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Remote monitoring of the bycatch of demersal chondrichthyans using video imagery: a case study from a deep-water crustacean trawler

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ABSTRACT: Effective monitoring and reporting of fisheries are crucial for successful management and are typically done by at-sea observers and fishers, respectively. However, this system can produce biased information due to economic and social limitations. Electronic monitoring and reporting systems (EMRs) are becoming more prevalent and are seen as a solution to combat illegal, unreported, and unregulated fishing. The present study aimed to test the effectiveness of an integrated EMR in identifying demersal and deep-sea sharks, skates, and chimaeras (hereafter chondrichthyans), which are bycatch in the Portuguese crustacean bottom trawl fishery. Footage (42 h) was thoroughly examined and provided identification of 2182 individuals representing 11 taxa. The majority were identified to the genus level, and some even to the species level. Only 0.9% of the chondrichthyans could not be identified. Furthermore, the highest bycatch rates of chondrichthyans were from the genera *Etmopterus* and *Galeus*. The limitations of the technology are discussed, and suggestions for improvement are made to enhance future research proposals and improve the overall design of the system. However, the successful implementation of the EMR in this study and other case studies worldwide demonstrates its potential for upscaling to other fisheries, contributing significantly to more sustainable fishing practices and better management of marine resources.

KEY WORDS: Electronic monitoring · Electronic reporting · Fisheries logbook · Fisheries management · Sharks · Skates

1. INTRODUCTION

Ensuring the sustainable future of fisheries relies on the successful implementation of effective monitoring and reporting systems, an ongoing challenge faced globally (Boenish et al. 2020). Diverse monitoring schemes are employed worldwide, such as dockside and at-sea observation programs, fisheries surveys, interviews, collaborative sampling initiatives, smartphone reporting, and electronic monitoring and reporting (Gilman et al. 2012, Mangi et al. 2015). However, these approaches face various difficulties, including limited funding, technological constraints, logistic complexity, inadequate coordination, and resistance from fishers (de Graaf et al. 2011, Poos et al. 2013).

The reporting systems often rely on data provided by fishers, which can introduce biases and frequently omit information about discarded species, including those species that are endangered (van Helmond et al. 2020, Suuronen & Gilman 2020). Economic and regulatory pressures may lead fishers to underreport

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or fail to record the capture and discard of non-target species (Brown 2001, Walsh et al. 2002, 2005, Gilman et al. 2020). Additionally, fishers' reports may be considered unreliable due to the absence of formal training in standardized data collection and reporting methods (Stobberup et al. 2021). Thus, how fisheries are reported depends on the local fishery authorities. Requirements vary from place to place, but usually, they are focused on the industrial fisheries landed catch and fisher-based information (Poos et al. 2013, Boenish et al. 2020). For instance, in the European Union (EU), how fisheries are reported depends on the size of the vessel: paper forms are used for vessels from 10 to 12 m in length, while electronic reporting is used for vessels >12 m in length (EU Regulation 404/2011; https://eur-lex.europa.eu/eli/reg_impl/2011/404/oj/eng), both focused on the landed catch. However, recently, legislative proposals emphasized compulsory camera use for boats exceeding 18 m in length 'that may pose a risk of non-compliance' (EU Regulation 1224/2009; https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32009R1224, EU 2023). However, the landed catch reporting scheme poses a worldwide challenge. This method lacks information of an important portion on the catch since discards are not counted and/or are exclusively monitored by expensive and low-coverage human observer programs (van Helmond et al. 2020, Suuronen & Gilman 2020). For instance, the bottom trawl fishery represents 46% of the total global annual discards and can reach up to 60% in the EU (Condie et al. 2014, Pérez-Roda et al. 2019).

To cope with these problems, human at-sea observers are thus far the most widespread, accurate, and reliable source of fisheries monitoring (Mangi et al. 2015). This method is recommended by the Common Fisheries Policy (EU Regulation 1380/2013; https://eur-lex.europa.eu/eli/reg/2013/1380/oj/eng) and adopted by countries worldwide and in the EU (including Portugal). Nevertheless, this type of monitoring program presents its own set of challenges. Observers are not always available to record data because of basic physiological needs (sleep, nutrition) or may be coerced by fishers to not report certain situations (Ewell et al. 2020, Teye et al. 2020). Additionally, the digitalization of information collected onboard may result in long delays in the analytical process and can introduce errors and inaccuracy in the results (Alverson et al. 1994, Liggins et al. 1996, Gilman & Zimring 2018, Suuronen & Gilman 2020). Hence, this system has been transiting to electronic monitoring and reporting systems (EMRs), which are proving to be more reliable and efficient, providing means for speeding up the analysis (Lee Son et al. 2023). Further, EMRs are already implemented in various fisheries in countries such as Australia, New Zealand, the Netherlands, and the USA (Borges 2015, van Helmond et al. 2020).

Electronic monitoring (EM) has been suggested as a reliable approach to observer programs for the purse seine fishery (Murua et al. 2020) and for the crustacean bottom trawl fishery (88% effectiveness; Moncrief-Cox et al. 2020). EM has also been presented as a solution to combat illegal, unreported, and unregulated (IUU) fishing and biased information (Barkai et al. 2010, van Helmond et al. 2019, Stobberup et al. 2021), and can assist authorities in monitoring catches of endangered and protected species (Suuronen & Gilman 2020, Pierre et al. 2022). Likewise, EM is helpful for monitoring species with a total allowable catch (TAC), especially those subjected to landing obligations (Catchpole et al. 2017). Hence, EM could and should be used to monitor bycatch and discard rates of protected species that must be discarded upon collection, such as deep-sea sharks (EU Regulation 2021/91; https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32021R0091), or that have a TAC, and thus are subject to landing obligations, such as the skates of the order Rajiformes (EU Regulation 2024/1015; https://eur-lex.europa.eu/eli/reg/2024/1015/oj/eng). EM is particularly relevant in fisheries such as longline, purse seine, and bottom trawl, that have high bycatch of chondrichthyans (i.e. sharks, skates, and chimaeras) and other megafauna such as sea turtles and marine mammals (Alverson et al. 1994, Komoroske & Lewison 2015, Oliver et al. 2015, Graça Aranha et al. 2025). For instance, the crustacean bottom trawling activities on the southern coast of Portugal are responsible for high bycatch weight of chondrichthyans, reaching up to 60% of the total catch weight (Borges et al. 2001, Monteiro et al. 2001, Coelho & Erzini 2008, Graça Aranha et al. 2023, 2025). However, the general lack of (or biased) data on the chondrichthyans discarded by bottom trawling and other fisheries emphasizes the need for combining EM systems with electronic reporting for data verification (Barkai & Meredith 2010). This lack of data was the premise for the implementation of the project 'Electronic Monitoring and Reporting Technology for Fisheries in Portugal' (EMREP; https://www.eeagrants.gov.pt/en/programmes/blue-growth/projects/projects/emrep/). The goal of the EMREP was to integrate an existing and commonly used commercial fishing logbook technology (eLog) with footage from onboard cameras, creating an integrated electronic monitoring and reporting solution (iEMR) using the Portuguese crustacean bottom trawling fleet as a case study. The Olrac® eLog technology developed by OLSPS® was selected for this purpose. The system comprises a vessel-based eLog software application named Olrac Dynamic Data Logger® (Olrac® DDL) and a web-based fleet management application named Olrac Dynamic Data Manager® (Olrac® DDM). The Olrac® DDL is certified and used by commercial fisheries and government agencies in several countries (e.g. Australia, New Zealand, UK); however, in Portugal, this study represents the first trial of the software. In the present study, the Olrac® iEMR was used to remotely count and identify demersal and deep-sea chondrichthyans to the lowest taxonomic level possible, working to improve discard data collection and reliability.

2. MATERIALS AND METHODS

The EMR trials were conducted using a volunteer commercial crustacean bottom trawler (23 m total length, 8 m width). The vessel operates off the south and southwest coasts of Portugal (36.7–37.8° N, 7.7–9.6° W), the most important crustacean fishing ground for Portuguese bottom trawlers (Borges et al. 2001).

2.1. Operational system

The operational system consisted of 2 cameras (Marine HD PoE®, model 0482-6030), with a scalable resolution up to 1920 × 1080 providing razor sharp 1080p HD video at a frame rate of 25/30 fps with auto focus, 48× digital zoom, and integrated IR LED illuminators for day and night observations. They were connected to a network switch with 16-way power over ethernet. The cameras were installed in the participating fishing trawler in areas allowing the best view of discards and fishing activities (e.g. net arrival, catch sorting) while guaranteeing the crew members' privacy. The first camera was positioned above the sorting table (Fig. 1), strategically installed to provide a clear and undistorted view of the whole sorting table and discards belt and to be out of the way of the fishers to avoid collisions and prevent the images from being obscured by the fishers. The second camera was installed on the main mast to capture the entire main deck, aiming to cover the net arrival and deployment area (Fig. 2), where larger organisms are sometimes discarded prior to the arrival at the sorting table. Both cameras were screwed into metal fixtures to guarantee the same catch observation angle and position throughout the study.

The cameras recorded the fishing activity in an external hard drive with 2 or 4 TB of space, which

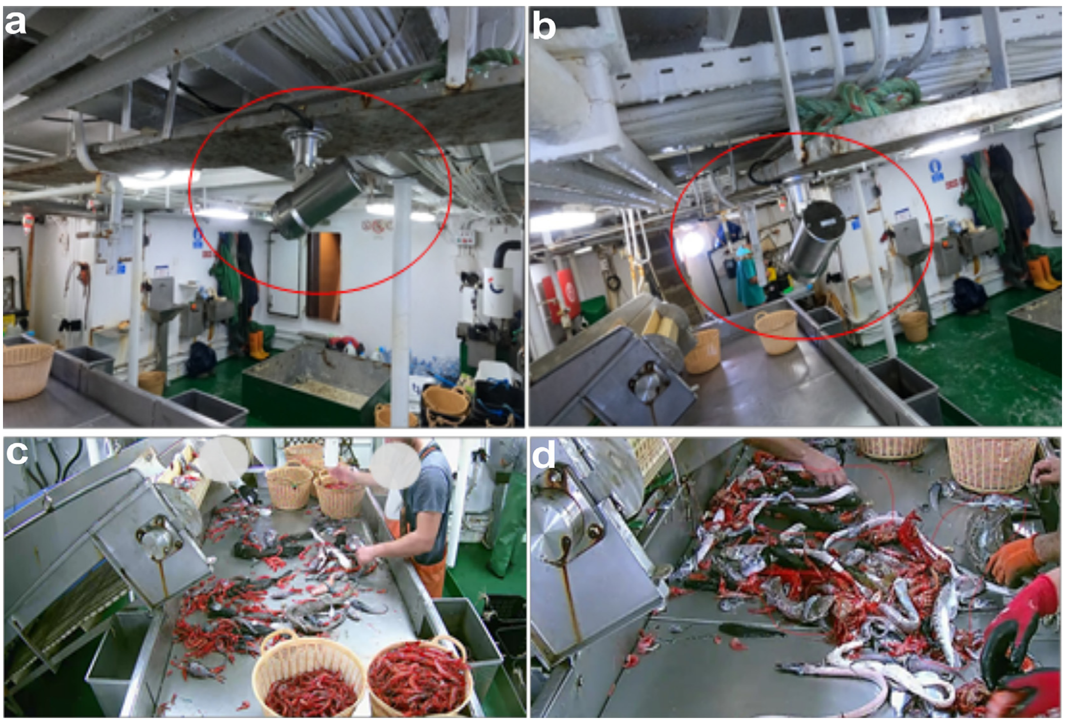

Fig. 1. (a) Side and (b) rear view of a camera (circled in red) installed above the sorting table and (c,d) images with zoom from the integrated electronic monitoring and reporting solution, the Olrac® iEMR

was manually replaced every 15 d. The recording system is activated with motion detection in a designated frame area previously selected by the user. Recording started every time a movement was detected on the main deck and/or at the sorting table, and stopped when no activity was detected. The electronic reporting system, i.e. the Olrac® DDL, was then integrated with an EM system using

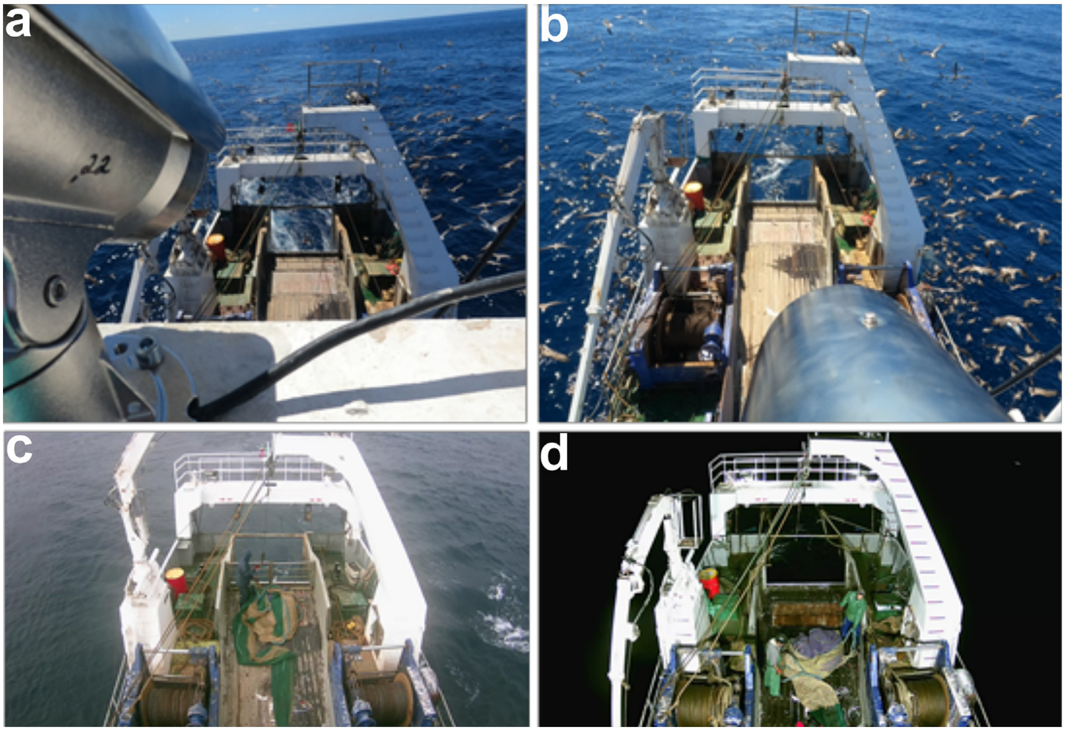

Fig. 2. (a,b) Camera aimed at the main deck, with its (c) daytime and (d) nighttime view accessed from the images of the integrated electronic monitoring and reporting solution, the Olrac® iEMR

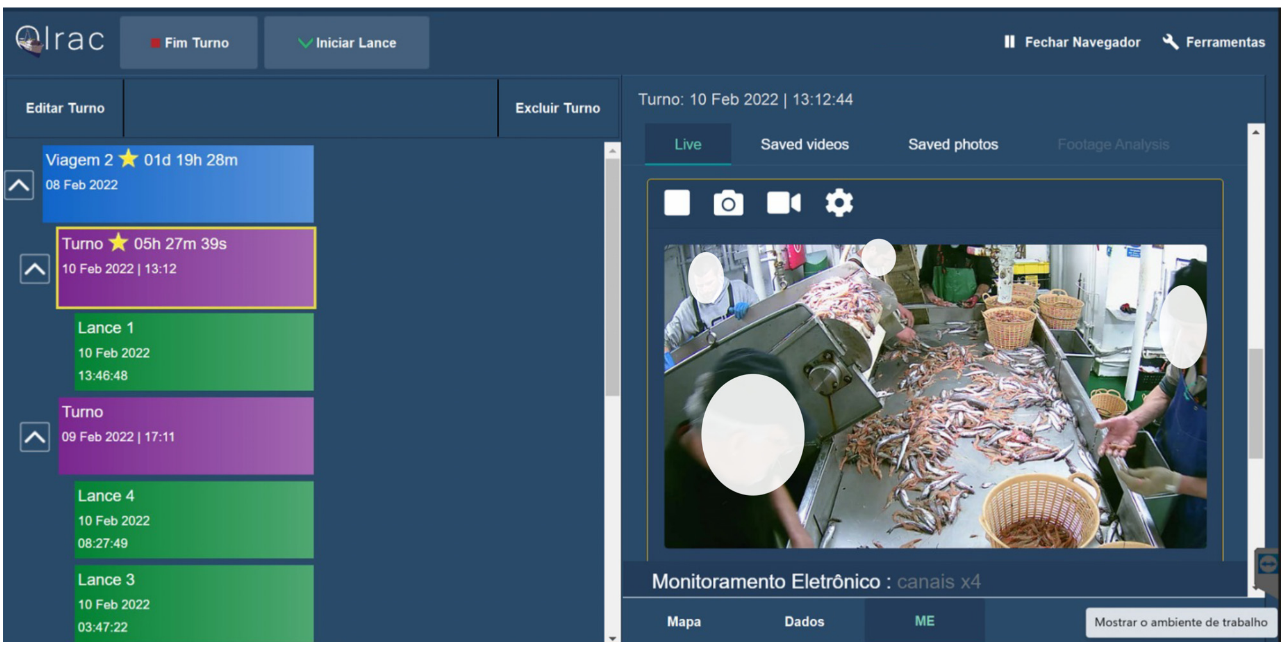

Fig. 3. General view of the Portuguese version of the integrated electronic monitoring and reporting solution, the Olrac® iEMR, showing the data input during operation for each haul (left side) and the general view from the at-sea cameras (right side)

footage from the at-sea cameras, creating the iEMR (Olrac® iEMR) (Fig. 3).

The Olrac® iEMR holds essential information related to the target species and discards for compliance with the authorities, and has an option to change to a scientific version where further information about each chondrichthyan individual could be inserted (e.g. size, sex, weight). Vessel coordinates (automatically registered using a GPS), fishing depth (m), codend mesh size (mm), and catch and bycatch information were entered into the Olrac® iEMR either by the skipper or by researchers when onboard. Whenever researchers were not onboard, data such as target type, fishing depth, season, vessel coordinates, and start and end of each haul were collected using the information entered by the skipper in the Olrac® iEMR. Haul duration was timed from the moment the fishing net touched the seabed up to the moment the net started to be lifted. Following each haul, sorting events took place, where fishers sorted the catch until there was no more activity at the sorting table. Hence, 1 haul is related to 1 sorting event. Sorting time was measured from the moment fishers began separating the catch until the end of the sorting procedures.

2.2. Footage analysis

In total, 210 h of footage were collected from fishing trips conducted in September 2021 and February, March, and April 2022. Approximately 20% of the total footage recorded was randomly chosen and thoroughly analyzed. The randomization process considered the total hours of footage available from each month and the number of sorting events. For instance, in September, 29 h and 24 min were recorded, corresponding to 25 sorting events. Thus, 20% of this total corresponded to 5 h and 53 min, and 5 sorting events were randomly selected and fully examined. This approach follows the risk-based analysis recommendation of the European Fisheries Control Agency (EFCA 2019), which recommends a minimum percentage of 5% footage review to achieve an overall picture. Furthermore, it aligns with common footage-reviewing practices in Europe for demersal trawlers where 10–20% of the collected footage is evaluated (Course et al. 2011, Needle et al. 2015, Ulrich et al. 2015, van Helmond et al. 2020).

For the sorting events conducted in September 2021 and the first week of February and March 2022, researchers were onboard the vessel to ensure the proper functioning of the iEMR system. The remaining footage, i.e. the last 3 wk of February and in April 2022, was obtained without researchers onboard.

The selected footage was thoroughly examined by a human video analyst, with expertise in the identification of chondrichthyans, using the open-source software Milestone Xprotect® Smart Client 2020 R3. Chondrichthyans were identified to the lowest taxonomic level possible, except for skates, which were identified to order, because in EU waters, all skates from the order Rajiformes are subjected to a TAC (except for *Raja undulata* in Subarea IX). The images were reviewed at normal speed, and varying zooms and focus adjustments were made as necessary for the precise identification of each individual. To validate the identification of the individuals using the Olrac® iEMR, there was an attempt to conduct *in situ* observations of the same sorting events, where at-sea researchers passively evaluated the catch, identifying the chondrichthyans from the same distance as the cameras. Unfortunately, the selected sorting events coincided with cameras' signal loss; therefore, cross validation with *in situ* data was not possible. Hence, in order to examine the taxonomic identification provided in this study using the EM method, screenshots of the sharks at the sorting table are provided (Fig. A1 in the Appendix) as well as the key aspects of each genus/species used to identify the individuals (see Table 3).

Key events, including the time when a chondrichthyan was spotted, the initiation and conclusion of the catch-sorting events, periods of camera signal loss, and chondrichthyan count by species and/or genus, were systematically recorded in an Excel spreadsheet. The dynamic nature of the analysis allowed for pauses, zooming in, or playing backward whenever specific details required closer scrutiny. After the footage analysis, data for each examined haul — such as fishing depth, season, and vessel coordinates — were verified using the Olrac® iEMR as previously mentioned.

The number of chondrichthyans per minute of footage was calculated considering the number of chondrichthyans observed during the sorting of the catch. The calculation was done by dividing the total number of chondrichthyans observed by the minutes that each sorting event lasted for each month. The chondrichthyans per minute of footage calculation did not account for footage signal loss (when applicable) or the total collected footage time.

3. RESULTS

We analyzed a total of 42:20:46 h of footage, of which 21:04:43 h were from sorting procedure. The analyzed footage corresponded to 27 different hauls (sorting events) conducted across 4 mo, with an aver-

Table 1. Evaluated months with the amount of sorting events, fishing effort (average haul duration), total amount of footage analyzed, duration of each sorting event, camera signal loss, total number of chondrichthyan individuals, and number of chondrichthyans per minute of sorting time analyzed from an electronic monitoring trial on the S and SW coasts of Portugal

Month	Sorting events (n)	Effort (h) (mean ± SE)	Footage time analyzed (h:mm:ss)	Sorting time (min)	Signal loss (hh:mm:ss)	Chondrichthyans (n)	Chondrichthyans min^{-1} (n)
September 2021	5	4.45 ± 0.31	05:53:47	94	00:48:00	141	1.5
February 2022 (Week 1)	2	4.03 ± 0.09	02:53:57	82	01:03:00	99	1.2
February 2022 (Weeks 2–4)	16	5.82 ± 0.51	26:51:16	853	0	1422	1.7
March 2022	3	4.07 ± 0.22	05:08:50	192	0	482	2.5
April 2022	1	5.93 ± 0	01:32:56	41	0	51	1.2

age fishing effort of 5.17 h per haul. The average duration of each sorting procedure was 47 min (Table 1).

Sorting events that took place in September 2021 and in the first week of February 2022 presented connection problems, given that cameras were set to record only when a maximum footage quality (1080p HD, the default setting) interval was available, which caused latency and led to a system error. As a result, there was a total footage loss of 14 and 36% (Table 1). However, after changing this setting to record regardless of the quality available, results showed an improvement in the EM system, resulting in no signal loss in the months following the setting adjustments (Table 1).

Each minute of footage analyzed from the sorting procedure included at least 1 elasmobranch individual for the months of September, February and March and more than 2 for April 2022 (Table 1). A total of 2195 individuals, representing 11 taxa, were identified to the order (1, n = 6), genus (4, n = 1997), or species (6, n = 179) level. Notably, only 13 sharks could not be identified in the footage analysis, constituting only 0.9% of the total observed individuals (Table 2). Regarding the most captured taxa, the genus *Galeus* was the most representative, followed by the genera *Etmopterus* and *Deania*.

Table 2. Taxa of demersal and deep-sea chondrichthyans and the total number of individuals identified using the integrated electronic monitoring and reporting solution (iEMR). 'Skates' refers to demersal species of Rajiformes that are not deep-sea species

Taxon	Individuals (n)
Galeus melastomus/atlanticus	922
Etmopterus spinax/pusillus	870
Deania calceus/profundorum	199
Scymnodon ringens	97
Scyliorhinus canicula	72
Unidentified deep-water shark	13
Dipturus spp.	6
Skates	6
Dalatias licha	4
Chimaera monstrosa	3
Galeorhinus galeus	2
Chlamydoselachus anguineus	1
Total	2195

Due to taxonomic concerns, specimens that required manipulation for correct identification, or that did not have satisfactory details in the footage to allow identification to species level, were grouped at the genus level. This taxonomic similarity was the case for deep-sea species from the genera *Galeus*, *Etmopterus*, *Deania*, and *Dipturus*. These species differed by details that could not be resolved in the footage (Table 3).

The key taxonomic characteristics used to identify the species/genera in this study and identification limitations using the footage are summarized in Table 3. Additionally, Fig. A1 shows example footage of some of the specimens identified in the present study.

4. DISCUSSION

Commonly used fisheries monitoring procedures pose a challenge for the acquisition of accurate and reliable catch and bycatch data. EMRs have increasingly been used as innovative solutions to replace the traditional observer monitoring programs, combating IUU, and working as a compliance and fisheries management tool (Needle et al. 2015, Gilman et al. 2020, van Helmond et al. 2020). In the present study, EMR technology was tested for the first time in a Portuguese fishery. The solution used an integrative EM system (video cameras) with an electronic reporting system (eLog Olrac® DDL), resulting in the Olrac® iEMR. This system was tested by identifying demersal and deep-sea chondrichthyans through video analysis.

Table 3. Taxonomic key characteristics (Compagno 1984, Nelson 1994, Last et al. 2016, Ebert & Fowler 2021) used to identify the chondrichthyans observed in the footage in the present study and the identification limitations from video analysis

Genus	Genus characteristics	Species	Species characteristics	Species identification limitations
Galeus	Color light grey or brown with dark barring, blotches and spots pattern; long and wedge-shaped snout; anal fin present	*G. melastomus*	White color of the groove formed by the labial furrows; caudal upper edge with small denticles	Species identification requires manipulation
		G. atlanticus	Blackish color of the groove formed by the labial furrows; caudal upper edge with larger denticles	Species identification requires manipulation
Deania	Color dark grey or brown; extremely long snout, large, grooved spines on dorsal fin	*D. calceus*	No subcaudal keel on caudal peduncle	Species identification requires manipulation
		D. profundorum	Subcaudal keel on underside of caudal peduncle	Species identification requires manipulation
Etmopterus	Short to moderate snout; small body; color variable, from blackish to tan, often with prominent dark markings on underside of head and caudal peduncle; no anal fin	*E. pusillus*	Smooth skin, relatively uniform color	Species identification requires manipulation
		E. spinax	Coarse skin, strongly marked body coloring	Species identification requires manipulation
Dalatias	Snout broadly conical, rounded, and short; color greyish to black or blackish brown; spineless dorsal fins; no anal fin	*D. licha*	Only species of its genus	None
Scymnodon	Moderate long to short snout; stocky body; dark color; small dorsal fin spines; no anal fin	*S. ringens*	Only species of its genus occurring in Portugal	None
Galeorhinus	Snout moderately long and parabolic in dorso-ventral view; eyes horizontally oval and lateral; second dorsal fin much smaller than first; extremely long terminal caudal lobe about half the dorsal caudal margin; anal fin present	*G. galeus*	Only species of its genus	None
Chlamydoselachus	Eel-like shark with 6 gill slits; dark brown or grey in color; only 1 dorsal fin; anal fin present	*C. anguineus*	Only species of its genus occurring in Portugal	None
Scyliorhinus	Color pattern extremely variable, # ranging from simple dark saddles, reticulating dark bars, or large dark spots on a light background to combinations of light and dark spots and saddles; second dorsal fin much smaller than first	*S. canicula*	Small dark spots all over body, but completely white ventral region	Can be mistaken with *S. stellaris*, depending on the area and depth sampled
Dipturus	Skate with a long and pointed snout; anterior disc margin concave	*D. batis*	Brownish-green color with white spots on the dorsal surface; ventral side with dark spots or marbling; absence of black mucus in the abdomen	Species identification requires manipulation
		D. oxyrinchus	Black color with white spots on the dorsal surface; ventral side with dark and white spots; absence of black mucus in the abdomen; rostrum 60% longer than head	Species identification requires manipulation
		D. nidarosiensis	Uniformly dark color on ventral and dorsal sides; dark mucus in the abdomen	Species identification requires manipulation
Chimaera	No gill slits; anal fin which is separate from the ventral caudal margin by a notch; smooth skin; large eyes; rabbit-like appearance	*C. monstrosa*	Reddish-brown, silver-grey body coloration; longitudinal stripes on dorsal side	None

The quality of the footage and camera settings of the Olrac® iEMR were satisfactory to identify and count individual chondrichthyans of the species *Scymnodon ringens*, *Chlamydoselachus anguineus*, *Dalatias licha*, and *Galeorhinus galeus* and from the order Rajiformes. These data could help decrease IUU fishing and support and enhance fisheries monitoring and management, by providing essential information on their abundance and distribution for effective conservation efforts (Ruiz-García et al. 2023). Understanding their abundance and distribution will contribute to increase the scientific knowledge and help to map high-density bycatch areas. These data are crucial for mitigating impacts on endangered species and species of conservation concern such as *C. anguineus, D. licha*, and *G. galeus*. Thus, the use of EM for deep-sea chondrichthyans can support information for the implementation of measures such as fishing closures or serving as a bycatch avoidance tool by authorities and skippers. In the case of individuals from the order Rajiformes, which have biannual quotas and are subject to landing obligations in the EU, EM could provide a means to remotely monitor the discards of specimens that are not landed due to minimum size restrictions (<52 cm) or low commercial value. Landing obligations started in 2015 through the Common Fisheries Policy (Article 15 of Regulation 1380/2013) to reduce unwanted catches by EU fishing vessels. In the North Atlantic, under the landing obligation, fishers were asked to land all species subjected to a TAC, with some exemptions. To facilitate the implementation of the landing obligations and avoid the risk for early closures of fisheries, TAC was increased above scientific advice, in general by 36% (up to 60% for demersal species, Borges 2021). However, fishers are not complying with the landing obligations (Savina 2019, Borges 2021). Hence, the discard issue in EU fisheries remains and has worsened due to a combination of TAC top-ups and the non-compliance of the landing obligations. This non-compliance could be overcome with EM using similar tools as the Olrac® iEMR, which was effective for counting and identifying individual Rajiformes. This system could equally help in identifying other species with TACs. Thus, further trials should be conducted to test the effectiveness of this system in counting and identifying other species of interest in bottom trawls and other fisheries.

In addition to the Olrac® iEMR, applied here to monitor chondrichthyan discards, other systems have been implemented worldwide, showcasing advances in fisheries monitoring. For instance, Murua et al. (2020) demonstrated that EM can be as reliable as observer programs for the purse seine fishery. In turn, in the crustacean bottom trawl fishery, Moncrief-Cox et al. (2020) achieved an observation rate of 88% effectiveness, which, although slightly lower than that of at-sea observers, aligns with findings from Ames (2005) in longline fisheries. Furthermore, EM has also proven to be effective in monitoring megafauna bycatch, including sea turtles, sea birds, and marine mammals in gillnet and hook fisheries (Bartholomew et al. 2018, Emery et al. 2019, Glemarec et al. 2020). Moreover, the scope of EMRs is expanding, adding fisheries to monitor at-sea labor rights, enhancing the safety of at-sea observers and fishers, and reducing corruption risk (Garcia 2024, O'Neill & Kaiser 2024). These advancements highlight the broad applicability and growing potential of EMRs in fisheries management and beyond.

Although EM is a helpful solution for fisheries management and catch and bycatch data collection, some challenges still need to be overcome (Needle et al. 2015). The greatest limitation to using EM in the present study was the inability to identify most individuals to the species level because of the remarkable morphological similarity between some congeneric species. Species of the genera *Galeus*, *Etmopterus*, *Deania*, and *Dipturus* are difficult to identify without careful manipulation due to intricate details that separate the species, and even then, they are still difficult to tell apart by less experienced at-sea observers. For instance, identification of *G. melastomus* and *G. atlanticus* is challenging, since careful handling is required to check the color of the labial furrows (Table 3, Rey et al. 2006). Furthermore, *Deania* spp. are mainly distinguished by the presence of a subcaudal keel on the ventral side of the caudal peduncle of *D. profundorum* (Last et al. 2016). Likewise, *E. spinax* and *E. pusillus* are identified by their slight differences in color and denticles (Ebert & Fowler 2021). While the genus *Dipturus* includes deep-sea skates that are challenging to distinguish, previous studies have shown that *D. nidarosiensis* and *D. oxyrinchus* are frequently found in the studied area (Graça Aranha et al. 2025) and are distinguished by the existence of small white dots along the dorsal surface of *D. oxyrinchus*, which are absent in *D. nidarosiensis* (Last et al. 2016). The similarity between these congeners, and the inherent difficulty in remotely identifying individuals to the species level is of concern, since they are frequent in the bycatch of crustacean bottom trawlers and have different levels of protection (Oliver et al. 2015, Graça Aranha et al. 2025). Some of these species, such as *Galeus* spp., *E. pusillus*, and *D. profundorum*, are not protected. Others, like *E. spi-*

nax, *E. princeps*, and *D. calceus*, are included in the EU list of deep-sea sharks, which means they have a zero TAC and should be discarded upon capture (EU Regulation 2021/91). Additionally, other chondrichthyan species that were not observed during this study can occur on the Portuguese coast and may also present identification challenges, such as *Chimaera notafricana* and *Hydrolagus lusitanicus*, *Scyliorhinus stellaris*, and *E. princeps* (Almeida & Biscoito 2019).

Ensuring the correct functioning of the EM system is of utmost importance to properly monitor fisheries. Connectivity issues were detected in this study, resulting in data loss. The data loss issue, as a result of poor footage quality, storage problems, or camera view obstruction by fishers, was also addressed in other trial studies (Götz et al. 2015, Plet-Hansen et al. 2015, 2019, Bergsson & Plet-Hansen 2016). In our study, the cameras were initially set to record only when a maximum footage quality (i.e. when using the default setting of 1080p HD) interval was available, which caused latency and led to a system error. The fluctuations in quality could be attributed to factors such as the autofocus adjustment, changes in luminosity, or reflectivity from surfaces within the camera's field of view (e.g. the metal sorting table). However, after changing the camera's default streaming setting to record continuously, regardless of the available quality interval (always prioritizing the maximum available quality), there was a noticeable improvement in the EM system. Following this adjustment, there were no instances of latency or signal loss in subsequent months. Hence, when establishing an EM system for future studies, trials are advised, where the quality of the image, camera angle, and position and the camera settings are tested prior to the actual data collection to ensure that no data are lost during the refinement process and that the best view and image quality are achieved.

Other concerns relate to the adoption of EM tools by fishers and agencies, and the time-consuming review of the footage (van Helmond et al. 2020). For instance, reviewing 100% of only 1 wk of the catch and bycatch footage from bottom trawlers can take up to 3 mo (Needle at al. 2015, van Helmond et al. 2020). The latter issue is being addressed in the longline fishery through the implementation of machine learning algorithms using artificial intelligence (AI) which automate and speed up monitoring procedures (Oliver et al. 2015, Awalludin et al. 2020, Kay & Merrifield 2021, Mei et al. 2021, 2022). In bottom trawlers, the EMREP project is testing the usefulness of AI in automatically identifying deep-sea elasmobranchs among the catch from onboard footage. However, the similarity between congeners, combined with the procedures conducted onboard the study vessel, poses a significant challenge. These procedures include fast bycatch discarding, crew overlapping or shading the images, and animals overlapping each other. This challenge is particularly pronounced in muddy bottoms, where the catch is usually covered in mud. Nevertheless, AI can be beneficial for some trawlers, because each vessel operates in different settings (e.g. crew number, sorting procedures, different sorting table layouts). Modifications to sorting procedures in trawl fisheries, such as using a sensor with cameras at the conveyor belt (Vilas et al. 2020) or placing conspecifics inside baskets or separately on the sorting table or discarding belt (Fig. A1; van Helmond et al. 2020), could potentially facilitate the use of AI for the bottom trawling sector. However, it is believed that even with the highest footage quality, and the great advancements in the AI technology, identifying individuals up to species level is an issue that may remain. In this matter, in order to make use of the available EM tools to remotely monitor elasmobranch bycatch, an effort could be made to set uniform regulatory measures for these congeners, which would require further bio-ecological studies to improve the existing knowledge about their populations and distributions.

Given that EM is still undergoing trials and requires refinement, especially in the context of bottom trawl fisheries, the continued deployment of trained at-sea observers is still necessary when applicable (e.g. to monitor deep-sea fisheries) for accurately identifying individuals and ensuring proper handling. Furthermore, at-sea observers have access to critical information on the sexual maturation, age, and individual life status, which cannot be addressed by EM (Sylvia et al. 2016, Suuronen & Gilman 2020), but is crucial for understanding species dynamics of elasmobranchs. On the other hand, the ability of EM to monitor elasmobranchs without an at-sea observer onboard may be beneficial. This ability can mitigate potential bias introduced by variations in skipper behavior when an observer is present (Borges et al. 2008). Therefore, for the time being, the combined use of EM and at-sea observers to control and monitor IUU catches and enforcement of regulatory measures in bottom trawlers is advised. For future studies, we recommend incorporating additional cameras, especially on the sorting table and discard belt in the case of bottom trawlers. These extra cameras can improve catch visibility angles and aid in identifying individuals at the highest possible taxonomic level. Furthermore, implementing a backup system is crucial to prevent any footage loss. We also recommend configuring the recording CCTV system to capture video in all image quality intervals, as the quality may vary depending on lighting conditions, material reflectivity, and focus adjustments. Despite the constraints found in the present study, mainly regarding identification to species level, it is crucial to acknowledge EM as an innovative and helpful technology. The iEMR has the potential to streamline the feedback process for fisheries data analyses, aiding fishery managers, improving data treatment for the scientific community, and guiding fishers toward more selective practices. This system not only addresses existing knowledge gaps, but also holds promise for advancing monitoring and reporting technology, both within Portugal and globally.

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Appendix.

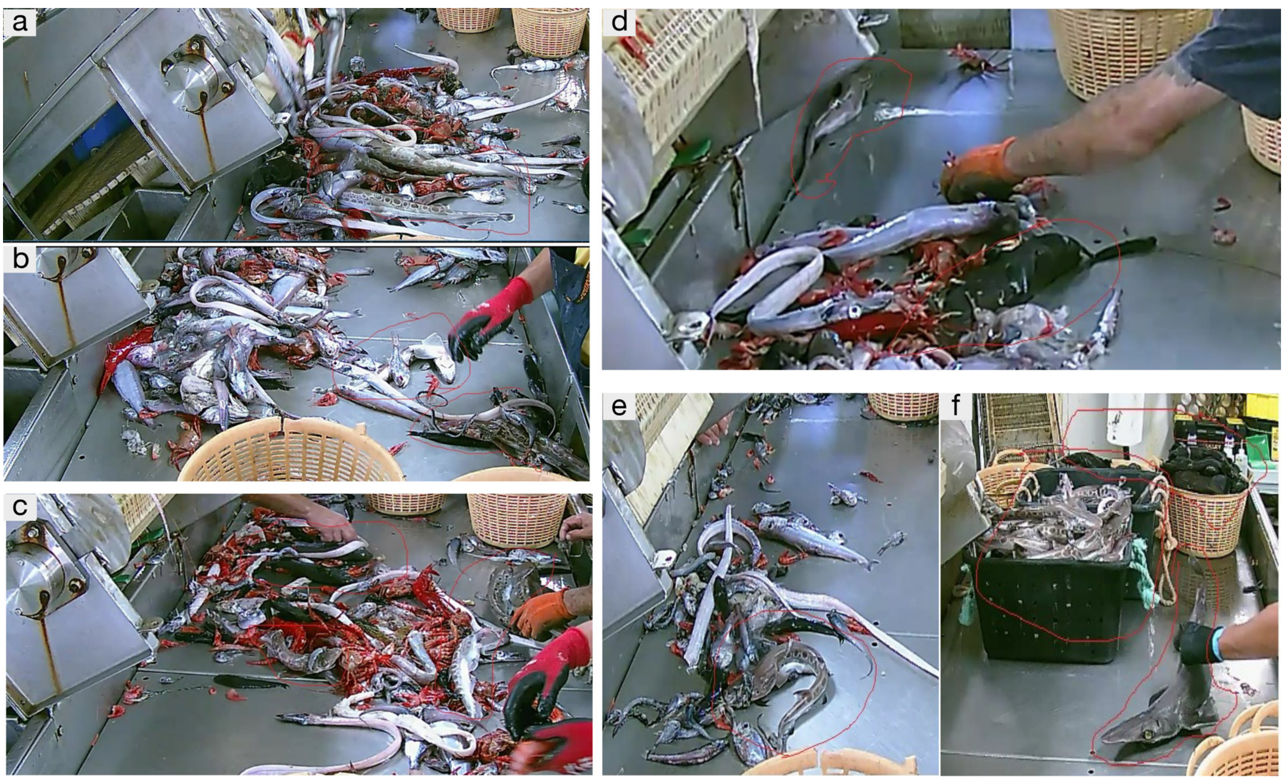

Fig. A1. Examples of footage used in the identification of elasmobranchs (red faint circles) found in the present study. (a) Catch overlapped; presence of *Galeus* spp., *Etmopterus* spp., and possibly *Scymnodon ringens*. (b) Catch overlapped; presence of *Galeus* spp. (c) Catch less overlapped; presence of *Galeus* spp., *S. ringens*, and possibly *Etmopterus* spp. (d) Image zoomed in on *S. ringens*. (e) Image zoomed in on *Galeus* spp. (f) Example of the catch sorted in buckets that could facilitate species identification using artificial intelligence: one bucket with *Galeus* spp. and another with *S. ringens* mixed with *Etmopterus* spp. and a single *Deania* spp.

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