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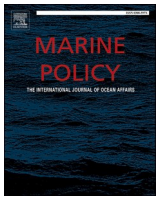

Fishing for solutions: Norwegian fishers' perspectives on the implementation of automatic catch registration for combating IUU fishing

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ABSTRACT

Fisheries and other activities that exploit nature threaten biodiversity if not effectively managed. With global population growth and increasing demand for seafood, pressure on marine resource-based activities, including fisheries, increases. Concurrently, economic incentives, weak management, and inadequate enforcement enable Illegal, Unreported, and Unregulated (IUU) fishing, undermining sustainability. Achieving a sustainable global fishery that meets rising nutritional demands, in line with Sustainable Development Goal 14, requires efforts to reduce IUU fishing. Automatic catch registration on fishing vessels is proposed to enhance transparency and traceability, improving monitoring, control, and surveillance in fisheries. However, its success depends on industry adoption. We engaged Norwegian fishing fleet representatives in a workshop to discuss their preferences for implementing such technologies. Through conceptual mapping, we identified key themes likely to influence successful implementation. Technological and regulatory factors were perceived as particularly impactful. Participants raised concerns about equipment and operational costs, technological reliability and accuracy, and frustration with perceived top-down management. Although initial skepticism was evident, participants acknowledged potential benefits under certain conditions, including the opportunity to achieve higher prices for fully documented fish, replacement of existing reporting procedures, and greater legal protection and fairness in enforcement. Realizing these benefits was seen as dependent on transparent policy development and stakeholder involvement in the implementation process. To support industry adoption, participants emphasized the need to address the practical, financial, and regulatory challenges they may face. These findings underscore the importance of stakeholder-informed policy to support adoption, strengthen legitimacy, and enable effective implementation in efforts to reduce IUU fishing.

1. Introduction

Fisheries have been a vital source of food and income for centuries in nations across the world [1]. However, in earlier times, the available fisheries harvesting technologies were limited in capacity, operating within the natural boundaries of the environment. Recent significant developments in these technologies have enabled the fishing capacity to exceed natural limitations, which, in turn, has opened for detrimental effects on single species or even whole ecosystems in the absence of efficient resource control. In Norway, for example, this led to the collapse of the Norwegian spring spawning herring in the late 1960s [2]. Globally, exploitation of nature, such as through fisheries, has been identified as one of the major drivers for biodiversity loss. In turn, this has generated an increasing concern about Illegal, Unreported and Unregulated (IUU) fishing [3,4]. Population growth and increased per capita consumption of aquatic foods, combined with the fact that the fishing industry employs approximately 34 million people worldwide and contributes significantly to global food security, underscore the importance of implementing sustainable harvesting methods. This, consequently, hinges on appropriate resource management and accurate catch documentation from fisheries [1,5,6].

Despite continuous efforts to create and maintain sustainable fisheries, fish stocks at maximum sustainable yield levels have been declining [1,7]. Without an equivalent decrease in effort (e.g., vessels, fishers, or (IUU) catches), current practices will continue to stimulate overcapacity in the sector. This, in turn, can be unfavorable by reducing predictability in expected catches, limit the income of fishers, and incentivize more IUU fishing [8]. Since misreporting of catches can lead

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to losses in future growth of the industry and income from taxes as well as unaccounted fishing mortality of marine resources specifically, IUU fishing threatens the future of commercial fisheries [9]. Estimates have indicated that around 20 % of global catches originate from IUU fishing, which intensifies the risk of further biodiversity loss and over-exploitation of marine resources while undermining the United Nations Sustainable Development Goals (SDGs) [10]. The actual level of IUU fishing may be underestimated, given that global catches could be significantly higher than reported [11]. SDG targets 14.4 (Sustainable fishing) and 14.6 (End subsidies contributing to overfishing) reflect the global ambition to end IUU fishing, but the targets were due in 2020 and have not yet been reached [12], despite the increasing implementation of instruments to combat IUU fishing globally [6].

IUU fishing can generate short term benefits for those who carry out illegal practices, creating so-called "free riders" [8]. Existing fisheries monitoring efforts in Norway struggle to successfully monitor vessels, which consequently challenges enforcement [13]. This can have implications for risk perception and, as a result, compliance rates. Considering the impossibility of deploying physical observers on all fishing vessels, one option that has been considered in the past years is to explore compliance by design through automated catch registration. Although, for such an option to be successful, it needs to both support governing mechanisms as well as account for the fishers' willingness to use the systems. Fishers' acceptance, in turn, is strongly influenced by their perception of the fairness of new solutions and regulations, the meaningfulness, and the compatibility with traditional practices and patterns [14,15].

Balancing this merger of at times contradicting needs is critical for developing management strategies in line with a given socio-political context, with specific conditions of social-ecological systems. This is particularly important considering how successful implementation may facilitate compliance and enhance sustainability in fisheries. Therefore, the primary aim of this paper is to provide knowledge on Norwegian fishers' perceptions of automatic catch registration and to examine how these perceptions relate to the broader objective of achieving informed and successful governance design. More specifically, this paper (1) investigates how fishers frame opportunities and barriers related to the implementation of automatic catch registration, and (2) explores how their experiential knowledge and values intersect with evolving management strategies. These aims are situated within the policy priorities of Norwegian authorities, as outlined in the Official Norwegian Report "Fisheries control of the future" [13], and seek to inform future development of monitoring and control systems that are both effective and accepted by stakeholders.

Considering this, the current article starts by providing relevant background information including existing governing mechanisms and relevant technological solutions for automatic catch registration on board fishing vessels. We then describe the participatory methods used to uncover topics identified by Norwegian fishers as relevant for enabling automatic catch registration on board fishing vessels and thus contributing to move towards evidence-based policy making. Finally, we provide the results of a thematic content analysis from the workshop data and discuss our findings in light of the existing regulatory framework, technological developments, and compliance by design in a Norwegian context.

2. Background

In 2001, the United Nations established an international voluntary legal framework called the International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated fishing (IPOA-IUU), aiming to address IUU fishing. The IPOA-IUU provides guidelines for states aiming to disincentivize IUU fishing. One of the sections is on monitoring, control, and surveillance (MCS), where it provides measures in this regard to be applied throughout the value chain [16]. Following the IPOA-IUU initiative, other international frameworks have also entered into force. There is large political will to combat IUU fishing on a global scale, and the UN Specialized Agencies the Food and Agriculture Organization (FAO), the International Maritime Organization (IMO), and the International Labour Organization (ILO) have developed various instruments that have combatting IUU fishing as a natural side effect [6,17].

In areas within national jurisdiction, in states' exclusive economic zones (EEZ), the first binding international agreement to target IUU fishing specifically was the Agreement on Port State Measures (PSMA) that entered into force in June 2016. The PSMA aims to prevent vessels that participate in IUU fishing from using ports and bringing their catches to shore [18]. The port state measures include that regulations applicable to the port in question also apply to the entering vessels, regardless of which flag the vessel flies. This provides jurisdiction for vessel inspections, which may lead to uncovering and reporting on vessels participating in IUU fishing or driving them away from the ports [19]. These measures thus disincentivize IUU fishing by reducing market access for the vessels in question [18]. Indeed, a recent study by Hosch et al. found that the risk of catches from IUU fishing activities moving through global ports via third party countries have been significantly reduced since 2017 in all seven world regions [20]. However, assessing the effects of measures against IUU fishing remains difficult, and there are large geographical differences in trends due to such as a lack of resources and capacity [21].

Norway is at the forefront of fisheries management globally, and still, less than 1 % of commercial landings are controlled. The Norwegian Directorate of Fisheries (NDF) reported that they had performed 1259 landing controls, document controls, and full controls of commercial fisheries and 1283 recreational gear controls in 2023, and 1105 and 1111 in 2022 respectively [22]. Comparatively, there were 187,013 commercial landings in total in 2023 and 186,498 landings in 2022 [23]. The NDF acknowledges that the MCS of today does not ensure that the fisheries regulations are followed, and the use of resources and organization of the control resources have been criticized by the Office of the Auditor General of Norway [13,24]. Furthermore, in 2013 a questionnaire revealed that only around 40 % of Norwegian fishers have no knowledge of underreporting being done by their close relations [25], while results from a similar questionnaire in 2019 had only 30 % stating that they do not believe that fishers misreport species or sizes of caught fish [13]. This indicates high rates of misreporting. In fact, Svorken & Hermansen found that 40 % of their respondents admitted to misreporting themselves [25]. This apparent decreasing level of compliance has led to the Norwegian National Authority for Investigation and Prosecution of Economic and Environmental Crime (Økokrim) stating that organized crime is an increasing threat to the fishing industry, and that it needs to be addressed by the relevant authorities [13].

Presently, commercial catches are reported manually using electronic software that is approved by the NDF, with the costs of the equipment and maintenance covered by the fishers themselves [26]. Discarding is not allowed. The fishers have to report their catches before returning to port, in where they must determine the species composition of their catch and estimate the total weight of each species within a reasonable margin of error (informally with a discrepancy of less than 10 percent [27]). They must also monitor the length frequency to ensure that they are not catching fish below the minimum size limits. These data are manually added to the software and electronically reported to the authorities and later verified upon landing. Additionally, all vessels larger than 10 m fishing in Norwegian waters must send tracking data to the Norwegian government using a Vessel Monitoring System (VMS) [28,29]. The sender automatically sends the vessels' position, speed, and direction of travel at short time intervals. The equipment used must be approved by the NDF [26] and fishers cannot turn off the equipment at any time [28,29]. Foreign vessels larger than 15 m fishing in Norwegian waters must also be equipped with an Automatic Identification System (AIS) [30]. In short, various technologies for electronic monitoring (i.e., using camera (e.g. CCTV) or sensor technology to electronically register

e.g. catches on board fishing vessels [31]) are already in use aiming to improve reporting and fisheries management, including MCS, while also enhancing traceability in fisheries.

In recent years, there has been increased focus on the need for improved sustainability in fisheries, and specifically the ability to prove this sustainability. It is possible that, in the future, import authorities and various markets may expect evidence of compliance, in which case verifiable documentation will be needed from the fishing industry [13]. Moreover, from 2015 to 2019, the European Union (EU) implemented a Landing Obligation. Enforcing this discard ban at sea is challenging and has been one of the catalysts for electronic monitoring in Europe as it may improve MCS, in which automatic catch registration may play a key role. Many pilots and projects have been initiated in countries like Denmark, the UK, and the Netherlands, [32] and the European Green Deal, presented in 2019, states that "The Commission will also take a zero-tolerance approach to illegal, unreported and unregulated fishing" [33]. The decision to use electronic monitoring in European fisheries came top-down from the EU to improve fisheries monitoring [34].

In Scotland, the Scottish Cabinet Secretary for Rural Affairs and the Environment stated that remote electronic monitoring using CCTV video footage collected valuable data for fisheries science to improve knowledge of fleet dynamics, the distribution and structure of fish populations, and the ecosystem overall, and data on compliance for management purposes [35]. Similarly, the EU Common Fisheries Policy includes remote electronic monitoring e.g. recording of engine power, sensors and cameras, artificial intelligence, and automated data analysis, as a user-friendly way to control and monitor the fisheries while also collecting data to be used in scientific and decision-making processes. This can create a level playing field for fisheries actors by ensuring that all fisheries are monitored fairly using objective methods [36]. In Norway, there is high political trust and a high rate of digitalization [37], however disagreements between fisheries actors and politicians are not uncommon [38,39]. The NDF highlights in their Action plan for the development of future fisheries control 2021–2025 that "digitalization and documentation" is crucial for an effective and credible fisheries control to succeed [40], facilitating a transition towards implementation of automatic catch registration technologies in fisheries.

2.1. Automatic catch registration

Fishers' support is essential, though, for successful implementation and use [14], as all the technologies enabling automatic catch registration require sensors installed on fishing vessels, whether these be cameras, lasers, or other equipment detecting catch composition. Oftentimes these technologies can determine species and estimate individual length and weight automatically. Such data should be collected as early as possible in the catch process and stored digitally for reporting, eliminating manual recording and reducing errors. The concept of automatic catch registration in fisheries is not novel; Svellingen et al. presented a camera system placed over conveyor belts on research vessels to determine the species and measure length of 10 commercial species already in 2006 [41]. Since then, numerous studies have explored methods for tracking vessels and catches and/or bycatch worldwide (e.g., [42–46]). In the Pacific, electronic monitoring with cameras provided unique data on bycatch species and fishing practices, contributing to improved management and species protection [42]. These emerging technologies may enhance transparency and information sharing, and as such improving fisheries MCS.

However, these remote electronic monitoring systems for automatic catch registration present challenges. Large fish quantities may obscure some individuals, making them uncountable by sensors, and species identification can be particularly difficult for less common species or those with similar morphometrics [14]. Camera lenses may be obstructed by contaminants or otherwise produce images of reduced quality, there may be limited space onboard, and monetary resources to cover equipment maintenance can be inadequate, especially for the smaller vessels [14,42]. Due to the individual strengths and weaknesses, combining different automatic catch registration technologies may be optimal, with adaptations for various fisheries and vessel types while ensuring standardized data collection and respecting fishers' privacy [14].

The NDF's Action Plan stresses the need to overcome these challenges to achieve "compliance by design", promoting responsible harvesting of marine resources and ensuring market access for Norwegian fish [40]. Compliance by design integrates compliance into the management system's architecture, ensuring that following reporting procedures leads to compliance, lowering the risk of misreporting – whether accidental or intentional [40]. This approach is expected to enhance fisheries monitoring and control with fewer resources, particularly through automatic catch registration, compared to existing practices.

When using an automatic catch registration system, controls can be conducted retrospectively, with inspections occurring after an action, or through embedded checkpoints collecting real-time data [47]. One solution is using cameras or sensors above onboard conveyor belts to record catches while measuring individual lengths and estimating weight of each fish [34,35], which in turn could be used for data collection for several purposes [35]. The architecture of the control system ensures accurate reporting and data distribution to relevant agencies, reducing the need for time-consuming manual controls [47,48]. A compliance by design system benefits both governments and industry through streamlined reporting, improved dialogue, and higher data quality with fewer opportunities for human error [34,35,47].

Building trust is crucial for successful implementation of such plans. Recent dialogues with Norwegian fishers indicate that they largely view the NDF's automatic catch registration plan as a top-down decision imposed without their input [49]. Many feel surveilled and controlled at their workplace [8], a sentiment echoed in other countries regarding electronic monitoring [14], likely applicable to automatic catch registration technologies as well. Norwegian fishers have argued in industry news articles that estimates of illegal fishing in Norway are inaccurate and should not justify the implementation of automatic catch registration [8,50–52]. Additionally, a study surveying 300 Norwegian cod fishers found that over half doubted the technologies' effectiveness in reducing overfishing, with fishers from northern Norway being the most skeptical [8]. Concerns have also been raised about equipment maintenance, onboard space requirements, and the costs and risks of breakdowns preventing vessels from continuing their fishing operations, particularly if repairs are not accessible where and when a vessel lands [8,14,42].

Effective resource control hinges on robust enforcement and high compliance [53]. In fisheries MCS, the Norwegian government seeks to shift from an object-oriented approach (targeting specific vessels or businesses) to a value chain focus, employing both "sticks" and "carrots" (punishment and persuasion [53]). Norwegian authorities expect that fully automated MCS will enhance compliance by reducing the need for manual input from fishers, drawing inspiration from tax reforms where third-party data reporting nearly eliminated tax fraud while also reducing manual reporting [13].

3. Methods

In this study we applied a participatory approach using conceptual mapping and thematic content analysis to examine which efforts are needed to enable the successful uptake of automatic catch registration systems on board fishing vessels in Norway, based on the perspectives of Norwegian fishing fleet representatives. As any implemented change will affect the fishers directly, it is crucial that they take part in the development and shaping of measures to ensure compliance, ownership in decisions, and that measures fit the context in which they will apply.

Previous studies have interacted with fishers to collect data on their perceptions (e.g., [8,9,25,54]). However, these studies have commonly allowed the participants to orient towards and elaborate on their

negative affiliations with MCS technologies and management. In this study, fishers were approached collectively with a problem-solving approach to turn the focus towards solutions. The system under investigation is a social-ecological system (i.e., a coupled human-environment system) in which fishers are a key component. Hence, they may pose as excellent sources of first-hand knowledge of solutions from having daily interactions with the system [55].

3.1. Internal preparational workshop

To define the research question, carry out a stakeholder mapping to identify relevant participants, and identify relevant system drivers to be used as conversation starters in the conceptual mapping workshop with fishers, the research team conducted an internal workshop. The research team consisted of individuals with interdisciplinary expertise particularly in governance, fisheries science, political science, biology, and technology implementation. The research team discussed exploratory questions such as "how do we expect automatic catch registration to impact fishers' socio-economic conditions", "which concerns may fishers have towards implementation of such technologies", "how can a transition towards automatic catch registration be fair and transparent", "how can these systems and the collected data be used and managed", and "how can we ensure the data collected is useful for management and research". From these discussions, seven drivers were qualitatively selected to stimulate dialogue during the stakeholder workshop. These drivers were not intended to be exhaustive; participants were encouraged to modify or replace them as needed during the stakeholder workshop. This method of developing drivers to be used as conversation starters has been used in several studies previously [56–60]. Each driver was framed in a neutral manner and could increase or decrease, allowing participants to assess their positive or negative impact on the system, and are listed below:

- Access to areas
- Climate change
- Market
- Quality of life
- Regulations
- Research
- Technology

3.2. Stakeholder workshop

By using the snowball method [61], relevant stakeholders (i.e., fishers from various fisheries and representatives from fishers' organizations) were identified and invited to participate in a collaborative and participatory conceptual mapping workshop (henceforth the stakeholder workshop). The stakeholder workshop had 20 participants from coastal and deep-sea fisheries, full-time and part-time fishers, and fishers' organizations, being women and men, all between the ages 20–80 years old. As the emerging technologies and regulations concerning automatic catch registration on board fishing vessels are expected to affect the whole fishing fleet, it was desirable to have participants with experiences from different fisheries and vessel sizes. All fishers that attended had been actively working as fishers at some point or continuously in the past three years. Based on feedback during the inviting process, a representative from The Norwegian Directorate of Fisheries was present as a motivator for the Norwegian fishers to attend the workshop.

When meeting with the fishers, we chose to focus on what is needed to drive the transition *towards* automatic catch registration to facilitate a debate on how to overcome any related obstacles. The main goals of the stakeholder workshop were to map concerns that fishers have in terms of implementation of automatic registration of catches and to identify related solutions. An additional goal of the workshop was to "put the topic on the agenda". We wanted to introduce to the fishers what is expected to come in terms of technologies and regulatory demands and talk about how it may affect them in practice to co-produce knowledge to inform decision making.

The stakeholder workshop was conducted in Norway in December 2023 and started with the research team informing all participants of the General Data Protection Regulation and providing a brief overview of the study. Then, the workshop question "what is needed to enable the implementation of automatic catch registration on board fishing vessels?" was introduced to ensure clarity on the topic to be investigated. The workshop applied a conceptual mapping methodology based on Systems thinking [62], which entails developing a conceptual map (similar to that of a mind map) representing a given system as the stakeholders perceive it. In this case, the system consisted of relevant concepts or variables that relate to implementation of automatic catch registration on board fishing vessels in Norway and how these variables connect and thus impact parts of or the whole system. This method is stakeholder-driven and facilitates co-production of knowledge by participants engaging in discussions and sharing their perspectives and experiences. As the discussion continued, the facilitator (i.e., one of the researchers) continuously created the conceptual map by writing words or short phrases on a whiteboard for all to see and comment on and connect these with arrows indicating how they impact each other. To facilitate the discussion, the seven drivers developed from the workshop with the research team were used by asking topical open-ended questions relating to the implementation of automatic catch registration (Table 1). However, it was made clear that these drivers were meant to serve only as *conversation starters* and that the participants were encouraged to bring up any topic that they deemed relevant to answer the research question.

3.3. Thematic analysis

The stakeholder workshop was recorded and later transcribed and anonymized prior to analysis. To analyze the empirical data, we applied an inductive qualitative thematic content analysis, following the approach outlined by Burnard et al. [63]. This was to uncover the participants' perceptions of the social-ecological system in question, specifically relating to challenges and opportunities associated with the implementation of automatic catch registration on board fishing vessels in Norway. The analysis followed a structured, iterative process. First, the transcript was read multiple times to ensure familiarity with the content. During this process, open coding was conducted manually by one of the researchers by taking notes in the margins of the transcript with observations, recurring topics, and statements of relevance to the research question. One of the other researchers, who was also present at the stakeholder workshop, validated the results.

Key themes were identified based on the frequency of mentions,

Table 1
Conversation starters and related example questions applied to facilitate the workshop discussions.

Conversation starters	*Example questions*
Access to areas	*Can fishers' access to areas affect the implementation of automatic catch registration in any way?*
Climate change	*Can climate change impact the implementation of automatic catch registration?*
Market	*Can any market forces affect the implementation of automatic catch registration?*
Quality of life	*Will fishers' quality of life have any impact on the implementation of automatic catch registration?*
Regulations	*Are there any existing or thought regulations that could impact the implementation of automatic catch registration?*
Research	*Will any specific research focus or developments affect the implementation of automatic catch registration?*
Technology	*Does the state of existing technologies have any effect on the implementation of automatic catch registration?*

descriptions of the themes or emphasis placed on certain issues (e.g., the use of expressions such as "this is very important"), and the extent to which a theme appeared to influence or be influenced by other topics discussed. Although the co-created conceptual map from the workshop represents several of the topics discussed during the workshop, it was not used as a standalone analytical output. Rather, it served as supplementary input to help contextualize the thematic content. For instance, directional arrows in the map indicated perceived relationships between variables, but not their relative significance. Some variables with few connections were described as having strong system-level impacts. Themes emerging from the transcript and the conceptual map were then grouped into broader thematic categories when they were found to be overlapping or closely related. These final themes, along with supporting descriptions drawn from the data, formed the basis of the narrative presentation of the findings, which highlights factors that may enable the successful implementation of automatic catch registration on board fishing vessels in the Norwegian fisheries context.

4. Results

The workshop session resulted in a complex conceptual map with 61 interconnected variables with topics that, from the participants' view, should be addressed when trying to implement automatic catch registration (Fig. 1). The conceptual map indicates the complexity of the fisheries-related social-ecological system where implementation of technology has implications for a wide set of regulatory, economic, social, and environmental variables.

The potential significance of implementing automatic catch registration technologies seemed to be acknowledged by the fishers, given the engagement for the workshop. It was evident that the fishers wanted to share their knowledge and take part in the development, although they remained critical to the proposed technology. At the beginning of the stakeholder workshop, concerns were raised by the participants about whether automatic catch registration on board fishing vessels should happen at all. However, during the discussions throughout the workshop the group's perceptions became more diverse, and the focus turned towards how especially the discussed technology and related regulations and plans could be realized. Consequently, the two conversation starters "Technology" and "Regulations" received the most attention during the workshop as is indicated from their many connected variables in the conceptual map (Fig. 1).

The fishers raised several concerns regarding the implementation of new technologies in general and for automatic catch registration technologies specifically. With new technologies comes potentially new (technologically related) challenges in addition to rather large initial investments both in terms of costs and time for the fishers. They emphasized that the technologies must be adapted to the different fisheries, sizes of fishing vessels, and operational patterns. However, relevant to all vessels was that after installation, regular maintenance can become quite costly. Costs were agreed upon by the group as decisive for their decision making, and – as a part of the problem-solving approach – we thus chose to explore a scenario during the workshop asking the group of fishers, "what if the purchase and use of the technology would not be as costly, which factors would then be of the highest importance?". When taking "costs" out of the equation, the immediate response from the group was to question the motivation of governance officials for wanting to implement the discussed technologies and what the participants perceived as a one-size-fits-all approach.

The discussion that followed painted a picture of how the interactions between the managers and the industry have changed over time from the fishers' perspectives. They expressed a feeling of often being "approached as criminals", indicating that the technology implementation may serve as a punishment or a "stick". Consequently, they questioned whether the ongoing discussion in the government on automatic catch registration was "just another effort" brought from the top down to address – in their opinion – unsubstantiated suspicions held by managers. The fishers were, however, more positively inclined to accept new control measures if management and research efforts would aim to use data from automatic catch registration technologies to improve monitoring of ecosystems such as by detecting species migrations and introductions of new species both internationally and in Norway specifically.

As described earlier, in Norway, catches are presently manually registered electronically through approved reporting equipment based

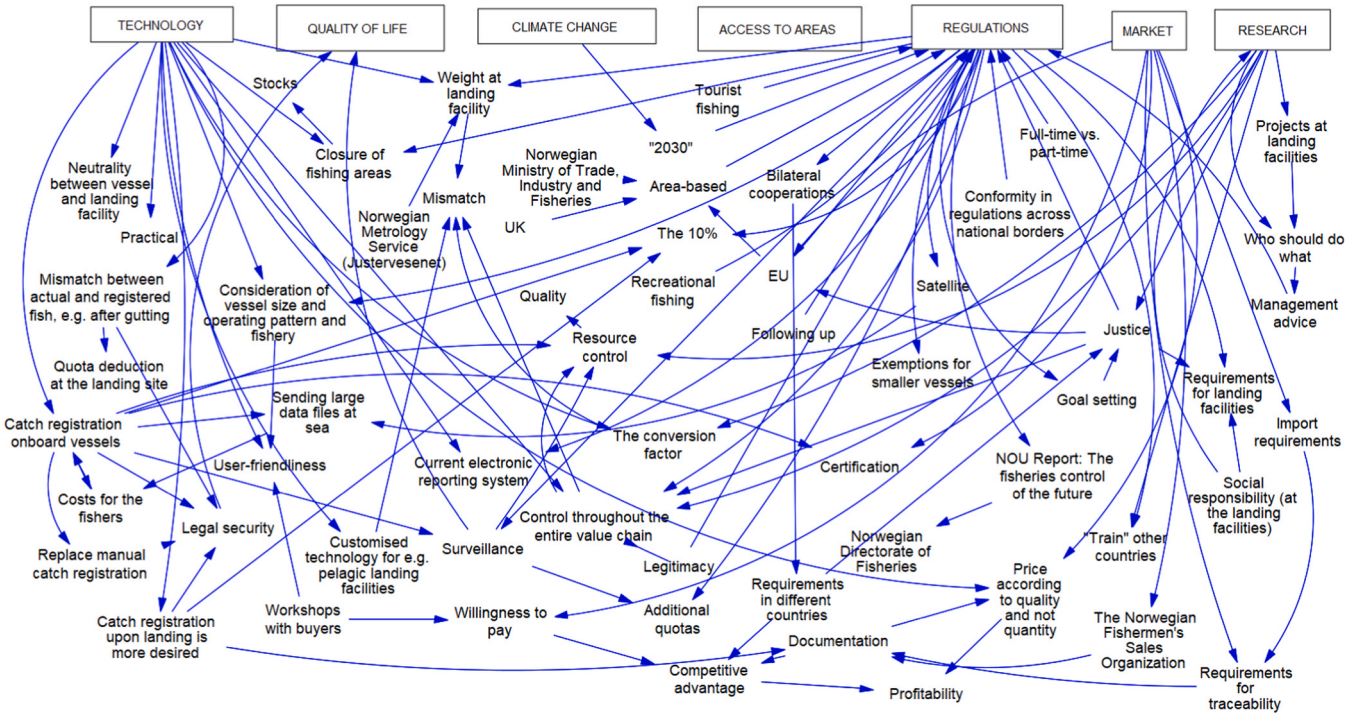

Fig. 1. Conceptual map co-produced with representatives from Norwegian fisheries and fishers' interest organizations in Norway during a workshop session.

on estimates made by the fishers. The participants expressed dissatisfaction with the existing reporting solution as it opens for (unintentional) misreporting which the fishers are held responsible for. As a fisher explained, "I am not impressed with the catch logbook. That I must admit. I suppose no one in this room is. […] You have to guess what is in the room [where the catches are stored]" (Norwegian fisher, 2023). The dissatisfaction with the current reporting system may drive new solutions such as automatic catch registration if the new technology can automate the process and reduce the manual labor required of fishers. As one of the participants acknowledged, "I think we are moving in the right direction [if] we talk about removing the manual catch logbook that is only built on estimates" (Norwegian fisher, 2023).

A key requirement for implementation of automatic catch registration systems to be successful though was reliability of the systems and the data to be derived from them. As one fisher said, "When the catch is brought on board […] [the data from the technology must] reflect the factual circumstances, confirming both species and weights" (Norwegian fisher, 2023). This was perceived as particularly challenging on the smallest coastal vessels, for which the fishers argued that implementation may need to be exempted until practical and technological challenges have been sorted out. Great concerns were raised related to responsibility in case of faulty or inaccurate results from the use of the systems for automatic catch registration, especially as skippers may not have experience working with these types of data and systems. Concerns were also raised about the accuracy and thus reliability of the technologies when working as intended, for example due to highly variable conditions in the fishes brought on board or loss or gain of water after slaughter. As a fisher explained,

Let us say […] that you get a catch on board, and let us say it passes through a scale, then this is reported in, for example, the catch logbook, automatically. And then you deliver your catch, but it is not correct. It is all data-controlled. Would you then say that the skipper would be in the clear? […] I mean, you can read the numbers, but a fault happened, so then what? Norwegian fisher, 2023.

To partly address this concern, the fishers discussed how the systems must be user-friendly to lower the chance of unintentional misreporting and include a function where the fishers could find out if the registered data is correct. Also, they stated that there would need to be processes in place for the fishers to receive the necessary support to address any technical issues that may emerge, especially at sea during steaming or fishing operations where cellphone reception may be unavailable.

Hence, to replace the current reporting scheme, the technologies would have to be reliable, and fishers would only be accountable for what they can control–not for automatic catch registration data processing and storage. The workshop participants were particularly worried about potential consequences if reported catches from vessels and landing facilities mismatched, as these discrepancies could raise suspicions of IUU fishing. One fisher explained that,

All fishers, and the Directorate [of Fisheries] and all others, know that to be a criminal at sea you need a criminal on land. But to be a criminal on land you do not depend on a criminal at sea. And this principle must be part of the foundation for resource control. Norwegian fisher, 2023.

As a result, much of the workshop discussion revolved around potential consequences for fishers if such mismatches occurred when using an automatic catch registration system. A proposed solution to safeguard legal security was to instantly "lock" data registered at sea, making it unchangeable and ensuring that all catches are recorded immediately after being taken on board. This would eliminate human intervention in data processing and, in turn, reduce opportunities for manipulation at sea.

There was some support for this approach, and one fisher who viewed it positively explained:

First of all, [presently] there is the opportunity to mess with the system on board each fishing vessel. It is much more possible [at sea] compared to that on land. […] You have the system for weighing, [and] you have the intelligent eye on land. And you need to have that to keep the landing facility [open]. What I see as an advantage is that if we have it [automatic catch registration technology] on board, we will not need to *estimate* [the catches]. Thus, our legal justice returns to us. Norwegian fisher, 2023.

This suggests that implementing automatic catch registration technology could reduce opportunities for catch manipulation and help combat IUU fishing, while also minimizing suspicions towards fishers who report their catches in good faith, even if unintentional inaccuracies may occur presently.

However, a new challenge would then arise, according to the fishers. If catches at sea are registered immediately after being taken on board, regardless of how they are to be delivered, they would need to remain whole and not headed, gutted, or bled until after delivery at the landing facility to ensure the same weight there as when at sea given challenges with accurate conversion factors. This could severely reduce the quality of the fish. While the fishers agreed that there is no secret that they are not paid for quality, it would be desirable to work towards achieving that at some point. A suggestion made to address this challenge was to base catch size and composition solely on the registered catches from the vessels rather than from the landing facility. Although this would represent practical and regulatory challenges, this approach could promote greater consistency in reported values throughout the value chain. One of the fishers illustrated this reasoning by pointing out that the time delay between catches and landing should not impact accuracy: "If [the landing facility] get [the caught fish] two hours later, then what is the difference in terms of reporting? You [still] get the fishes' weights" (Norwegian fisher, 2023).

Another fisher explained that,

There is no universal vessel design. […] We travel far and count all of what we catch, and we deliver the fish at an approved landing facility with an approved scale. So, I do not understand why the reporting cannot be done at the landing facilities. […] We know that we have a little over 200 landing facilities for fish in Norway. And then we know that we have 3 500 [coastal] fishing vessels. So, it is only logical that we [could] save a bunch of money. Because I think that the fishers now feel pressured by the legal system, the costs, and then the hours we spend working at sea. These are the three things we are pressured by here. […] As long as we are responsible for how this [automatic catch registration] shall work, our legal justice remains threatened. Norwegian fisher, 2023.

One of the fishers expressed concern about the practical implication from a mismatch not just between the vessels and landing facilities but throughout the entire value chain:

It will be very challenging since the numbers will not match at different points of control. If I look at the export statistics, I see that we export more cod than we land in Norway. And this is related to the conversion factor. Norwegian fisher, 2023.

One of the fishers questioned whether the proposed immediate storage and reporting of catches from fishing spots would require real-time data transmission at sea. Concerns were raised about the potentially high transmission costs, especially for deep-sea fisheries where data might need to be sent via satellite. As a fisher explained, "One thing is by the coast where you can use your phone [internet] […] but if you go further out at sea and get satellite [only] […] then it becomes quite expensive to send it in pictures" Norwegian fisher, 2023. A possible solution, at least during the implementation phase, could be to integrate the collected data with a digital catch logbook that is stored on board, cannot be altered, and is only transmitted when a better connection, such as mobile internet, is available.

One of the positive outcomes from using automatic catch registration technology is the possibility to increase traceability in fisheries by making them fully documented. The workshop participants acknowledged the current and future need for documentation throughout the value chain and the possibilities for receiving competitive advantages. Although, for this to be realized, the fishers emphasized the need for

equal demands for traceability and transparency throughout all parts of the value chain, from sea to the final customers in stores. There was a joint belief that better documented fisheries could result in higher prices for products. However, presently, overall demand for seafood was argued to be a more influential driver for prizes. As a fisher explained,

[Price for] quality has proven to not be the case. We saw it with the loss of the Marine Stewardship Council certification on Atlantic cod. It was not decisive for the price. […] The demand for marine resources will not decrease, it will increase […]. Norwegian fisher, 2023.

Ideally, providing prices based on quality and traceability could be an effective incentive for the implementation of automatic registration of catches. As explained by a fisher,

Traceability […] *can* be important to receive a good price for the catch. Also, the quality of the documentation throughout the value chain [can be a factor]. It is no secret that we are not paid for quality today, it is more "paid by volume". Imagine if a system like this could make it so that we would be able to get paid for quality! Norwegian fisher, 2023.

While one fisher emphasized that no fisher is against control, another remarked, with a sense of resignation, that,

We are an industry that is the most monitored. From when you leave your bed in the morning till you are back in your bed again you have so many points that you have passed through during one workday that is monitored. Norwegian fisher, 2023.

These arguments indicated a dissatisfaction of being surveilled. However, a third fisher added to the discussion that "I disagree a little with that the fishers are "afraid" of being controlled. This is the occupational group that is the most controlled, and most fishers are interested in being compliant. […] But it is about the legal justice" (Norwegian fisher, 2023).

If national authorities mandate the use of automatic catch registration technology top-down, the fishers emphasized that it must be implemented fairly, with equality and conformity as key principles. They stressed that regulatory requirements should be uniform across all countries adopting such systems. The fishers also proposed that vessels operating in or passing through different waters (national EEZs and areas beyond national jurisdiction) should follow the rules of the area, regardless of their flag. Specifically, they suggested that all vessels crossing multiple zones should adhere to the strictest regime–which they expected to be Norway's. This was perceived as crucial for maintaining fair competition and would require multilateral cooperation. As one fisher stated:

It is important that a vessel flying under another flag than the Norwegian one that fish in Norway cannot have fewer obligations than that of Norwegian vessels. I believe that there must be conformity in the regulations. A foreign vessel cannot have fewer demands when it comes to registration than Norwegian vessels will be imposed by. Norwegian fisher, 2023.

Another argument for multilateral cooperation on the topic of automatic catch registration, as discussed by the fishers, was that food fraud is more prevalent in countries described as having "more challenging conditions"–with the Netherlands used as an example–than in Norway. Additionally, the fishers expressed dissatisfaction with how the Norwegian government historically has, from their point of view, operated in terms of setting overly ambitious policy goals, making regulations costly and cumbersome to follow in Norway compared to in other countries.

5. Discussion and conclusion

The biodiversity crisis and IUU fishing are global challenges, and current efforts to address them have fallen short, making policy innovations essential. Implementing automatic catch registration could complement existing regulatory tools and enhance monitoring efficiency, reducing enforcement efforts and freeing up fisheries management capacity–an identified weakness contributing to weak MCS and poor compliance [21]. The IPOA-IUU states that "national legislation should address […] the use of electronic evidence and new technologies" and calls on states to implement comprehensive and effective measures against IUU fishing. This aligns with automatic catch registration, which improves data accuracy, traceability, and transparency, strengthening fisheries management [16]. Additionally, automatic catch registration could be a key tool for enhancing monitoring and enforcement in remote areas, such as in the high seas.

By uncovering more instances of IUU fishing, automatic catch registration could strengthen the effectiveness of the PSMA by enabling early and more consistent detection of illegal activities, increasing the likelihood of identifying and denying port access to non-compliant vessels. Since automatic catch registration is expected to improve compliance, it may also alleviate pressure on existing regulatory tools by reducing the levels of non-compliance they are designed to address. Consequently, these mechanisms may no longer need to operate at their current intensity to effectively manage residual IUU fishing under an automatic catch registration regime.

More specifically, a compliance by design system like automatic catch registration can reduce the need for controls and audits, freeing up governance resources and easing the reporting burden on industry actors by replacing the manual system currently in place. The NDF's Action Plan envisions this approach as a way to foster trust between the industry, management, consumers, and the society by ensuring a transparent value chain [40]. However, its effectiveness in addressing IUU fishing depends on strong communication between the government and the industry. Poorly managed enforcement may backfire – if fishers perceive regulations as excessive or unjustified (e.g., not founded in evidence of non-compliance), they may become less cooperative [53].

The participants at the stakeholder workshop identified several factors that could enhance the sustainability of Norwegian fisheries with the introduction of automatic catch registration. They emphasized that addressing IUU fishing while fostering synergies proposed by stakeholders could help resolve practical, economic, social, legal, and environmental challenges. However, implementing such changes will require substantial coordination among fisheries managers, markets, scientists, and fishers. If successfully integrated by accommodating for the conditions of the social-ecological system, automatic catch registration could contribute to informing policy development that is both contextually relevant and aligned with the socio-political and social-ecological dynamics of the fisheries sector.

In terms of practical considerations, the Norwegian fishers emphasized the need for solutions that are accurate, reliable, user-friendly, and well-supported (e.g., technical assistance) to improve their work at sea by replacing existing practices. Ongoing technological advancements should integrate user feedback to address these practical needs where possible. A transdisciplinary approach to developing catch registration technology and regulatory framework is crucial for exploring its potential to replace current legal procedures (e.g., the logbook) while ensuring ongoing support, such as system updates, technical assistance, and training for fishers.

From an economic standpoint, markets accessed through fully documented fisheries could drive the adoption of automatic catch registration. However, this depends heavily on international market demands for documentation. For instance, the United States implemented import requirements for certain marine species, mandating clear documentation of legal fishing activities. Imports without the necessary documentation are seized by customs, creating an import ban on seafoods without sufficient documentation. However, as of 2021, weak enforcement and vague requirements have limited the potential impact significantly. Additionally, the effect of such measures depends on the purchasing power of importers. If a buyer without strict documentation requirements offers better terms for purchase, sellers may orient their products there instead [64]. For Norway, who harvests and exports large quantities of seafood, leading the way with fully documented fisheries could set a precedent for sustainable and transparent practices. This could potentially open for new market segments, offering first-movers a

competitive edge in markets with stricter documentation requirements, like the American initiative.

During the workshop, fishers emphasized that the investment and operational costs of automatic catch registration technologies were major factors in whether they would support such solutions. Achieving higher prices, in particular for fully documented fisheries, may therefore be fundamental to offset the costs of implementing and using automatic catch registration on fishing vessels, especially for the first-movers. However, other means of financial support e.g. governmental compensation schemes could also be effective to increase stakeholder acceptance.

Incentives in general to ease the transition were welcomed by the workshop participants, though only if the rationale for implementation was seen as just. Historically, tensions between the industry and management have fostered skepticism toward new regulations, with some perceiving that Norway's high standards have previously put its industry at a disadvantage. Since compliance hinges on appropriate governance strategies, strategies should be developed using available knowledge about the system in which regulations or other efforts will be implemented. This is also key to maintaining or improving political trust seeing that the use of stakeholders' knowledge to inform decision-making may improve decision-making legitimacy, and in recent years this has become evident in Norway. Criminal behaviors related to catch landing and reporting are being discussed to a greater extent [65], with some in the fishing industry seeing more advantages than disadvantages with automatic catch registration technologies [38,66].

However, as became clear during the workshop, fishers at times hold differing viewpoints on the topic of automatic catch registration and management practices for MCS. The fishers who participated in our workshop represent only a small subset of Norway's fishing industry, which comprises more than 5000 vessels. The open invitation to the workshop was distributed through the research team's professional network. As such, it is possible that the recipients of the invitation were already familiar with the topic from a research, policy, or management perspective. It is also likely that those who chose to participate held relatively strong views on the matter, potentially differing from the broader fisher population. This introduces a selection bias that may have influenced the themes and opinions that emerged.

Although the workshop successfully captured key industry perspectives from the participants, it is important to acknowledge that not all relevant topics may have surfaced. The direction and content of the discussions were shaped not only by the structure and duration of the workshop, but also by the participants' individual backgrounds and viewpoints. Consequently, the findings may not fully reflect the diversity of opinions across the broader fishing community. Future research could benefit from incorporating statistical analyses and broader survey-based quantitative data or key interviews to complement the insights gathered from the workshop discussions, which served as the sole method of data collection in this study. While this approach allowed for in-depth exploration of stakeholder views in a group setting, it does not permit generalization of findings or testing of relationships at scale.

Nonetheless, automatic catch registration technologies are expected to reduce the incentive for IUU fishing. However, implementing these systems from the top-down alone will not ensure the complete elimination of such practices. Among the steps to make IUU fishing less attractive when implementing new reporting systems, as discussed during the workshop, is to highlight the potential synergies and benefits for fishers using these while presenting arguments for new regulations or policies transparently. Understanding the advantages of technologies and related regulations could facilitate a more positive mindset towards their adoption, and these insights are essential when developing a new management regime.

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CRediT authorship contribution statement

Hatlebrekke Hanne Hjelle: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Conceptualization. **Ahlquist Ina Helene:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Tiller Rachel:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization.

Declaration of Competing Interest

The authors declare no conflict of interest.

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Data availability

Data will be made available on request.

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