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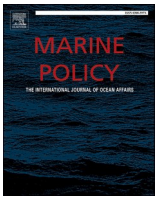

How performance standards could support innovation and technology-compatible fisheries management frameworks in the U.S.

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ABSTRACT

A healthy fishing industry requires real-time, adaptive, and flexible management to overcome increasing human and ecological threats. Electronic technologies (ET) are at the center of present-day discussions for how to enable robust fisheries management in the face of change. Looking at the United States as a case study, this work identifies the practice of centering regulation around defined, discrete classes of technology (e.g., electronic monitoring (EM), electronic reporting (ER), vessel monitoring systems (VMS), etc.) as a critically unaddressed challenge that limits the technologies' usefulness and ability to evolve fluidly. We argue that shifting towards a regulatory strategy that focuses on purpose and performance rather than specific technical attributes would provide more space for technology to evolve and enable more efficient fisheries management.

Drawing on insights gathered from > 40 subject matter expert (SME) interviews from across a wide range of stakeholder perspectives and diverse geographies as well as examples from within fisheries globally and other U. S. agencies such as the Federal Aviation Administration (FAA) and the Federal Railroad Administration (FRA), we highlight opportunities for clear performance requirements and data standards to provide appropriate system-wide oversight while also allowing sufficient regional flexibility to tailor technology and programs to local needs. This work synthesizes a set of recommendations for a forward-looking national level fisheries policy framework that integrates ET in an efficient and adaptable manner. Building on existing recommendations, we also highlight key topics for stakeholder communities to address during the process of designing an innovation-friendly policy framework to meet science, management, enforcement, and business needs.

1. Current State of Affairs

Fisheries in the United States serve as a critical and sustainable source of nutrition, employment, and income for the nation with the commercial fishing industry accounting for ~708 thousand jobs and ~ $53 billion in sales and the recreational fishery supporting another ~24 thousand jobs and ~$2.9 billion in sales [1]. Ensuring that this industry remains healthy in the face of increasing human and ecological threats will require real-time, adaptive, and flexible management. A rapid evolution in technology has opened an array of previously impossible data collection and management possibilities to achieve these goals. Taking advantage of these technologies will require the National Oceanic and Atmospheric Administration (NOAA) to rethink its regulatory frameworks to allow innovation.

The U.S. is on the cusp of having the technology, the analytical capacity, and the social capital to implement an interoperable, comprehensive management framework that capitalizes on electronic technologies (ET) at a national scale. However, while other countries such as Chile, Australia, and New Zealand have moved ahead with mandatory electronic monitoring (EM) and electronic reporting (ER), the U.S. currently lacks an integrated framework to facilitate and accelerate this transition. A policy framework that leaves space for technology evolution has been in discussion for > 7 years in the U.S. with respect to EM [2] and remains consistent with the current NOAA Fisheries policy directive [3] (04-115) guiding the use of ET in U.S. fisheries. However, the uptake of ET has been quite slow [4] compared

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with other on-water monitoring technologies such as VMS in part due to the patchwork of review and approval processes for ET created within NOAA at the federal, regional, and regional fishery management council levels.

As the climate changes, marine species are experiencing population fluctuations and migrations through different management regions in unprecedented and accelerating ways. The fishing communities and industries dependent on these resources must be sufficiently agile to adjust their efforts in response. This requires that managers and regulators have tools and protocols in place that enable them to coordinate, collaborate, and work together using accurate data from multiple sources to make well-informed decisions in a timely manner. While improving the speed, accuracy, and availability of data does not necessarily require the most cutting-edge technology, better technology can certainly help. However, at present, much of NOAA Fisheries staff lacks experience writing technical regulations and policies, and their biggest effort to date in this space — vessel monitoring systems (VMS) — is seen as cumbersome and contributing to isolated data silos that hinder the data's utility. A lack of coordination across regions has also created a piece-meal patchwork of highly specific requirements and standards for ET locally that prevents the technology provider community from developing scalable and affordable solutions.

Constrained budgets and the uneven distribution of core competencies across agencies impede the development of integrated, consistent, and forward-looking regulations despite the existence of overarching frameworks that support this goal, such as the Federal Data Strategy, NOAA's data strategy, and the Fisheries Information Management Modernization (FIMM) report [5–7]. The desire to rapidly adapt regulation to accommodate newer technologies can propagate technical artifacts simply because it is easier to use existing regulation as a template with minor changes than to create substantially changed regulation that is tailored specifically for new technologies and move this through the approval process. Furthermore, nearly all stakeholders undervalue the long-term costs of continuing to do regulatory business as usual, and thus also favor these "minor" or "rapid" updates that feel faster and less expensive in the short term.

Electronic monitoring technologies are at the center of present-day discussions for how to incorporate new technology into fisheries management. However, the current practice of regulating technology use by category (e.g., EM, ER, VMS, etc.) creates artificial distinctions that limit the technologies' usefulness and ability to evolve. Currently, vessels can be required to purchase and carry multiple devices to stay in compliance when, from a technological perspective, a single unit could readily be streamlined to capture all of the needed fishery-dependent data to be sent simultaneously to each of the relevant regulatory entities and offices. A shift towards a regulatory strategy that focuses on purpose and performance of regulation rather than discrete technical specifications of the tools used to comply with the regulation would allow technology to evolve more quickly and enhance management outcomes. While this concept is not new to government, existing NOAA Fisheries structures and practices are still far from actualizing it even though the legal structures required generally already exist [8,9].

This work identifies the practice of centering regulation around defined, discrete classes of technology as a critically unaddressed challenge to fisheries management. Here, we synthesize a set of recommendations for a forward-looking national level fisheries policy framework that integrates electronic technologies (ET) in an efficient and adaptable manner by gathering insights from $>$ 40 subject matter expert (SME) interviews from across a wide range of stakeholder perspectives and diverse geographies, drawing on lessons learned in U.S. fisheries management, case studies for EM internationally and the experiences of other U.S. agencies making a shift toward performance standards. Building on stakeholder dialogues and existing recommendations [10–13], we highlight key topics for stakeholder communities to discuss during the process of designing an innovation-friendly policy framework to meet science, management, enforcement, and business needs.

2. The big vision

The first step in creating a paradigm shift is to clearly articulate the end point the changes aim to achieve. In this case, the desired outcome is a national U.S. policy framework that enables the use of evolving technologies for sustainable fisheries management and supports efficient, effective, innovation-friendly programs that are managed at the regional scale. Such a national framework would provide sufficient unity, guidance, and predictability for a robust ecosystem of technology providers to exist and would incentivize providers to continuously innovate and iterate their offerings in ways that benefit all stakeholders through improved affordability, accessibility, and functionality.

2.1. Framework Components

- ***Federal level performance-based and data-focused standards***, rather than technical standards, are used to articulate the goals of (and expectations for demonstrating compliance with) regulation while maintaining sufficient flexibility for innovation to flourish and be readily integrated into existing programs.
- ***Federal regulations and policy guidance*** serve to unify the field in which technology providers operate, while the authority and flexibility to customize data collection and monitoring programs to fit specific local needs are retained by the regional governing bodies.
- The service provider ***contracting structures*** used by the fishing industry or managing bodies align providers' incentives with the desired outcome of continual quality and performance improvements, innovations, and cost-reductions. Furthermore, ET programs are designed to explicitly streamline the scope of work with a focus on the core data needs such that programmatic cost-savings can be achieved.
- A ***comprehensive and secure data flow*** allows integration from a variety of sources, enabling the information to be efficiently and effectively used by multiple stakeholders and to serve multiple purposes (science, management, enforcement, business, etc.) while protecting the privacy and confidentiality of sensitive information for all stakeholders.
- The ***tools used to collect data*** are treated separately from the performance standards and data requirements themselves, such that the tools (hardware, software, and methodologies) can continue to evolve and merge without confinement to a specific, defined classification of technology in on-going support of "best available science."

2.2. Roadmap and Foundation

So, how can we actualize this vision? First, it is important to recognize that there are two parallel conversations happening simultaneously within U.S. fisheries management bodies that can disguise a fundamental underlying structural issue that must be addressed: the need to shift the types of standards employed in fisheries data collection policies such that they are no longer focused on discrete technologies.

On one hand, there is an overarching discussion about how to modernize data collection and management in fisheries that includes the type of integrated data repository (thoroughly indexed and searchable) that would unify fisheries information from many sources into a usable format and location, with appropriate privacy protections in place, to serve multiple purposes (science, management, enforcement, etc.) and end-users (managers, businesses, etc.) [14]. On the other hand we have discussions specifically centered around regulating individual types of electronic technologies (EM, ER, etc.) and the development of fully operational programs that employ them. While the adoption of ET is generally seen as progress towards data modernization, a critical hurdle buried between these two overlapping yet distinct conversations is the

fact that a fundamental shift in ***how*** we structure policy around data collection is required to actually achieve data modernization that can be lasting, scalable, and interoperable. If we focus solely on how to create a framework for the use of EM in fisheries management, we distract ourselves from the bigger, timely opportunity to use EM as a catalyst to fundamentally shift the paradigm of regulation to better serve all stakeholders and the ocean now and into the future.

Data modernization at large demands that we center performance and data standards around the outcomes required for a modernized, sustainable fisheries management system and treat the technical specification of the tools used to acquire that data separately, and in a way that can more readily and quickly evolve with changing technologies. While we spend intense effort to wrap our heads around the details of current EM technical specifications and configurations that are available for implementation on the water (which is absolutely required for successful operationalization of an EM program), the capabilities and details of those systems continue to evolve. Thus, fisheries are inherently and perpetually behind the curve when regulations are crafted with only today's available tools in mind. This situation, which has been discussed previously but not in detail, [15,16] necessitates a shift to performance standards whereby the core regulations define the purpose of the policy, the minimum standards required of data to demonstrate compliance, who is subject to the regulation, and the timescales upon which compliance is required. Meanwhile, the details of specific technologies that could be used, projected costs, transparency around how an entity can demonstrate compliance, and similar critical details that enable successful implementation of good performance standards can be made clear through other agency instruments such as non-binding policy directives. In this manner, expectations of industry performance (i.e., with respect to discarded catch, non-target species by-catch, landings, etc.) to achieve specific regulatory outcomes can be clear and lasting while the specific technologies used to demonstrate compliance can continue to evolve without rewriting the underlying regulation.

2.3. Performance vs. technical standards

The fundamental distinction between a *performance standard* and a *technical standard* (sometimes also referred to as a *design standard*) is that the first specifies the outcomes a regulated entity must achieve without prescribing the specific means of achieving them while the latter explicitly describes the details and design of **how** an entity will achieve an outcome [17]. Similar to a performance standard, a data standard may describe the specific information that must be collected, establish acceptable formats and margins of error, and clarify expectations of how the data must be validated without specifying the specific tools or methodologies that must be used. There has been on-going encouragement from the executive branch for U.S. regulatory agencies to shift from technical standards to performance standards from every administration since President Clinton's 1993 Executive Order that directed agencies to "specify performance objectives, rather than specifying the behavior or manner of compliance that regulated entities must adopt" [18].

While performance-focused standards are generally considered to promote flexibility and innovation with respect to technology, they can be challenging to skillfully craft because a regulated entity must feel sufficiently clear in what is expected of it and how it can demonstrate compliance, as well as have enough transparency to feel confident that all regulated entities will be evaluated similarly and fairly [19]. Any poorly or incompletely crafted policy will perform sub-optimally, and thus it is important to take a comprehensive rather than piecemeal approach to building the regulation, [20] as well as to clearly and transparently articulate both the requirements for satisfying a performance standard and guidance on how to demonstrate compliance [21]. The added challenge of creating skillful clarity around a performance standard contributes to a contingent of stakeholders who continue to advocate for technical standards. In interviews with both national and international regulators, agency staff, and fishing community constituents, we heard a number of voices preferring the certainty that comes with a technical standard — regulators feel reassured that a known technology and methodology will be used to collect the data while vessel owners are confident that simply purchasing a unit specified by regulation will meet the requirements without having to interpret what is being asked of them. However, this traditional approach works against other aspects that the same stakeholder groups value highly, such as cost, the efficiency and flexibility of a program to meet their individual needs, and the production of high-quality, useful, accessible, and secure data.[i]

3. Examples of U.S. agencies making the transition

3.1. Federal Aviation Administration (FAA)

Other U.S. agencies are already working through a shift to performance standards and can serve as models for fisheries. In 2012 and 2013, Congress passed legislation that pushed the Federal Aviation Administration (FAA) to modernize and reform its regulatory processes in consultation with the aviation industry [22,23]. The 2013 legislation required the FAA to create a regulatory regime for small airplanes that would replace prescriptive rules with performance-based regulations and use consensus standards to clarify how safety objectives may be met by specific designs and technologies [24]. The agency then defined "consensus standards" as "industry developed standards the Administrator has accepted for use as a means of compliance to the. regulations" [25]. The agency set forth mandatory performance standards for safety and then worked directly with industry to agree upon a specific set of consensus standards that were non-binding to clarify acceptable ways the safety objectives could be met by specific designs and technologies. The consensus standards were published in an agency circular rather than directly in the code of federal regulations (CFR).

The crux of what helped these more flexible performance standards succeed was the collaboration with industry to lay out clear guidance describing potential means of achieving compliance. All stakeholders benefit by being able to adjust to changing markets and technologies more readily than when regulations are set forth in the CFR. The FAA also allows regulated entities to propose alternative means of compliance beyond the consensus standards, which can in turn become additional acceptable paths of compliance going forward. This has been a dramatic shift from using technical design standards to a more flexible performance-focused set of standards for the way that the FAA requires the aviation industry to ensure the safety of its passengers and crew.

The FAA continues to push ahead with forward-looking performance standards that allow technologies not-yet-known to come into existence and be put into practice directly within the existing regulatory framework. For example, it now uses performance standards to regulate human space flight (i.e., CFR 14 460.5(b)), leaving sufficient room for new methodologies, technologies, and commercial opportunities of space travel to evolve. The FAA continues to work with industry to clearly articulate how to demonstrate compliance as the landscape of options and technologies evolve.

Consensus standards, like those employed by the FAA, tend to be best suited for well-established industries, and may be more challenging for smaller, emerging industries to effectively deploy. The fishing industry is well-established while the technology sector serving fisheries is

[i] There is an important discussion to be had around data itself that covers privacy, security, accessibility, interoperability, and a slew of other important considerations that are fundamental to successful policy reform. Much of this discussion has already been laid out in the literature cited throughout this manuscript, and thus we consider it outside of the scope of this work. However, we wish to underscore the timeliness of an integrated policy reform that capitalizes on Cloud and Data strategies that NOAA published last year (July 2020).

younger and still emerging. The general model of setting flexible performance standards together with clearly articulated, non-binding expectations for compliance is a model that should be employed in fisheries. However, the specific path of outlining the potential routes of compliance may benefit from a different approach than the fully industry-driven consensus standard model used by the FAA. Building on the collaborative model that fisheries have been using to pilot EM technologies, agencies, industry, technology providers, and NGOs should continue to work together to help articulate guidance and establish norms for acceptable means of compliance with performance and data focused standards. This approach, which is more inclusive and collaborative than a fully industry-driven consensus standard, has the added advantage of safe-guarding against regulatory capture.

3.2. Federal Railroad Administration (FRA)

A second example of an agency actively making a shift toward performance standards is that of the Federal Railroad Administration (FRA). Cost-savings, a frequent discussion topic within fisheries with respect to technology implementation, is one of the main driving forces behind its regulatory reform. There has been dramatic evolution in railway technology internationally, especially with respect to high-speed passenger rail, that has largely been excluded from use in the U. S. due to outdated and prescriptive technical standards [26]. The agency predicted that regulatory reform using performance standards to set a minimum threshold for acceptable safety requirements will generate substantial cost savings, specifically by ensuring that "existing and future alternative trainset designs can operate in the U.S. railroad environment on a widespread basis, beyond the constraints that have been imposed by FRA regulations" [27]. The final rule represents a move toward technological and design neutrality, with alternative designs permitted as long as the minimum regulatory requirements are fulfilled [28]. The FRA anticipates that the rule will produce net annual regulatory cost savings of at least $284.8 million, and possibly up to $837.8 million [29]. Infrastructure-related cost savings are estimated to make up the majority of the savings, which "will be generated by the ability of railroad operators to take advantage of a blended operating environment, avoiding costly new construction and maintenance of dedicated track and acquisition of new rights-of-way" [30]. The ability to blend technologies should be of particular interest to fisheries because it is currently lacking from the existing fisheries regulatory structure and it holds the potential to unlock substantial cost savings both to industry and to regulators.

3.3. Atlantic Coast comprehensive fisheries landings data portal

The best example within U.S. fisheries of data standards being used to improve data usability and access across multiple stakeholders is the Data Warehouse which integrates landings records for the entire Atlantic coast and is hosted by the Atlantic Coastal Cooperative Statistics Program (ACCSP). The ACCSP is a state-federal cooperative program representing 23 individual member organizations that includes 5 fishery councils and commissions, 2 federal agencies, and 16 state agencies. The organization sets data standards and collects and manages data for the Atlantic coast, hosts data in the Standard Atlantic Fisheries Information System (SAFIS) portal and online Data Warehouse, and coordinates recreational fisheries data collection to identify opportunities for future integration across jurisdictions. ACCSP was established in 1995 to address data deficiencies that constrained fisheries management along the Atlantic Coast. The mission of the ACCSP is to integrate data collection "into a single data management system that will meet the needs of fishery managers, scientists, and fishermen" [31].

While U.S. fisheries do not yet have a fully established example of performance or data standards implemented to facilitate more efficient and fluid data collection, ACCSP serves as a model for how emerging technologies, such as ER, can be structured such that multiple vendors can work across regions and states to allow vessels to use a single ER system to meet multiple reporting requirements. The Atlantic coast fisheries management authorities set the requirements for reporting, and the ACCSP provides detailed data standards that must be met by all reporting entities within the jurisdictions of the 23 cooperating member organizations. Furthermore, ACCSP provides free data collection tools (SAFIS and eTRIPS) that meet all member fishery requirements, they perform quality control on all data coming in, and they also host and warehouse the data. Vendors that conform to ACCSP data standards can be approved by the regional authority to meet reporting requirements and their products can be used by industry in place of the ACCSP tools, if desired. The program has the goal of any approved eVTR software being able to fulfill all reporting requirements with the submission of a single trip report for a vessel that may be required to report to multiple entities.

Though the ACCSP currently services only the Atlantic Coast and has been most effective for fisheries dependent data sharing and electronic trip reporting integration, the program has the potential to be an effective model for data harmonization and accessibility in a broader, improved national electronic technology framework. One of the strengths of the ACCSP model is that it helps overcome the challenge felt by the agencies of how best to regulate complex technical issues. It provides an effective forum to talk through regulatory obligations of the agencies and the technical details associated with meeting them in efficient ways. By engaging all stakeholders to develop data standards that are consistent, enforceable, and adaptable to individual fishery and regional needs, the federal agency can think proactively about designing performance standards as well as data sharing/synchronization protocols that will improve science-driven fisheries management across the nation.

4. What holds us back?

4.1. Keeping ahead of obsolescence

Technology is constantly evolving to become more efficient and streamlined. The merging of telephones and cameras over the past 20 years into a single, mobile device occurred as phones and cameras each evolved in parallel. There has been a similar blurring of distinctions among phones and computers when we consider landline telephones and desktop computers as a starting point compared with the current continuum of smartphones, tablets, and laptops. That has presented regulatory challenges, such as modifying TSA screening procedures in airports as they attempt to define and distinguish among these ever harder to distinguish categories of technologies. The truth is that these devices now lay on a fairly well-connected continuum rather than being obviously separate classes of technology, and the same evolution is occurring in fisheries technologies even though regulation has not yet caught up.

For a time, people hiked or ran with handheld GPS units until smartphones took over this function with the incorporation of location tracking technology directly into the phones. This is predictive of how current EM and ER technologies hold the potential to make VMS obsolete in the near future given that they each have location recording capabilities built into them. However, though a few EM units have achieved dual-use certification for EM and VMS, as our regulations currently stand, EM, ER, and VMS are separately defined classes of technology that cannot efficiently be merged into a single unit at this time without going through multiple certification processes. For example, we currently have policies on two different vessel location tracking/transmitting technologies, AIS and VMS, at the national level while ER and EM policies are evolving at the regional level which generally require EM and ER systems to also record and report vessel position. And yet, if we circle back up to the national level, VMS units are required to have two-way communication to preserve the potential for things like electronic logbook submissions (e.g., ER) to be submitted through the VMS unit, even though the feature is rarely used and ER is

regulated separately. As technology continues to evolve, the cost-effective addition of multiple functions to a single unit will likely become ever more prevalent. However, our current frameworks are too clunky and distributed across too many distinct offices within the agency to allow a vessel to easily carry a single unit that meets all requirements for vessel tracking (VMS), electronic reporting, as well as electronic monitoring. An added layer of complexity associated with integrating an overarching and forward-thinking data collection strategy with respect to ET stems from the fact that VMS was originally adopted as an enforcement tool (that also happened to collect vital information for science) under the guidance of NOAA's Office of Law Enforcement (OLE), while EM and ER have both originated as science and management tools (that can also serve enforcement). If we shift our regulatory structures to focus on the specific data elements needed to serve each agency/stakeholder and focus our discussions around setting data standards that would ensure the information is useable, reliable, accurate, cross-referenceable, and has a verified chain of custody, the specific technical elements used to meet those requirements could evolve much more efficiently and cohesively.

The challenges that have surrounded recent efforts to update VMS regulations (see 4.2 Case Study: VMS Regulation Slowing Modernization) to accommodate the use of cellular transmission presents an important reminder that all stakeholders will continue to pay hidden costs in perpetuity if we do not make the time and effort necessary to reconfigure the underlying regulations within which fisheries technologies exist. Not only are there direct financial costs associated with constant policy revisions as well as limited access to the most affordable and effective technologies, but there are also indirect costs of forgoing or slowing fisheries recovery due to handicapping the best available sustainable management practices.

Case Study. : VMS Regulation Slowing Modernization.

VMS was first required in the pelagic longline fishery around Hawaii in 1994 and expanded on a fishery-by-fishery basis over the last two decades. VMS regulations have been effective at creating a national framework that outlines minimum performance standards while also allowing for regional variation, but have fallen short in both the framework (by narrowly defining VMS so as to exclude emerging technologies) and by creating high costs and data limitations, which have created some vendor lock-in and stifled innovation. Since the inception of VMS regulation in 1994, NOAA Fisheries has updated the type-approval process for VMS units seven times [32]. This process has been laborious and further amendments are inevitable as technology continues to change.

The basic structure of the federal VMS regulations has changed little since its introduction. 50 CFR §600.1500 set out the definitions of mobile transceiver units (MTUs), which historically limited type-approval to satellite-only MTUs. Enhanced Mobile Transceiver Units (EMTUs) were defined as "a type of MTU that is capable of supporting two-way communication, messaging, and electronic forms transmission via satellite." The satellite communication method was therefore inscribed in the definition of EMTU, which inhibited cellular EMTUs (EMTU-Cs) from being type-approved until the CFR was revised through the federal register in July 2020.

The most recent amendment added cellular-based units to the type-approval application and testing procedures (85 FR 40915) and now separately defines EMTU-Cs as "an EMTU that **transmits and receives** data **via cellular communications**." Prior to this 2020 update, only satellite-based EMTUs could pass through the NOAA Fisheries type-approval process. A notable limitation of this updated regulation is that a critical residual technical specification ("two-way communication" — requiring the unit to both transmit and receive data) was carried over and applied to the cellular units simply to avoid making changes that might be seen as unnecessary or reducing stringency so that the regulation could be more quickly passed through the approval process. The goal of moving quickly was to make less costly units immediately available to the for-hire fleet in order to comply with new regulation in the Gulf of Mexico region. However, retaining the two-way communication requirement eliminated 50% of the units that the fleet had previously piloted and found satisfactory to meet the new position reporting requirement [33]. Only three of the six cellular transmission units that the fleet had tested included two-way communication capabilities because it is not necessary for most applications and each additional feature comes at a cost of manufacturing. Thus, the market options were both unnecessarily limited, and vessels are now cornered into paying for technology that includes capabilities they may never need and that may be duplicative of services and devices they already use to satisfy other requirements (e.g., for ER).

Furthermore, while this amendment updates VMS to include some of current-day technological advancement, it does not allow for the uptake of any future technology development in transmission capabilities, such as high-seas WIFI. As different forms of communication develop in the future, the CFR will need to be further amended to accommodate these changes. The CFR revisions to allow EMTU-C units in 2020 was a missed opportunity to reframe VMS regulations through performance- and data-based standards that would allow VMS hardware and software to continue to develop without further need for revisions each time a new technology is invented, and to better facilitate the use of VMS data across different stakeholders to maximize not just the enforcement, but also the scientific, management, and business benefits that it offers.

In contrast to VMS, AIS is regulated at the international level by the International Maritime Organization (IMO) and domestically within the U.S. Coast Guard (USCG). AIS is defined under Title 33 of the U.S. Code of Federal Regulations as a "system" rather than a specific technology, so changes to the technology are permissible as long as they still satisfy the required performance standards. For example, in the early 2000′s private companies began to develop satellites that could capture AIS data on the high seas, beyond the reach of land-based stations. Satellite AIS (S-AIS) data has since been seamlessly integrated into vessel safety without the need to adjust any performance standard policies at the federal or international level. More recently, dynamic AIS (D-AIS), launched in January 2020, provides a 16% increase in global position updates by tapping into thousands of S-AIS receivers traveling throughout the busiest shipping lanes in the world [34]. This "system" approach has allowed a network of innovations to spring up around AIS without repeated regulatory modifications. U.S. Code of Federal Regulations has been updated only once to revise the performance standards for AIS since the initial publication in 2003.

4.2. Structural and cultural barriers

The U.S. federal fisheries observer program is a historic pigeon hole in which EM appears to be stuck that limits the technology's ability to be applied to a more diverse set of use cases, such as direct use by industry for business purposes. There are legal readings of the MSA that have propagated this pigeon hole and may require reconsideration in the context of our current technology landscape. The MSA separates the observer program from other types of data collection, a statutory distinction that has been embraced by NOAA and resulted in EM often being viewed either as an observer analogue *or* as a scientific data source, but rarely both. In reality, EM has the potential to contribute data for many different purposes. Future versions of the MSA should recognize the potential of EM to contribute broadly.[ii]

This is intimately linked with an overarching challenge of shifting from a model where data is primarily collected by, held by, and governed by NOAA to one where NOAA is primarily receiving, retaining, and auditing data provided to the agency by industry/third parties who

[ii] And early drafts of the MSA reauthorization look promising on this point: the current Huffman draft seems to embrace a role for EM beyond simply as an observer replacement.

also retain the ability to use that data for other purposes. Evidence from emerging and existing EM programs (e.g., Northeastern U.S., Australia, and British Columbia, Canada) suggests that using third-party providers to gather, store, and analyze data is the most cost-efficient and effective EM program structure to use under most conditions, and may be required to scale up EM dramatically. This model has met resistance, for example in the western U.S., and remains contentious for a number of reasons, including whether or not the data collected by a third party would become a federal record during the auditing process. If the agency audits the data analysis directly, the current guidance is that any audited data would become a federal record subject to Freedom of Information Act (FOIA). Having independent, private industry auditors would potentially alleviate that concern while also ensuring the consistency and reliability of EM data. Stronger advocacy at the federal level for ET-derived data to be available across broader use case applications (such as use for business purposes by the fishing industry itself) would help to reduce this barrier. The Fisheries Information Management Modernization (FIMM) Report from NOAA Fisheries provides a foundation and launch pad for this transition [35].

The pervasive culture among fisheries law enforcement and regulators seems to be risk averse with respect to new technology and actively prefers setting out specific technical standards and requirements surrounding a known technology. This is in direct opposition to the need for technology to evolve to meet the data (and thus decision-making) needs of managers and industry, and it actively prevents innovation from doing its job from the perspective of maximizing service to all stakeholders.

Furthermore, some policies in the U.S. have inadvertently created perverse incentives that dissuade the uptake of ET. There are numerous examples of where clear government support is articulated for industry with respect to cost-reimbursement for human observers but not equally so for vessels that elect to use EM to fulfill the same requirements in the same fishery. Similarly, in order to meet science and monitoring thresholds, the percentage of trips currently required to have an observer on board may be lower than the percentage of vessels required to carry EM, or the EM data audit and review levels. EM should not be viewed exclusively within the confines of the observer program itself, but as a complementary tool to human observer coverage and a technology flexible enough to adapt as needs change.

5. Opportunity: EM as a catalyst for change

As we examine the current landscape of opportunities in the U.S. to harness technology in fisheries management, it is clear EM presents a timely opportunity to step back and rethink how and where technology fits into our fisheries management regulatory structures. EM is a sufficiently broad umbrella, both from the perspective of what the actual hardware-software systems can look like as well as its diversity of potential use cases, that it demands more tech-savvy and forward-looking regulatory frameworks. Even the initial task of defining EM presents an opportunity to create flexibility for future configurations of hardware, software, use cases, and protocols and learn from and move beyond the challenges that VMS has faced over the past quarter of a century.

We can look to the way in which the Australia Fisheries Management Authority (AFMA) defines EM:

(a) "a thing used for, intended to be used for, or capable of being used for, generating, transmitting or storing data; or
(b) a thing that makes, is intended to make, or is capable of making, a thing covered by paragraph (a) operational." [36]

This provides an example definition of EM that is broad and performance focused, leaving room for technology to evolve within the existing regulatory framework. As discussed in the standards section above, it is then critical to provide ample clarity and guidance outside of the binding regulations that describe details of what EM options look like today and how one might go about using them.

There is an opportunity to create policy and guidance at the federal level in the U.S. that encourages the uptake and evolution of ET in fisheries. In particular, a more clearly defined marketplace would enable technology providers to build viable business models that serve fishery stakeholders. A lack of guidance from NOAA Headquarters on which vessels will be required to report specific data elements and on what timescale currently inhibits fishery managers from synchronizing their efforts and technology providers from reasonably assessing the market size and developing appropriate core/general offerings that could then be customized to meet specific needs of a given fishery. The specific technical requirements of any data collection program must be defined and guided by the regional management councils, not at the federal level, in instruments that enable regular, efficient updates as the programs and technology evolve; however, more unity and consistency in what may be asked of providers across regions could unlock economies of scale that cannot currently be accessed due to the intense effort required to customize proposals and EM systems for every individual fishery/tender on the part of the providers. The regional EM policy for longline tuna fisheries in the Western and Central Pacific Ocean is one example of how some unity and minimum standards can be created at a high level, in this case by The Pacific Islands Forum Fisheries Agency's (FFA), while still enabling individual member states to retain control over the structure, design, and implementation of the EM programs [37].

We note here that experience globally underscores the importance of including early and frequent discussions with stakeholders during the development of federal regulation that would place new requirements on vessels. New Zealand's experience mandating and subsequently rolling out a national scale EM program highlights that industry engagement is fundamental to success [38]. Initially industry was not sufficiently consulted prior to the announcement in 2017 that EM would become mandatory for 100% of vessels, which precipitated strong pushback and stagnated the program rollout. After pausing and carrying out an extensive industry and stakeholder engagement processes, New Zealand has overcome the pushback and appears to be on track to expand a national EM program that will cover 84% of inshore landings (by weight) by 2024. The E.U. has similarly experienced intense pushback on EM uptake due in part to the fishing industry's view that EM represents government mistrust of their actions and that the technology is an intrusion of privacy [39,40].

Although the U.S. currently has EM on more vessels (~600) than any other country by a wide margin, it has not yet capitalized on the potential purchasing power that could be achieved with some coordinated effort within and among regions. Two opportunities to drive down costs of EM, or ET more broadly, include rolling out programs of sufficient scale that there is bulk purchasing power and opportunity for competition among technology providers, as well as reducing the amount and duration of data storage. To materialize cost-savings for ET, the regions must refine the articulation of their data *needs* vs. *desires* to more explicitly streamline programs down to only the minimum performance standards. Focused discussions among managers, agency staff and industry around what is really needed to achieve the programmatic goals, without getting distracted or bogged down by the seemingly limitless possibilities of what could be added to a program, will be important as programs more carefully weigh data *costs* vs. *value*. These conversations should be guided by the principle that a program starts as simply as possible and then adds functionalities as needed over time. Furthermore, any reductions in the duration of time that large amounts of data must be stored is an opportunity to reduce cost.

6. Action steps

Setting U.S. fisheries on the course to leadership and innovation, in service of our shared management and conservation goals, will take efforts from across the fisheries community, from vendors to fishermen,

regulators, scientists, and advocates. We believe there are many roles to play in advancing fisheries technology policy for the greater good, and the time to act is now.

1. NOAA Fisheries should establish a core team of cross-agency policy makers who are well versed in writing regulations and fully literate about the needs and nuances of crafting forward-thinking performance standards that can foster and sustain continued technological innovation within the context of the overarching Federal Data Strategy and the related data strategies within NOAA [41,42]. This is needed to provide necessary support to all who are tasked with writing regulations around this topic. This group should draw from existing fisheries management experts at NOAA as well as policy-makers from the Office of Science and Technology Policy, artificial intelligence experts from the National Science and Technology Council, the National Institute of Standards and Technology, and others with experience crafting forward-looking technology policy.
2. Socialization of performance and data focused standards is needed among all stakeholders to better understand where they are appropriate, how they can serve different stakeholder aims (for example, of achieving cost-effective, high-quality data collection), and how to use/implement them in practice to avoid feelings such as "there is insufficient guidance or information for actually implementing this requirement on a given vessel." This is tightly linked to the existing best-practice and recommendation of engaging all stakeholder groups, including the fishing industry, all potential end-users of the data as well as the technology provider community, early and often throughout the process. Developing communication materials, broadly disseminating key messages, and facilitating conversations and cross-regional sharing of experiences will support this process.
3. Cultivate an open marketplace of agency-approved vendors[iii] that includes a competitive bidding process, as this approach appears to be most appropriate for achieving the vision outlined at the start. The data from a given vessel most immediately resides under the control of the owners of that vessel who have contractual agreements with technology providers to house the data, ensure its integrity, and fulfill the required data sharing obligations (set forth by the permitting authorities) with other stakeholders at the appropriate granularity and with adequate privacy and confidentiality protections in place.
4. A federal fisheries management framework should clarify the cornerstones of ET policy to ensure consistency across regions with applicable regulatory schemes, but leave as much room as possible beyond that for flexibility in how regions and vendors meet these requirements. Specifically:

   (a) Federal regulation that focuses on the broad regulatory goals of systems, rather than specific technologies or functions, should provide a clear mandate defining the minimum data elements required to be reported, by which vessels/fisheries, and over what timescale implementation of new reporting will be required for all fisheries under U.S. jurisdiction.
   (b) Federal regulation should provide clarity on key high-level legal definitions and interpretations to ensure consistency across regions, particularly in areas where there is legal uncertainty (e.g., privacy implications, data storage requirements etc.).
   (c) Federal legal frameworks should support ET data access for 3rd parties, particularly fishermen, by allowing technology providers to retain control over data and data access.
   (d) Federal ET guidelines should recognize that ET data can be used for a variety of different regulatory ends and explicitly allow EM to support efforts beyond simply satisfying observer requirements, including contributing to best available science requirements, safety at sea regulation and other regulatory needs.

[iii] "The "third-party" model involves each participating vessel retaining an EM service provider to collect and review EM data, provide required information to NOAA Fisheries, and store, manage and dispose of EM data in accordance with performance standards and the service provider's contractual agreement with the vessel." For more details, see: https://media.fisheries.noaa.gov/dam-migration/04–115-03.pdf

7. Conclusions

While there is compelling evidence that a structural shift toward performance focused standards in U.S. fisheries regulation could enhance the efficiency, effectiveness, and utility of ever-evolving technologies in support of robust fisheries-dependent data collection, a strong collaborative effort will be required by all stakeholders, including funders, to overcome the socio-political and historical barriers currently blocking the way. Amending the Magnuson-Stevens Fisheries Management and Conservation Act (MSA) to better support the integration of electronic technologies in fisheries management through performance-focused standards is a key opportunity to help move the federal fisheries management framework in a more innovation-compatible direction. Given that a discussion draft for MSA reauthorization was introduced during the 116th Congress by Rep. Huffman (D-CA) and a reintroduction is anticipated for the 117th Congress, there is a timely and critical opportunity for the U.S. to make progress on this front. For example, the discussion draft introduced during the 116th congress specifically suggests adding ET to the activities that can be included under a Secretarial Information Collection Plan (16U.S.C. 1881a(a)), which should dramatically broaden the uses of ET beyond its current limitations within the observer program [43]. There is an opportunity to further strengthen the framework by more directly provisioning for ET-derived data to be used across management, science, enforcement, and business use cases. Additionally, any reauthorization of the MSA should consider revising outdated data confidentiality and access provisions to allow broader and more timely use of fisheries data outside of NOAA. There is no better time than the present to modernize the fundamental structures governing U.S. fisheries, and it will require a coordinated effort among industry, regulators, fisheries managers, scientists, enforcement agencies, technology providers, funders, tribes, and community stakeholders.

CRediT authorship contribution statement

Annie Brett: Conceptualization, Investigation, Writing. **Melissa Garren**: Conceptualization, Investigation, Writing, Supervision, Funding acquisition. **Forrest Lewis**: Investigation, Writing, Data Curation. **Laura Sanchez**: Investigation, Writing. **Daniella Spina**: Investigation.

Competing Interest Statement

Declarations of interest: none.

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