse video material was developed by Anchor lab K/S (www.Anchorlab.dk), with a unit price of 45.000 DKK for a system (1 DKK/0.14 USD, 14th November 2016). REM systems were installed on the vessels by a company specialised in ship electronics (SkibsElektro), with the installation cost of approximately 30,000 DKK per vessel, depending on the home harbour and size of the vessel. Due to the wireless transmission of data, operational cost of the REM were relatively low (roughly 10,000 DKK in total, all trips and vessels included) compared to other trials using REM technology that require changing hard disks at regular intervals, which have an annual running cost per vessel of approx. 30,000 DKK (van Helmond et al., 2015). The difference in cost is likely due to man hours spent changing hard disks, which are absent in wireless transmission.

A team of six video inspectors verified the discard, as data were uploaded to the servers. Video inspectors were University students with a background in fisheries science, but with no prior video inspection training. Introductory meetings with the video inspectors were held before initiation of inspection, where the inspectors were instructed in the video inspection procedure and the first week of inspection was done in pairs, to obtain a common understanding of how the inspection should be conducted.

Inspectors would access the oldest trip from participating vessels, which had not been inspected. Hauls would be identified, using data from pressure sensors on wire winches, which indicate deployment and retraction of gears. Inspectors would note time of deployment and subsequently fast-forward to gear retraction and note the time. The sorting and discarding process would then be inspected at 2 x–5 x times speed, with pauses when fishers would display discard buckets to the camera.

Fishers were instructed to sort all discard of the selected species into discard-baskets and show the basket to the camera before discarding. Discard was verified, species identified and discard amounts were estimated by inspectors, along with the monitoring of fish being discarded without sorting. Discard weight was estimated by inspectors by counting baskets. Partly full baskets were estimated in percentages. Subsequently, the number of baskets was multiplied by 35 kg/basket. The weight of 35 kg/basket was used as best estimate of the weight of a basket with mixed fish in the discard size class, derived from experiences in the Danish Agrifish Agency and research on the research vessel DANA. Inspectors did not know the self-reported catch composition, catch amounts or discard amounts, from the fisher, in advance.

To obtain "true" discard values, some trips were made with an on-board observer, who measured all discard of each species, including length and weight. The final dataset thus comprised of discard estimates from fishers, video inspectors and on-board observers.

Video inspection did not start until the trial was half way through, which also meant that video errors and positioning could not be corrected when they were detected. Instead, video inspectors commented on each video in terms of challenges, when inspecting the video and possible errors. To optimise the data set, these errors and challenges were categorised into three groups: camera errors, protocol errors and inspection errors. Camera errors could be hauls with missing footage, reduced video quality and other physical challenges with the video stream. Protocol errors were situations where the fishers did not behave according to experiment agreements and either forgot to show the discard basket to the camera, or did not use a discard basket, etc. Inspection errors were hauls where camera coverage was not sufficient and either discard buckets were out of view of the camera or cameras did not cover the sorting table.

Only hauls with registered discard from either fisher or video inspector were included in the analysis, to avoid a zero inflated data set, due to several trips where both fisher and video inspector agrees on zero discard. All statistical analysis was done in the R statistical software (Full of Ingredients, version 3.2.0) (R Core Team, 2014).

We quantified systematic differences in estimation between fishers and video inspectors. A systematic difference is the continuous over- or underestimation of discard by one method (e.g., fishers discard estimate) in relation to the opposing method (e.g., video inspectors discard estimate). The systematic difference between fishers and video inspectors' ability to estimate discard weight was analysed using normal linear regression. The linear regressions were conducted with video inspectors' discard estimates as the dependent variable and fishers' estimates as explanatory variable, using the *lm* function in R-package base. The intercept was set to 0, which assumes that agreeing on zero discard would be easy. This also allows easy interpretation of the model fit, because the systematic difference can be inferred from the estimated slope of the regression line, α. The model may thus be written as:

$$y_i = \alpha x_i + \varepsilon_i$$

where y is the video inspectors' estimates of discard in kg and x is the fishers' estimates of discard in kg and i is an index for trip.