Critical Considerations for Implementing Electronic Reporting Methods in Recreational Fisheries

Report of the Marine Fisheries Advisory Committee Recreational Electronic Reporting Task Force

Presented to the Marine Fisheries Advisory Committee

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EXECUTIVE SUMMAY

Saltwater recreational fishing is a significant social and cultural activity in the United States and a significant economic driver for many coastal communities. This fishing sector supports over 550,000 jobs, generates almost $90 billion in sales impacts, and provides $50 billion in economic value added, according to 2019 Fisheries Economics of the United States Report (NMFS NOAA 2022). Because of its importance, proper management of recreational fisheries relies upon timely and accurate estimation of recreational harvest, and the engagement of private recreational anglers in the management process.

Angler engagement in data collection and reporting was a major topic of discussion at the 2018 NOAA Fisheries National Saltwater Recreational Fisheries Summit. The Summit's final report indicated that angler-supported electronic reporting and other kinds of collaborative data collection to provide more timely and accurate data would ultimately lead to enhanced fishing opportunity and stability. As a result of this outcome, the Marine Fisheries Advisory Committee (MAFAC) empaneled the Recreational Electronic Reporting Task Force to explore how NOAA Fisheries might best guide and make use of electronically reported data for recreational fisheries. MAFAC asked the Task Force to address and provide guidance on the full suite of factors that it believed were relevant and necessary to be addressed by the agency when developing an implementation roadmap for the use of electronically reported recreational fishing data.

Over the course of 2 years, the Task Force reviewed literature, gathered input from other experts, and discussed a plethora of topics. They concluded,

- Electronic reporting technology is advancing quickly and is being employed to gather data and provide insight globally.
- The opportunities for improving data collection, analysis, and management of fisheries is enormous.
- Anglers must be engaged for any electronic reporting process to be successful.
- The data standards, data collection, management, and analytical systems must be developed in a stepwise manner and be allowed to adapt and evolve.

Based on these conclusions, the overarching recommendations of the Task Force are that NOAA Fisheries should use data reported electronically by anglers to enhance and complement other data sources, such as the Marine Recreational Information Program. While there can be statistical challenges associated with electronically reported data, most can be addressed by establishing clear data standards and a plan for integrating the data into management. Thus, the agency should draft a Data Standards Plan and a Data Integration Plan that lays out these requirements for any electronic reporting platform (Section 2). In addition, the agency should include considerations and guidance for electronic reporting platforms to ensure angler participation and retention as part of the Data Standards Plan. Research is needed to inform all of these actions (Sections 3, 4). Data verification is important, common, and should follow clear protocols for evaluating the accuracy and relevance of new data (Section 5). While probability-based sampling is the gold standard, other statistical methods (such as

conducting a census or careful application of model-based approaches) have value. NOAA Fisheries should consider (i) mechanisms for including data collected by other means, (ii) identify the scale and set of assumptions that are useful for integrating the information defensibly and appropriately, and (iii) opportunities for expanding the data horizon (Section 6). If it is determined that a marine recreational electronic reporting effort or pilot can help to fill a data gap or provide supplemental data to an ongoing data gathering effort, a process is outlined in Section 7 for how to develop such a program at a regional, state, or federal level.

1. INTRODUCTION

This Task Force was established under the authority of the Marine Fisheries Advisory Committee (MAFAC) to provide expert advice to MAFAC on the generation, delivery, and use of electronic private recreational angler self-reported data. MAFAC will use this advice in its work and advice to assist NOAA Fisheries in fulfilling its mission activities. The information provided by the Task Force and MAFAC will assist NOAA Fisheries in fulfilling its central role in providing usable, high-quality, accurate data on recreational fisheries, and will contribute to the development of an agency roadmap to advance and guide the implementation, where appropriate, of electronic data collection in private recreational fisheries.

1.1 Terms of Reference

MAFAC provided the following Terms of Reference to the Task Force. Initial actions for consideration included:

- Identify and prioritize known data gaps relative to NOAA Fisheries' role in supporting management of marine recreational fisheries that could be addressed through mandatory or voluntary private recreational angler electronic reporting programs.
- Identify realistic and achievable goals for voluntary (also known as opt-in) and mandatory electronic reporting for private recreational anglers, as well as associated challenges and solutions, where identifiable.
- Provide recommendations on how the aforementioned goals could be best supported or achieved by NOAA Fisheries.

To achieve this, the Task Force was asked to:

- Consider both catch and effort and non–catch and effort data, such as length, weight and distributional data, and citizen science applications when formulating its guidance.
- Provide guidance to MAFAC that covers the full suite of factors it believes are relevant and necessary to be addressed by the agency when developing an implementation roadmap. Examples of potential factors include known challenges (e.g., angler participation, validation of reporting, and sources of bias), data sharing and ownership considerations, common data and system standards, infrastructure and programmatic needs and impacts, angler reporting burden, and partnership roles (state, federal, commission).

- Consider existing references on the subject of opt-in and related electronic self-reporting survey methodologies including, the Marine Recreational Information Program (MRIP) angler electronic reporting project reports and other agency reports.

1.2 Data Gaps in Recreational Fishery Data

NOAA Fisheries Regional Offices and Science Centers have identified a need for high-quality data that might best be collected from recreational fisheries sources. The first step in this process is to identify data gaps, namely data that are knowingly or unknowingly missing from current databases that can be collected from recreational fisheries sources. For the purposes of this report, these data gaps can be broken down into specific needs that may be met using electronic data reporting technology. Here we identify high-priority categories of fisheries data that can be collected; data that might not otherwise be available through more traditional means such as systematic trawl surveys or through MRIP; or otherwise may serve as a strong complement to these sources (National Academies of Science, Engineering and Medicine, 2021). The categories below are not listed in any priority order because there may be regional differences in needs and priorities. The data needs listed here are those relevant to acquisition opportunities available through electronic reporting. The report provides examples of such opportunities to consider without making specific recommendations for specific data requirements.

The top five identified data gaps associated with marine recreational fisheries are:

1. **Released catch characterization:** Size distribution, identification, location and depth, and release condition and method of released catch.
2. **Species infrequently encountered:** Increased precision of estimated catch for species infrequently encountered in intercept surveys. For example:
    a. Those with imprecise estimates that generate high levels of uncertainty for stock assessors and managers, such as reef fish and highly migratory species (e.g., tunas and sharks).
    b. The need for finer scale spatial and temporal catch estimates for fisheries with short seasons.
3. **Protected resources:**
    a. Interaction (frequency, location, and species involved) of hooked or hooked and released protected resources (sea turtles, marine mammals, and protected sharks) or other predators.
    b. The number of individual marine mammals and ESA-listed species caught as bycatch, including disposition at release (i.e., dead, alive, injured), to inform post-release mortality estimates.
4. **Trip-related angler behavior on and off of the water:**
    a. *On water:* Fishing time in each area fished, movement to other areas, angler or vessel identification, gear used, and catch rate by species.
    b. *Off water:* Travel distance to fishing locations; trip expenditure subjects and amounts.
5. **Private access sites**: Catch rates for trips made from private access sites, including catch rate by species and area fished, date, and mode of fishing.

Important to Continue to Collect:

- General information (species and length).
- Specific gear used (e.g., hook size and shape and line type).
- Geographic distribution (range of species caught).

1.3 Role of the Angler as a Citizen Scientist

The value of enlisting the public in observing nature for the purposes of advancing science, known as citizen science, is recognized and its use has been growing over recent decades (Irwin, 2002; Bonney, 2009; Sullivan et al. 2014). As technology advances, a growing opportunity exists to engage anglers, and in particular recreational anglers, as citizen scientists to gather information about landed catch, species encountered, discards, targeting, gear use, and environmental conditions. While barriers exist in terms of data quality (Downs et al. 2021; Brick et al. 2022) and scientist perceptions, preferences, and requirements (Burgess et al. 2017), opportunities remain especially if clear data standards are implemented, and how the data are to be used or integrated into science and management are well thought out in advance (National Academies of Sciences, 2000, 2013, 2017, 2021; Liu et al. 2017; de Sherbinin et al. 2021; Stokes et al. 2021).

2. COMMON DATA STANDARDS AND DATA INTEGRATION

2.1 Common Data Standards

Any data collection process should have a clear intent of how the data will be used for science and management. Data may be used in stock assessments, monitoring catch limits, to better understand changing system dynamics, or to initiate or change a management action. Before collecting data and information, data standards should be considered to ensure that minimum data requirements are met. Standards allow for consistent data collection and comparability, promote collaboration, and provide for successful use of the data across all government sectors (state, regional, national, international). Standards also allow the system to evolve and grow so that data are scalable and useful (Bonar et al. 2009). Electronic reporting data collection efforts should use consistent or common standards and be coordinated across all sectors (stakeholders and state and federal partners) to promote collaboration and data utility.

This section provides the context for why data standards are useful and identifies the need for common standards in many recreational electronic reporting initiatives.

NOAA Fisheries has data standards for catch and effort surveys, which are outlined in their Recreational Fishing Survey and Data Standards framework. These standards ensure data quality, consistency, and comparability across MRIP's national network of recreational fishing surveys. NOAA Fisheries has a series of policies and procedures that must be followed when considering any data collection effort with standards. Standards

facilitate consistent metrics for global comparisons across time and space, while recognizing the needs of local jurisdictions. In U.S. federal jurisdictions, one must also meet the requirements of the Paperwork Reduction Act (PRA) of 1995. The purpose of the PRA is to ensure data collection efforts are not redundant and do not cause undue burden on the public, and that all data collection efforts have a clear purpose. Furthermore, NOAA Fisheries has policies and procedures on data quality, data and information management, and electronic technologies and fishery-dependent data collection, to which the agency must adhere.

The Magnuson-Stevens Fishery Conservation and Management Act—the primary law that governs marine fisheries management in U.S. federal waters, first passed in 1976—provides a flexible approach to fisheries management that incorporates a regional fisheries management structure. Its implementation has led to regional variability in science and data used for management and monitoring. For example, whereas trap surveys in offshore waters greater than 15 m are used to monitor fish populations south of the North Carolina and Virginia border, trawl surveys are used to monitor fish populations north of this border. Although this regional approach has historically worked for many data collection systems, climate change has caused fish movement across regional boundaries to new habitats (e.g., Watson et al. 1998, Rijnsdorp et al. 2009, Kerr et al. 2017, Townhill et al. 2019, Purtlebaugh et al. 2020), and led to concerns about how cross-regional metrics can be used to assess population vulnerability and legitimacy of quota allocations. Data collection systems need to adjust so that data are comparable across management regions and other jurisdictions.

Fishery scientists and managers have requested alternative data sources and approaches to improve fishery management. Supplemental data from the private recreational sector might help to satisfy this need by complementing rather than replacing existing data sources (Venturelli et al. 2017). Ensuring the utility of supplemental data requires a concise yet flexible directory of data fields with clear and concise definitions that can be referenced when creating supplemental and supporting data collection methods. These data fields and definitions would ensure that data collected are coherent, realistic, measurable, and comparable, while achieving data standards established by NOAA Fisheries. The directory of data fields and definitions should be reviewed on a regular basis, with a maximum of 5 years between reviews, to address the changing landscape of fisheries science and management. The supplemental data collections should be allowed to change over time, but changes in data fields and definitions should be evaluated based on the need for consistency versus improvements in data accuracy and utility. Additionally, discussions among analysts, data scientists, app developers, managers, and anglers are necessary during the planning phase of any new data effort to ensure that the desired data can be collected in a consistent way (considering the scope of why the data would be collected and the data collector) via the available technology, and will ultimately meet the needs of the analyst or manager.

2.1.1 Data Standards Example: Atlantic Coastal Cooperative Statistics Program (ACCSP)

It is valuable to consider successful collaborative data platforms (e.g., Marshall et al. 2021) when implementing new data collection methods or developing new data

standards. The Atlantic Coastal Cooperative Statistics Program (ACCSP) is a good reference for considering fishery-dependent data. The ACCSP maintains a comprehensive list of data standards, and includes state partner and stakeholder involvement from Maine to Florida to ensure complete and integrated data collections.

The ACCSP offers a comprehensive program to ensure that fishery-dependent data are consistent across fisheries datasets, while making collaborative data solutions possible among the 23 state and federal program participants. The ACCSP is also a committee-based organization. Committees such as the Recreational Technical, Standard Codes, and Information Systems are composed primarily of partner representatives. These committees provide the framework for the collaborative processes that create and manage the data standards and govern the program. Furthermore, the ACCSP coordinates the Access Point Angler Intercept Survey (APAIS) from Maine to Georgia. The APAIS is the catch component of MRIP. ACCSP (and the Gulf Fisheries Information Network (FIN)) contractually supports execution of the data collection components of MRIP's APAIS and FHS by the states. Data and survey standards and deliverables for these programs are established by MRIP.

The ACCSP stores recreational catch and effort data from 1981 to present within the data warehouse. This online warehouse makes it possible to combine datasets from different sources for larger scale analysis. The mission of the ACCSP is to be a "cooperative state-federal program to design, implement, and conduct marine fisheries statistics data collection programs and to integrate those data into a single data management system that will meet the needs of fishery managers, scientists, and fishermen." Recreational fisheries standards are just one aspect of this comprehensive program and data collection infrastructure. The ACCSP is one example of the FIN partnerships with NOAA. Others include Gulf FIN, PacFIN, Pacific RecFIN, and AKFIN.

2.1.2 One data gap example – size and depth of discards

Table 1 provides an example of how a national data standard could be developed to address a minimum data requirement. Table 1 uses the grouper/snapper complex as its example and demonstrates how use of a data standard allows for the integration of additional, more robust data, according to the specific needs of a regional target fishery. If the national standard is unlikely to satisfy the data needs of a specific fishery, then the standard should be adapted to the fishery so that it provides usable advice. Section 3 (Angler Recruitment, Retention, and Innovation) includes a flow diagram of the process for deciding what data are important to include as a way of highlighting how to involve the fishing community in such decisions.

The National Information Exchange Model (NIEM) is also a good reference for developing common standards. Formally launched in 2005 by the U.S. Department of Homeland Security and the U.S. Department of Justice, NIEM creates a common vocabulary that enables efficient information and data exchange across diverse public and private organizations. Rather than starting from scratch, NIEM can save organizations time and money by providing consistent, reusable, and repeatable data terms, definitions, and processes.

Table 1. Developing Data Reporting Standards for Electronic Angler Reporting

A case example for one data gap: ***Discards***

Field	*Minimum data required - applied universally*	*Ideal dataset - Required for unique situations only*
Fishery Example:	Family (Snapper Grouper)	Individual Species
Reporting Type	Trip or Catch	Catch level
Type of Reporting	Individual or vessel	Individual or vessel
Trip Duration	NA	Time from leaving dock to return
Fishing Duration	NA	Time lines in the water
Percent of Total Catch	Percentage of total catch reported	Percentage of catch reported
Date	Day	Time of day
Location	State / region	Latitude and longitude
Depth	Atmospheric equivalent (~30 ft.)	Nearest foot
Descending Device Used (including venting devices)	NA	Y/N
Descending Device Type	NA	Type
Fish Condition at surface	NA	Healthy/Injured/Near Death/ Dead/Predated
Fish Size	NA	Nearest centimeter

NOTE: These minimum values are for illustration only; it is up to NOAA Fisheries to identify required fields and minimum requirements for addressing the ***DISCARDS*** *data gap. This should be done in collaboration with the fishing community to ensure practicability and foster trust and understanding.*

2.2 Data Integration

Well-defined standards are a critical piece of any data integration process. NOAA Fisheries has started to formalize this process through their *Recreational Fishing Survey and Data Standards* guidance document, which provides a single set of guidelines for recreational fisheries data collection and estimation. These standards support the Marine Recreational Information Program (MRIP), and describe a general process for integrating new fisheries data. Conversations with staff indicate that this process is in its early stages of implementation. Similarly, the International Council for the Exploration of the Sea (ICES) has a data integration plan that was outlined during the 2021 Ices Workshop on Standards and Guidelines for Fisheries Dependent Data (ICES 2021). These two documents provide a convenient starting point for exploring data integration and developing recommendations related to recreational electronic reporting.

The general process of data integration followed by NOAA Fisheries and proposed by the ICES workshop are illustrated in Figures 1 and 2, respectively. NOAA's process

begins with a written plan that includes goals and objectives, survey design, data quality, and a transition plan. The plan is reviewed (passing through two layers of approvals) before data collection can begin. The data collection stage is generally not discussed; however, the final stage covers data integration, where details about the data, formats, and data management are discussed and form a necessary part of the initial plan.

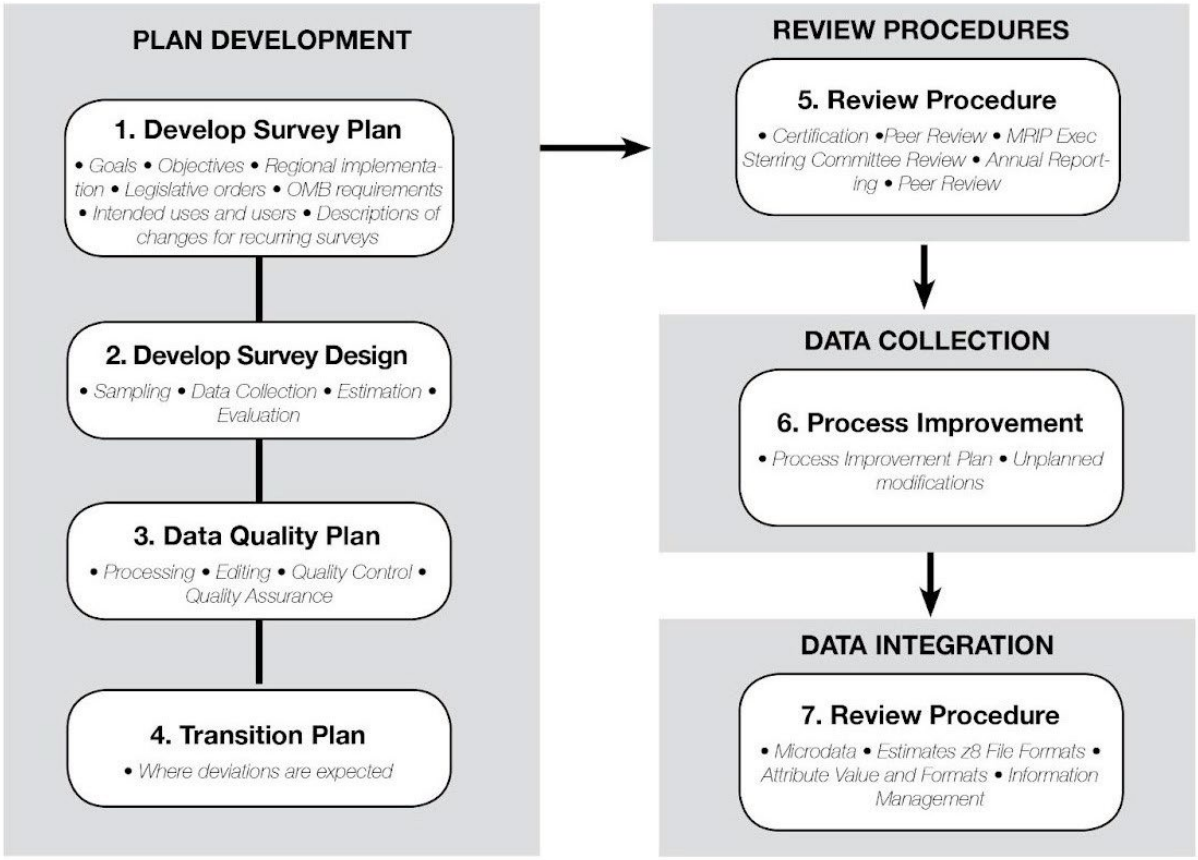

Figure 1. Key process flow map for recreational survey and data standards currently used by NOAA Fisheries for integrating recreational fishing survey data.

The ICES approach follows a similar process wherein the application is defined and quality standards are set in advance of data collection. In addition, the approach provides details on the stages of data collection, how the data are accepted and applied, and the various types of standards that are expected with fishery-dependent data. The ICES workshop document specifically states that they *"did not identify any existing developments of guidance or standards for the emerging approach of Collaborative industry-science surveys,"* which illustrates a key gap in the standards for these types of data, including data collected by individual apps (ICES 2021).

The Task Force recognizes that to advance the development of electronic reporting methods and standards, NOAA will need to rely upon its existing data platforms while anticipating changes that will occur in those platforms as they continue to evolve. The Task Force believes that, while progress in the development of electronic reporting programs should not be delayed, current and future development of existing platforms

could greatly inform how these programs are shaped. New and existing tools must be integrated thoughtfully in order to achieve a smooth and reliable transition toward better science and management.

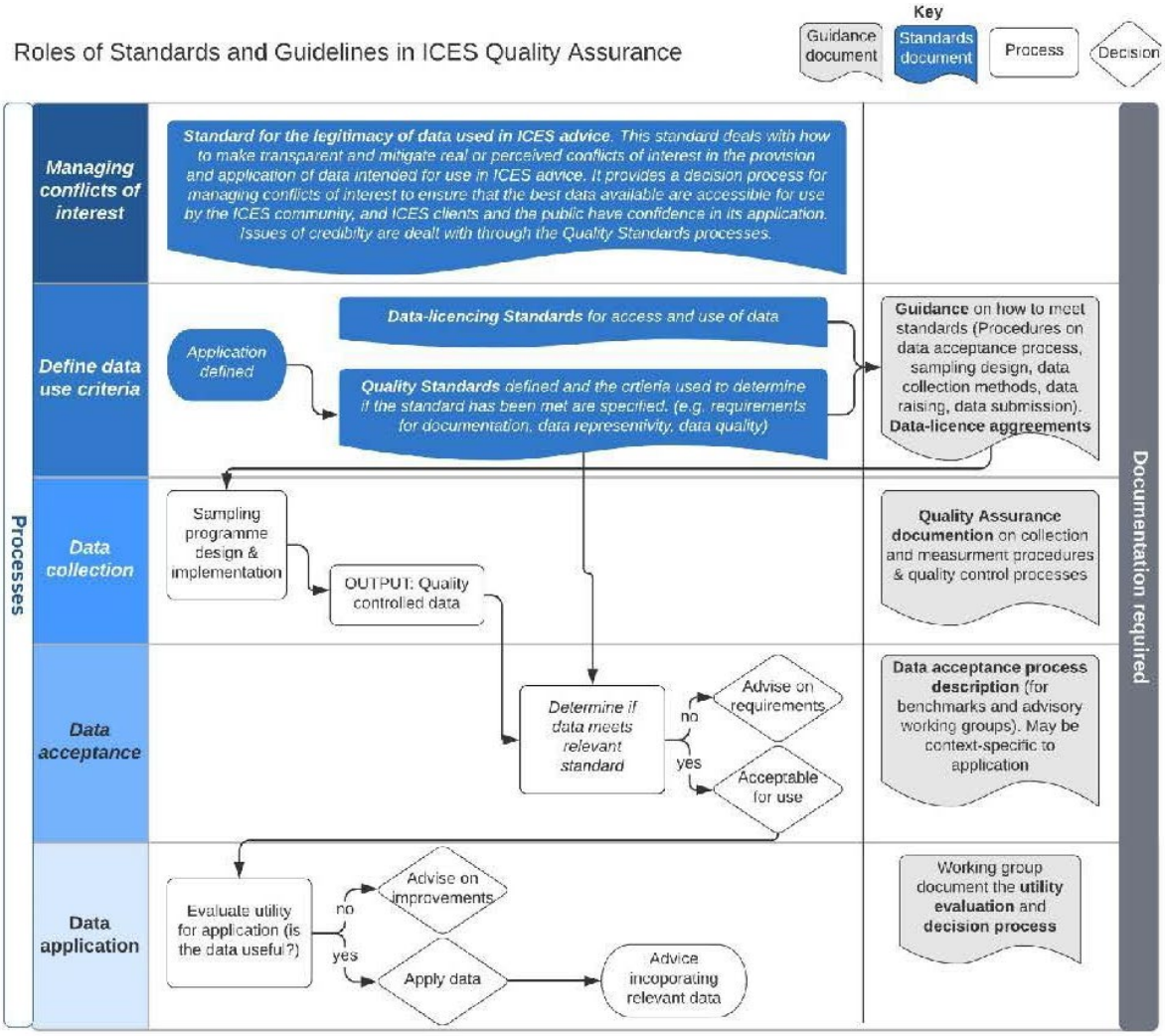

Figure 2. ICES role of standards and guidelines in quality assurance process for fisheries data. Setting of standards and data use criteria are the responsibility of the Benchmark and Data Governance Group, while provision of guidance on how to achieve that is within the remit of working groups.

2.3 Future Considerations for Data Standards and Integration

One drawback of the NOAA and ICES processes described in the previous section is that they require a specific question or research objective to be identified prior to data collection. Similar processes have yet to be developed for situations in which extensive (and sometimes high-quality) data are already available, but for which no question has yet been formed (Lennox et al. 2022). For example, what if quality-assured acoustic data from anglers became available at a large scale? Should these data be excluded simply because there is no immediate question or application to justify it? How should such a dataset be integrated into management?

In these situations, the current processes do not address how or whether such data should be collected. Should there be a way of onboarding it into this process at a different stage? Should there be a parallel process that integrates data that are not tied to a specific question, but can be made available for future use (for example, data sources that could be used to refine or adjust current data inputs)? Mechanisms available for vetting the need for information, such as the Paperwork Reduction Act (PRA), focus on the burden of gathering such information on the consumer, but cannot anticipate the need for or integration of such data into newly formed or existing databases, or its anticipated need for use in analysis. Given the emerging scale of recreational fisheries data, these questions should be considered for a robust data standardization and integration process (consider also the report by Stokes, L., McShane, R., Williams, B. and Zalsha, S., 2018, SMU Recreational Fisheries Report for CLS America).

2.4 Recommendations

Minimum data standards should be developed for private recreational electronic data collection. These standards should:

- Clearly define the data elements (fields) that are being collected to ensure the effective and consistent implementation of data collection, database creation, and opportunities for its use in data management.
- Determine reporting requirements.
- Provide quality control and assurance documentation.
- Create a process to apply adjustments and modification to standards over time.
- As a priority, ensure that at least the minimum data elements are collected. Consider opportunities for use in data management when multiple fields must be collected in unison and are to be used in a coordinated manner.

Furthermore, the development process for these data standards should:

- Be developed for individual data gaps to be able to determine how well the standards match with what can actually be collected from anglers.
- Involve a collaborative, iterative process with state agencies through the established regional Fisheries Information Networks to ensure the fishing community, scientists, and managers help create, manage, and understand the standards, and that the standards are of high quality for analysis, which is critical for gaining trust for a successful electronic data collection effort and will help avoid future challenges.
- Coordinate with NIEM and include a process to document and track changes to compare past and future data collections. The NIEM model serves as a seamless, interoperable way for the exchange of data across government agencies. Having a common vocabulary when creating a standard will enable efficient information exchange across all sectors.

If non-governmental organizations or third-party vendors are developing electronic reporting data collection platforms, they should consistently coordinate with NOAA

Fisheries to ensure that data collected meet minimum data standards and are usable for both science and management.

As an integral part of the development of any electronic reporting data collection platform to address a recognized data gap and according to the data standards, NOAA Fisheries should develop a data integration plan that includes goals and objectives for how the collected data will be used, survey design, data quality protocols, and a transition plan. This plan should be developed with all user groups (anglers, scientists, managers, and the public).

The data integration plan should be adaptive and flexible to be able to address new or additional information that may be needed in the future. It should anticipate how data collection methods and designs may change with new data collection technology and analytical methods. At a minimum, this should include a listing of how anticipated changes may influence the value of the data in hand relative to the additional data, data management needs, and advances in analytical procedures expected to come.

3. ANGLER RECRUITMENT, RETENTION, AND INNOVATION

3.1 Introduction

Electronic reporting from recreational anglers presents an enormous opportunity for NOAA Fisheries to fulfill its mandate to provide usable, high-quality recreational fisheries data. The successful integration of anglers into a collaborative fisheries framework can provide data that cannot be feasibly obtained via current methods. NOAA must overcome three key challenges to establish a viable recreational electronic reporting program:

1. Recruiting and retaining enough anglers to generate data.
2. Ensuring data quality and validity.
3. Providing the opportunities for flexibility and innovation.

This section focuses on the first and third challenges; the second challenge is covered in Sections 4.3, 5.2, and 5.3.

This section reviews common methods for motivating anglers to generate data (Section 3.2), and emphasizes the importance of using market segmentation (Section 3.3) to align program objectives with the inherent values and motivations of participating anglers. Section 3.4 argues that the user experience needs to be front-and-center to ensure NOAA develops something that anglers want to use, and Section 3.5 provides a road map for creating a data collection system in which anglers and partnering organizations are brought together to address core data requirements for NOAA Fisheries. The section concludes with a list of some of the known actions that are needed to promote participation and illuminate areas of opportunity (Section 3.6).

3.2 Angler Motivations (What's in it for me?)

Electronic reporting must appeal to a sufficiently large and representative audience of anglers to generate statistically meaningful data that are useful for fisheries management. This is the case regardless of whether reporting is voluntary or mandatory. Motivation can be a significant challenge to the success of voluntary reporting projects (Cooke et al. 2000) and must be central to electronic reporting system design. Motivation is also important for mandatory systems as a way to gain acceptance and maximize compliance in the absence of strong enforcement. Mandatory vs. voluntary reporting is discussed in further detail in Section 4.

Effective motivation requires an understanding of what grabs the attention of anglers. For example, avoiding fines or the closure of a fishery can be a significant motivation to report such things as sea turtle interactions (Howell et al. 2008, 2015). Anglers can also be motivated by the prospect of contributing to aggregate data that reveal where and when to fish so as to maximize efficiency and yield while minimizing risks (Bradley et al. 2019). Similarly, tournament anglers are motivated by competitive fishing for prizes and prestige (Policansky, 2002; Valtonen, et al. 2010). Tournaments often require the use of a fishing app to report catch and effort. These tournaments can also collect social and biological information such as ocean use, congestion, and access points along with fishing pressure; discard mortality; impacts of fish relocation; and interaction with rare species.

Many anglers are motivated to improve the quality of fisheries data (Crandall et al. 2018). Anglers may have an interest in providing the best possible data for managers by becoming "citizen scientists"—citizens who partner with scientists to study fish populations or develop management tools using electronic self-reporting applications. The potential for angler citizen scientists to be more avid and conservation-minded than the average angler (Gundelund et al. 2020) does not necessarily result in biased data (Gundelund et al. 2021).

Anglers may be motivated to participate in a reporting program because of its educational value. Learning about the resource, fishery, or management process can be a motivator for many anglers and encourage them to continue providing data. Increasing knowledge is often cited as a motivation for volunteering (Thiel et al. 2014).

It is important to keep anglers motivated over the long term. Attrition rates are shown to be high even with the most popular phone applications. Keeping people engaged and willing to contribute could be the greatest determining factor for avoiding user bias. Anglers who are unwilling to continue providing information and drop out of the reporting pool could skew the dataset, making integration into MRIP more difficult (Statista, 2022). Engagement can be achieved by fostering a collaborative environment that includes angler workshops and direct engagement with management. Feedback loops to the anglers (e.g., emails, social media posts, electronic newsletters, and similar outreach) have shown to increase and continue participation (Obar, 2013). Some examples of motivations for anglers to maintain participation in mandatory and voluntary reporting opportunities are provided in Table 2.

Table 2. Possible top motivations for both mandatory and voluntary report of trip and effort data.

Mandatory Reporting	
Motivators	"The Prize"
Maintain Rec Permits (Mandatory)	Continued fishing; not in violation
Tournaments	Desire to fish competitively, win prizes, recognition as the best
Change in regulations/special access to fisheries	Helpful to obtain the desired outcome from regulatory decisions on stock
Ocean planning efforts	Wind farm planning and mitigation/compensation
Business needs (for hire/charter) personal log	Quickly recall past customer trips/notes
Voluntary Reporting	
Motivators	"The Prize"
Contribute to science	Improved quality of data in fisheries
Preservation of fishing abundance	Ability to continue fishing in the future
Personal log to improve fishing	Record of fishing trip to review later
Rewards	Bragging rights/badges/recognition
Education	Learn more about fishing/species

3.3 Motivating Anglers (How to encourage participation)

Other factors that can be key for successfully motivating anglers to participate in voluntary or mandatory reporting systems include trust, good communications, addressing reporting fatigue, and overall ease of use of the app. The first three factors are discussed in this section, and Section 3.5 on User Experience is dedicated to the issue of ease of use.

Trust

Both voluntary and mandatory reporting require anglers to trust the requesting entity. Angler trust is high when there are good relationships, and when fishermen perspectives align with scientific advice and management actions. When trust is low and difficult to build, it may be important to identify third-party partners (e.g., other agencies, non-profits, academics, and industry) that can help bridge the gap to form a trusting relationship with the anglers. Anecdotally, some believe that anglers may be more

familiar with and trusting of state agencies and local/state conservation or fishing organizations than they are of federal fishery management councils or NOAA. However, a direct survey question by Southwick Associates added to their *anglersurvey.com* in spring 2019 (a survey distributed every 2 months to anglers across the country to collect information about fishing behavior and purchases) belies this anecdotal conclusion. Anglers in the United States consider state or federal wildlife agencies, fisheries scientists, and other fishermen (through personal communications, forums, social media, and other avenues), in that order, to be the top three most credible sources of information related to fisheries.

Trust or distrust may shift depending on how information and data from fishermen are used or not used, especially if fishermen have the perception that data they collect are ignored, not used correctly, or not used in ways they wish it to be used. Thus, clear communications (discussed next) and expectations about data use need to be set at the start and time may be needed to build trust (incrementally), if it doesn't already exist.

Additionally, working with trusted third parties may increase the likelihood that a trusting relationship can be developed between anglers and scientists and managers. If this approach is used, these third parties must still meet minimum standards for the data, as noted in Section 2.

Communication

Effective and regular communication about the need for reporting and the expected benefits are likely to improve angler trust and retention. From the angler perspective, understanding who is requesting the data, why the data are being collected, and seeing the benefits of reporting are important initial motivators.

Communication should include timely feedback regarding the overall program and the specific ways that angler data are benefiting the fishery. Ineffective feedback signals that angler efforts are not important or valued, which can limit both participation and retention (Cooke et al. 2000). Feedback can occur at multiple times scales—from a thank you notification the moment that data are submitted, to a website ticker, to summaries or reports that occur at regular intervals (e.g., monthly, quarterly, or annual reports). Anglers should also have ample opportunity to provide feedback that is aimed at improving electronic reporting.

Addressing Reporting Fatigue

A common refrain from anglers is that they spend more time reporting than fishing. Anglers who find reporting to be a burden or grow tired of reporting will report less or not at all. Reporting fatigue can be a significant factor in long-running programs. Demand for data from multiple sources, overlapping requests, and angler time limitations all contribute to this issue. Regular communication can counteract fatigue, as can other motivators such as rewards, contests, and other additive benefits. Section 3.2 provides examples of motivations and how they can work.

Limiting the number of required data fields can also help to minimize reporting fatigue. A large number of required data fields can create the perception of a disconnect between the purpose of the study and the data being collected, and can lead to distrust if anglers

become suspicious of the unrelated data fields. Minimizing "scope creep" and finding opportunities for automatic data collection can reduce angler fatigue and build trust. This issue has also been addressed in the Standards section (Section 2), where "minimum data fields" are established to prevent scope creep while still providing sufficient data for the scientific question related to the standard.

Reporting fatigue can also stem from the growing proliferation of electronic reporting tools. Data collection programs offered or mandated by entities at the local, state, and federal levels are vying for the attention of recreational anglers. These data collection tools are rarely integrated. The result is disparate technologies that require additional angler time to submit data. Efforts should be made to integrate and combine reporting tools where possible and appropriate.

3.4 Market Segmentation (Know thy angler)

Market segmentation is an approach to categorize and understand the diverse needs, behaviors, and motivations of different anglers. Market segmentation is commonly used in the business sector to identify high-yield customers that offer the best path to profitability or growth. However, segmentation can also define the needs and motivations that are common to different groups.

Electronic reporting systems should be designed and implemented with a clear understanding of the needs and motivations of the angler segments that will provide data. Whereas anglers who are motivated by competition are likely to respond to reward-based incentives, conservation-minded anglers are likely to respond to appeals to behave ethically or make a difference.

Angler segments should be identified early in the design process so that they can be paired with the appropriate motivation tools and guide development decisions in general. Segments should not be so broad that it is difficult to identify the appropriate motivational tools, or so narrow that the program is only successful in motivating a small (and likely non-representative) segment of the angling population.

Once the segment is reasonably defined, the next steps are: (1) design a wireframe prototype (i.e., simplified sketch of the design that forms a foundation for subsequent steps); (2) rapidly test the design with anglers from the target segment; and (3) use the resulting feedback to improve on the design (see Section 3.4). Connecting with the right angler motivation usually requires multiple iterations through these steps.

Market segmentation is less critical in a mandatory reporting system. However, it can play an important role in the implementation of the system, and therefore may mean the difference between a smoothly executed and widely accepted program, and one that discourages angler participation. Again, catering to the market segments that you are engaging can yield new efficiencies in the maintenance of a reporting program.

3.5 The Value of Innovation

A one-size-fits-all electronic reporting system is neither realistic nor achievable given the diversity of marine recreational fisheries and number of data gaps that could be addressed. Fortunately, angler innovation—when anglers are directly contributing to the process or app development—provides a useful framework for devising an achievable and realistic strategy for electronic angler reporting. Angler feedback, which could lead to innovation, should be considered at all times throughout the process of defining, building, and implementing any reporting efforts.

Technical innovations are important to consider, and in some cases may go hand in hand with user experience, but not always. Innovations in application architecture, network infrastructure, security standards, or data management processes are examples of ways to incorporate new technologies and innovations into the overall reporting system. These continued innovations may or may not be visible to the end user, but are very important to system integrity.

Innovations also come from the private sector and can grow quickly if there is a potential for profit or these companies are otherwise compensated for their work through grants or other such funding.

In the case of grant funding, care should be taken to provide clear standards for the recipients to work with, such as application interface (API) documents, certification processes, data collection standards, and clear objectives. Any agency or organization providing funding for recreational data collection should strongly encourage the adoption of standards and require recipients of funding to incorporate collection standards and best practices into their product.

The problem-solving abilities of some organizations can sometimes be limited by their procurement strategies. Many Requests for Proposals only allow for a single winner that proposed a single solution or strategy. This can limit innovation and prevent multiple ideas being tested simultaneously. Developing an alternative procurement strategy that uses clear standards and statistical tests can create a competitive arena that accelerates innovation by encouraging competing ideas. The standards and statistical tests outlined in Sections 1 and 3 could set the boundaries of the competition to ensure that necessary quality assurances and controls are in place. Once the arena has been defined, innovation can be harnessed through this new procurement process. Using this approach, entirely new methods for collecting angler data can be envisioned, tested, and allowed to either thrive or fail.

NASA's Commercial Crew Program is an excellent example of the success of this type of approach. NASA allowed innovation to thrive by setting clear objectives and standards, and then allowing multiple organizations to devise their own solutions for building a reusable rocket. The result was three viable options for reusable rockets—SpaceX, Virgin Galactic, and Blue Origin—with further possible solutions on the horizon.

Angler innovation means thinking beyond "developing an app" to much broader possibilities. For example, a number of organizations and companies already have large

angler audiences to tap into because they have overcome the angler recruitment challenge. Providing these organizations with a clear set of standards around data and sufficient compensation will incentivize them to innovate ways to motivate anglers to collect high-quality data. There are many examples of existing fishing app companies that might be open to this type of approach, such as FishBrain, Fishidy, and Navionics. Participation could also include organizations that count anglers among their users. For example, Garmin, Lowrance, and Humminbird all produce sonar products for the sportfishing community. Leveraging their existing technology could yield new sources of big data.

This approach to procurement should be tested and developed on a small scale (e.g., a specific gap in a handful of fisheries) to allow the agency to test ideas more rapidly. Eric Ries' *Lean Start-up* is a useful reference document for considering this strategy (Reis 2011). It recommends developing a "minimum viable product" or, in the case of procurement innovation, a "minimum viable market."

Lean Start-up also recommends incorporating a "build-measure-learn" approach that allows for rapid iterations where performance is continuously improved. This is similar to the "adaptive management" approach in fisheries, and is vitally important when testing new ideas.

3.6 User Experience—a design framework to create a process that works for anglers, agencies, and managers

User Experience (UE) utilizes design-thinking to build something that works for all. Design-thinking, or human-centered design, is a framework and approach for creative problem-solving. UE is a definition that is used commonly within software development. It relies on the philosophy and approach of design-thinking.

UE refers to *how* a user will use a software or product. Software and products, such as apps for electronic reporting, must fit within the user's life. When users struggle to use products, UE does not blame the user. Rather, it seeks to understand why a user struggles with a product and builds the product around the user. For example, a user may struggle to use an electronic reporting app because they are outside of cell reception, their hands are wet from handling fish, or they do not want to share their location and data regarding catch.

Users include more than just anglers—they also include agency staff and managers. Much of the focus of this report is on data collection from anglers. This is a key audience, but another important audience are the local, state, and federal managers who will be collecting and analyzing the data. These managers should also be incorporated in a UE process to ensure that they are able to efficiently access and use the data. Managers should be aware that the success of electronic reporting in one region may not translate to another region based on cultural, ecological, accessibility, or other important differences. With this possibility, managers should consider where to start on their electronic reporting journey.

The first step in using the UE approach is to empathize and understand the problem before moving on to solutions. There is a plethora of resources that researchers can use to help them ask the right questions and create a framework that reduces bias. Similarly, there are experts who can create and implement a UE process. Agency staff, managers, and anglers should all go through this framework to understand the needs of all groups.

UE may include a mix of user interviews, focus groups, surveys, and other qualitative and quantitative testing means for uncovering challenges and finding solutions to these challenges. It is an iterative process that may include creating personas, designing wireframes and interacting prototypes, as well as testing designs (Figure 3) (Interaction Design Foundation).

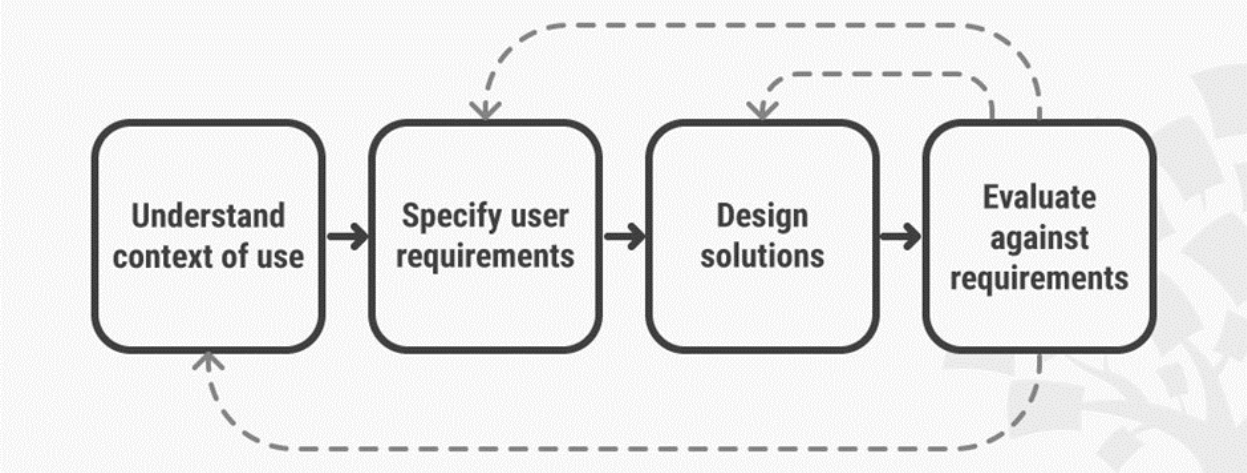

Figure 3. User experience testing is an iterative process to create an understanding of the needs, motivations, and challenges of users. The process uses many methods to test against user theories, referred to as "personas." Interaction Design Foundation (https://www.interaction-design.org/).

Suggested resources:

- On how to ask big questions: Customer Dev Labs Customer Discovery
- Wealth of resources on User Experience: Nielsen Norman Group
- Iterative design process: Mission Model Canva by Steve Blank (adapted from the Business Model Canvas for organizations that don't measure success by revenue)
- Successes and challenges with electronic reporting (Watson et al. 1998, Rijnsdorp et al. 2009, Kerr et al. 2017, Townhill et al. 2019, Purtlebaugh et al. 2020).

Helpful Definitions

Within technology and innovation, similar terms describe the approach to creating pleasant and functional technology, devices, and processes. These definitions may be interchangeable and overlapping. A few of these terms are described below.

Human-centered Design	An approach to problem-solving commonly used in design, management, and engineering frameworks that develops solutions to problems by involving the human perspective in all steps of the problem-solving process Wikipedia

User-centered Design	A framework of process (not restricted to interfaces or technologies) in which usability goals, user characteristics, environment, tasks and workflow of a product, service, or process are given extensive attention at each stage of the design process. These tests are conducted with/without actual users during each stage of the process from requirements, pre-production models and post production, completing a circle of proof back to and ensuring that "development proceeds with the user as the center of focus." Wikipedia
User Interface	In the industrial design field of human–computer interaction, a user interface is the space where interactions between humans and machines occur. Wikipedia
Usability	Usability is a quality attribute that assesses how easy user interfaces are to use. The word "usability" also refers to methods for improving ease-of-use during the design process.
User Experience	How a user interacts with and experiences a product, system or service. It includes a person's perceptions of utility, ease of use, and efficiency. Improving user experience is important to most companies, designers, and creators when creating and refining products because negative user experience can diminish the use of the product and, therefore, any desired positive impacts; conversely, designing toward profitability often conflicts with ethical user experience objectives and even causes harm. Wikipedia

3.7 Recommendations

There is a need for data standards to include an overview of angler motivation and to consider trade-offs between mandatory versus voluntary reporting to determine key motivating factors for angler recruitment and retention. Mandatory reporting "incentives" are legal, regulatory, economic, or competitive motivations, while voluntary reporting incentives include improving the quality of the fishery, the ability to fish in the future, understanding of the system and one's own fishing behavior, and, of course, bragging rights. Successful voluntary programs should provide useful stepping stones for advancing toward more expansive programs through angler experience and participation.

In addition, market segmentation should be used to clearly identify and understand the potential needs, motivations, and behaviors of specific groups of individuals that are the target users of the electronic reporting data collection platform. This should occur at the beginning of the process. Once angler segments are identified, the next steps include: (1) designing a wireframe prototype; (2) rapidly testing the design with anglers, and (3) using results from the user testing to iterate on the design and the motivation.

Experienced designers, either internally or externally contracted, should propose and create deliverables, establish timelines, and identify regions for their user research. Working with user-experience researchers will enable developers to understand what methods are being employed, and confirm that these make sense for the desired outcomes, region, goals, etc. Anglers who will be using the app and inputting the data should provide input to the design based on their user experience. As a result, it is

important that user-experience researchers, software designers and developers, and anglers work together closely.

There are four key requirements for an innovation strategy to work:

1. Set clear standards that define a specific data gap, including the statistical requirements to ensure that the data are of sufficient quality.
2. Develop methods for incentivizing anglers to start innovating around angler data collection.
3. Create mechanisms in which angler organizations can test competing data collection strategies for specific data gaps.
4. Apply an adaptive management approach that will allow the agency or entity to develop and refine its innovative procurement strategy.

As part of the data standards, NOAA Fisheries should include guidance that will help to best facilitate angler participation in any private recreational electronic reporting data collection platform, and recognize the actions that foster or prevent the success of angler reporting systems and have a bearing on angler recruitment and retention. These actions include building trust, developing a comprehensive communication plan, facilitating ease of use, and minimizing angler reporting fatigue through various means.

4. MANDATORY AND VOLUNTARY REPORTING

4.1 Introduction

Whether to make recreational reporting mandatory or voluntary is an important but challenging question. Chapter 8 of the 2002 FAO publication *A Fishery Manager's Guidebook – Management Measures and Their Application* entitled *Fishery Monitoring, Control and Surveillance* presents several observations that shed light on this issue. Here, we follow the general approach that FAO takes exploring the pros and cons of mandatory versus voluntary methods of gathering information to lay the groundwork for creating a best operating procedure for gathering data from recreational fishermen through more traditional means, as well as through the use of personal electronic devices.

Consider the use of vessel trip reports (VTRs) for providing information on landings, discards, and other trip attributes. Many challenges exist with paper versions of these forms: they are difficult to fill out at sea; much of the information may be lost if they are filled out after the trip is fully complete; information such as name, home address, and phone numbers are unnecessarily repeated each time the form is filled out; and, once all the information is on paper, this information must be entered into a database by hand. Electronic entry of personal information such as name, address, phone number, email address, and potentially port of landing, gear usage, and fishing time and location may be entered prior to the trip taking place and maybe even once for an entire season. Once the trip has begun, more information may be gathered on effort (boat days or fishing hours) as well as number of fish captured or discarded, including species ID, and potentially length and health status of the fish if discarded. Photo applications on personal electronic devices, such as cell phones, also increase the potential for data

gathering and data validation. This would imply that data are cheap and plentiful if one might gain access to it.

The question remains whether such information should be gathered voluntarily or through mandate. One might think the power of the law is sufficient to motivate participation, but the challenges with, for example, getting trained observers onboard vessels to monitor catch and bycatch indicate that making it a law is often not enough to encourage participation, let alone consistent behavior regarding the law. On the other hand, when valuable incentives exist, voluntary mechanisms for reporting can be quite successful. The online bycatch reporting system developed and participated in by the Gulf of Alaska and Bering Sea commercial pollock fishermen, which is used to identify hot spots where bycatch of prohibited species are likely to be high and thus avoided, is one such success story discussed in the National Academies of Science Report on *Improving the Collection, Management, and User of Marine Fisheries Data* (2000).

4.2 Program Development

To minimize the statistical challenges associated with bias in reporting, it may be important to consider making reporting mandatory at some level. First, consider whether reporting itself should be made mandatory and then consider what one might wish to make mandatory within the electronic reporting form being used. Using a stepwise approach for implementing a program, both voluntary and mandatory, is wise. Letting this stepwise approach develop gradually and in close communication with fishermen, scientists, and managers can overcome many hurdles (See Section 3.3 on Communications). Fishermen can see the benefit of such programs if they are not asked for too much information too soon. For example, one can note that it will not take long to fill out required information if much of it has already been recorded prior to the trip. Another benefit comes when anglers see that their data are being used for their benefit. Since scientists and managers require specific kinds of information to be provided in a specific format, start with a small and identifiable group of anglers that seem likely to engage. Ask for volunteers from this group and provide incentives to join. Incentives can include something monetary, such as entrance into a lottery, or something practical, such as expanded fishing opportunities. Some incentives can be fairly straightforward, such as providing a summary of the fisherman's own fishing information (e.g., catch per day, species landed or discarded, hours fished compared to friends or all participants). Providing incentives is a must for such operations, and in general for the success of a program (including probability-based sampling programs).

The next step after the pilot phase is to adapt and expand. What worked and what did not? Were the fishermen willing and eager to participate? Was the information useful? Was the technology adequate and easy to use? If not, then adjust and repeat. If yes, then consider expanding the group of fishermen participants. Promote participation through outreach workshops that highlight what was learned by scientists and managers as well as the benefits to the fishermen who participated. Here, one must be transparent about how the data will be used and the expected fishery benefits.

Also, consider the degree to which specific data fields are made mandatory. One should start with a few essential fields that are made mandatory initially for just the volunteer

participants in the program. Since reporting fatigue (discussed in Section 3.3) can be a big issue when gathering data, decide on a few high-priority fields—for example, the number of fish caught by species, effort, and number of fish discarded by species. Personal and demographic information can be collected relatively easily if it can be entered when the app is installed and requires infrequent updating. This information should include the MRIP ID code so that data can be matched with what is coming independently through the MRIP sampling protocol.

The app should also include voluntary data fields. For example, bait used, gear type, trip satisfaction, or more general open-ended comments. These voluntary data can be used to identify fields that anglers consider important and/or easy to complete. This information can then be used in conversations with anglers about expanding the list of required fields.

This adaptive, stepwise approach is critical to program success. It not only begins with a streamlined tool that is likely to appeal to anglers, but also provides designers and developers an opportunity to test and improve their product iteratively (i.e., build, measure, learn). In this way, the reporting system can be seen as an application that evolves to meet the needs of both data providers and users.

Creating standards for the information is also critical as discussed in Section 2. Using clearly defined standards for the data fields ensure that scientists and managers get the information they require, and should be communicated to the fishermen, so they understand the need for standardized inputs. It will also greatly aid the application developers as they define the mechanisms for collection, storage, and transfer of information as well as consider development of the human interface that allows data entry to be simple, easy, fun, and informative to all. Recognize, it's a process rather than a one-time mandate.

4.3 Self-reporting and Data Quality

Researchers and managers are often hesitant to use self-reported data due to concerns over the lack of randomization, reporting inaccuracies, and potential biases (e.g., avidity, non-response, or other biases that result in a non-representative sample) (Scherueder et al. 2001, Baker et al. 2013, Brick 2021). Although volunteer angler data cannot be managed in the same manner as estimates generated by statistically designed creel surveys, they can contain valuable information that can be used to help improve recreational data, provided that the properties of the volunteer data are well understood and issues are properly addressed.

The implementation of standards for data and metadata, along with improved structural and process design of the data collection tools and training of program participants, can greatly improve the quality of the data received. The introduction of quality assurance and quality control (QA/QC) discipline in the design and management of recreational electronic data collection programs will improve the quality of the data, and provide more insight into the reliability and limitations for their use in fisheries science and management.

Standards that cover how data elements are defined and data are collected are key to the acceptance of angler-provided data by both scientists and anglers. The requirements for data, including quantity, quality, collection procedures, and the needs for specific measurements should be strict, and contributing members of the recreational fishing community should be aware of the criteria. In most cases, the consistency of the contributors to meet the requirements for data validity can be resolved and handled via the design and management of the processes and tools that are used to collect the data. Data collection programs and tools used to collect recreational catch data, particularly mobile applications and cloud-based applications, can be structured to guide the participants' reporting activities to reduce issues and discrepancies in the data collection process. Rigor in the design of electronic data collection tools is required to ensure that information is recorded correctly and completely. Data verification routines and procedures can be included in the tool design to limit data quality issues and reduce the potential for human error. Automated validation and verification processes can eliminate most human errors and data entry issues, but human oversight is still required to monitor data quality and resolve process issues.

4.4 Voluntary Program Structure

It is important to have rigor in the design phase of both voluntary and mandatory reporting systems. The following design elements are particularly important:

- Identification of the purpose: A clear statement of the purpose of the collected data (i.e., the data gap being targeted) is required. This includes how the data will be used to address the stated purpose, a general description of the data to be collected, and how the data will be organized. Further, one should address whether the data will be expanded to estimates representing a larger population of which the sampled population is a part.
- Identification of the participant pool: While it is difficult to restrict access to tools that are used to electronically collect recreational fishing data, it is important to understand the tool users. Data about the tool users can be collected to allow analysts to segment data collected by specific user communities based on identified end-user traits. Of course, particular attention must be paid to evolving standards for participant privacy. All mobile application platforms have defined guidelines regarding the capture of end-user information; however, these platforms also allow end-users to "opt-in" to programs, thus justifying the need for limited personal information.
- Recruitment of participants: Larger user pools ensure that larger volumes of data are collected across a broader spectrum. The engagement of recreational angling communities is critical to securing initial and continued participation. A sense of local ownership and collaboration are essential to achieving public trust in the program. Participants must understand the need to collect the data, and agree that the data will be used to the mutual benefit of the local anglers and fishery managers. (More detail on recruitment and trust are provided in Section 3.)
- Communication strategies: Participant engagement is critical to user recruitment and retention. Target users must understand why the data are being collected, along with the benefit received from their personal participation. These messages must be communicated on a regular basis to sustain program visibility and

interest. Communication channels can range from online messaging to targeted social media campaigns. (More detail on communication is provided in Section 3.)

4.5 Mandatory Program Structure

Mandatory electronic programs face many of the same problems as voluntary electronic reporting programs, but a number of additional challenges exist in meeting program objectives.

- Identification of the participant pool: The participant pool is defined by program objectives, but effort is required to ensure that the pool meets the requirements for data quality. This may include consideration of existing licenses, license endorsements, stamps, and other permit types.
- Participant training: Designating a data collection program as "mandatory" does not guarantee angler participation. Electronic data collection tools must be designed to provide an intuitive user interface. Program participants must be trained to use the technology and have a clear understanding of data measurements and data definitions. Training opportunities should be available to all participants using as many delivery channels as feasible (e.g., in-person workshops, online options, and documentation (electronic or in print)).
- Program/participant support: Mandatory data collection programs must be designed to ensure that all participants can submit the required data. Angler interviews reveal frustration with attempts to submit data during system outages or lack of availability. The availability of help/support resources and access to alternative processes to submit mandatory data are critical to meeting data collection objectives and maintaining user satisfaction.
- Accessibility: Participants should have access to the tools necessary to report, and options are needed for users who may not have access to a particular data collection tool. Such considerations may include phone or tablet accessibility, model and age of tablet or phone (will it support the software?), internet accessibility, and data usage. Programs should follow ADA compliance and web accessibility guidelines to ensure that people with disabilities or limited tools are also able to access the app.
- Communication strategies: Participants in mandatory programs have a reasonable expectation that the entity requiring data submission will provide information about the program on a consistent basis. This information includes:
    - Program status information, including program performance, insights gained from data collected, process changes, and program objective changes.
    - Critical dates for data collection, such as fishery open and close dates.
    - Electronic data collection tool updates, including platform changes such as software updates, availability schedules, and bug fixes.
- Measures to ensure compliance, including enforcement and enforceability as well as angler engagement and implementation of technology-based verification methods.

4.6 Recommendations

As a first step, the Task Force recommends that managers and developers decide whether the data collection platform is to be voluntary or mandatory, and then the same determination needs to be made for specific data fields. Developers should always be cautious about asking for too much information because it could discourage compliance or participation. Incentives to motivate participation should be considered. NOAA Fisheries should provide guidance to program managers and developers of electronic reporting data collection platforms on mandatory versus voluntary reporting considerations, as noted in this Section.

A stepwise implementation approach may be considered to fully and appropriately engage anglers over the long term and to give platform developers time to create, test, and respond—thus allowing for effective data gathering and participation.

Data validity can be resolved and managed through the design and management of the processes and tools that are used to collect the data. Apps, and electronic reporting tools more generally, should be designed to guide participants in a clear and reasonable fashion. The apps themselves should also be designed to maximize the accuracy and completeness of the data collected. However, human oversight is still needed.

When developing volunteer programs, identify the participant pool (market segmentation); recruit participants through good communications, engagement, and shared recognition of benefits; and keep the dialogue going to identify hurdles and promote benefits.

When developing mandatory programs, identify the participant pool (market segmentation), provide the necessary training, plan for program support to maintain access and practical functionality, ensure ease of reporting, and make certain that clear pathways for communication are open, especially with regard to program status, critical dates, and electronic tool updates.

With quickly advancing technologies and disparate data collection platforms and tools, the technology quickly outpaces institutional ability to keep up. The best that can be done is attempt to plan for this and learn from current trends and missteps that are experienced in our day-to-day electronic world.

5. DATA VERIFICATION

5.1 Introduction

The Department of the Interior (DOI) in their Data Validation and Verification Guide (2003) recognized the need for data validation and verification to ensure data integrity and credibility. Validation in the DOI document is defined as assessing whether the data reflect what one is intending to measure, while verification assesses accuracy, completeness, consistency, availability, and thus the overall reliability of the data. We will follow the DOI definition of verification in this section to address accuracy,

completeness, and consistency. The general idea of achieving agreement among stakeholders, scientists, and managers on the appropriate metrics to collect while achieving consensus on best methods for collecting this information—what DOI defines as validation—is discussed in Section 4 above. The focus here is on technology-driven and comparison-driven methods of verification.

5.2 Technology-driven Data Collection and Verification

Emerging technologies can be used to assist with or even automate data collection, and to confirm the accuracy of the data collected. Examples of verification include:

- Using GPS to verify a reported location.
- Using photos to verify species identification.
- Alerting app users when a required field is empty.
- Flagging when data are out of bounds (e.g., fish length or species ID).

Companies like StreetLight (https://www.streetlightdata.com/) aggregate mobile device location data to infer traffic patterns and other "bulk" behavior. These data could be used to verify or calibrate program data, such as the number of boats passing through an access point. This approach is similar to the use of car counters or trail cameras, but with greater spatial-temporal coverage. Mobile data could also be used to infer fishing effort in specific zones.

Emerging technologies such as hydroacoustics, image recognition, artificial intelligence, and a growing list of linkable smart devices may be used to automate and enhance data collection, processing, and analysis. Technology already exists to automatically collect data from the ocean environment (e.g., fishing depth and temperature), identify fish to species, and estimate fish length. Developers should work with scientists to identify existing and emerging technologies and think creatively about using these technologies to address critical issues previously considered unsolvable.

5.3 Comparison-driven Data Collection and Verification

There are good reasons why fisheries scientists often resist incorporating unverified data into the governance process. Poor-quality data can lead to poor-quality results, and taint an entire dataset and interpretations thereof. Addressing data quality issues before data are used or incorporated into existing datasets is an important and necessary step.

Recreational electronic reporting data should be subject to the same verification techniques as traditional data. Data quality begins with program design (see Sections 3 and 4), and ends with post-hoc checks and analyses. Comparative analysis is a common verification technique in which a new, unverified dataset is compared to "reference" data of known quality to determine how they might differ (usually the mean, but also variance) and quantifying bias and uncertainty. These comparisons should be done with data from the same (or at least similar) population and timeframe. Results can be used to determine if data from a new method are valid or should be adjusted (e.g., bias correction via a conversion factor).

A common, underlying assumption of comparative analysis is that reference data provide the best approximation of truth. If this assumption is valid, then it is appropriate to interpret differences as meaning that a new approach generates biased results (and then attempt to address this bias programmatically or statistically). If the reference data are biased, then it may be more appropriate to integrate new data by averaging results across collection methods—with the caveat that averaging competing trends does not necessarily result in an accurate overall trend.

Rather than comparing like to like, verification may occur by using a completely different method to verify another. For example, one may use a more reliable but perhaps more expensive or time consuming method to verify a simpler but less costly method either periodically or in a supplementary fashion. Fish tagging methods are often used in this way to verify mortality estimates or movement, by tagging and recapturing fish over time. Similar methods can be applied to verify human behavior. Sometimes, this is done through panel surveys for longitudinal studies (e.g., Nielsen television ratings), which follow a smaller group of individuals, a panel, over a longer period of time.

Table 3 summarizes examples of comparative analyses applied to data from fishing apps. These comparisons change the role of traditional survey methods from being the primary source of data to serving as quality control for new and unverified data sources. In this way, existing methods, such as those found in MRIP, can be adapted to serve as benchmarks on which to continually test new data streams. This approach will allow agencies like NOAA Fisheries to estimate bias and variance, and determine how often new data sources need to be tested to account for possible drift (e.g., in the extent and demographics of app use).

The major advantage of using traditional methods as the source of data versus using it to verify new data streams is the scale at which data can now be obtained and used for fisheries analyses. This is particularly important when budget constraints limit the ability to collect sufficient data for research and management objectives.

As a final note, when making comparisons with conventional data streams, one needs to anchor it to something. This is sometimes difficult because it may not be valid to use traditional analyses to compare probabilistic to non-probabilistic data. Common solutions are to compare the mean of the raw, unweighted data from the non-probabilistic sample to the 95% confidence interval from the probabilistic sample (e.g., Bethlehem 2010, 2015), or to compare the ratios of the two means within a non-parametric bootstrapping approach (Gundelund et al. 2021 and references therein). Both approaches can identify bias in the non-probability sample. If a non-probabilistic estimate is unbiased, then it is likely to be as valid as the probability-based estimate.

TABLE 3. Examples of comparative analysis used to evaluate data quality from unverified data from voluntary apps.

Traditional survey method	App type	Study location	Comparison	Analysis	Result	Reference
Creel (access)	Commercial	Alberta, Canada	Fishing trips (app) vs. total angler visits (creel) for specific lakes.	Simple linear regression	Significant, positive relationship (slope = 254 creel anglers per app visit).	Papenfuss et al. (2015)
Creel (access)	Non-government organization	Florida, US	Fishing trips (app vs. MRIP) in counties in Florida - overall, and by species.	Chi-squared, means ratios	The distribution of app-based trips by county was significantly different from MRIP, but species-specific, app-based catch and trip estimates by county were similar to MRIP.	Jiorle et al. (2016)
Creel (access)	Commercial	Alberta, Canada	Catch composition and rate.	Chi-squared, Fisher's exact test, regression	Similar catch compositions and rates.	Johnston et al. (2021)
Creel (aerial)	Government	Funen Island, Denmark	App users vs. angler count for a given location and time.	Linear regression	Significant, positive relationship (slope = 7.2 anglers observed by air per active app users).	Gundelund et al. (2021)
Creel (aerial)	Government	Funen Island, Denmark	Total catch in a 3-month period.	Means ratio	Total catch estimates were similar.	Gundelund et al. (2021)
Creel (roving)	Government	Funen Island, Denmark	Participant age, specialization, and catch rate.	Generalized linear models	App users were younger, more specialized, and had higher catch rates than non-users.	Gundelund et al. (2020)
Creel (roving)	Government	Funen Island, Denmark	Participant catch rate, proportion released, and length of harvested fish.	Means ratios	App data estimated a larger proportion of fish released than the creel data; the remaining metrics were similar.	Gundelund et al. (2021)
Creel (roving)	Government	Funen Island, Denmark	Participant country, age, gender, and domestic origin.	Means ratios	App users were more domestic than creel participants, but similar in age and gender make-up. Where domestic	Gundelund et al. (2021)

					anglers traveled from to fish was similar in both programs.	
Gillnet	Commercial	Alberta, Canada	Catch rate and sportfish composition.	Chi-squared, Fisher's exact test, regression	Catch rates were positively correlated but weak, sportfish compositions were different.	Johnston et al. (2021)
Mail-in survey	Commercial	Alberta, Canada	Fishing trips (app) vs. fishing effort (survey) in Alberta's 10 management zones.	Simple linear regression	Significant, positive relationship with one outlier removed (slope nearly 1:1).	Papenfuss et al. (2015)
Mail-in survey	Commercial	Alberta, Canada	Annual relative distribution of angler origins, effort, and species caught in Alberta's 10 management zones.	Chi-squared, Fisher's exact test	No evidence of spatial bias in angler origins or effort, and only minor differences in catch compositions.	Johnston et al. (2021)
Mail, web, and email survey	Government	Funen Island, Denmark	Trip frequency, trip length, number of fish caught, and proportions released.	Means ratios	App data estimated a shorter trip length than the creel data; the remaining metrics were similar.	Gundelund et al. (2021)
Mail, web, and email survey	Government	Funen Island, Denmark	Origin of Danish anglers who fished on the island.	Means ratios	App users were from different parts of Denmark than survey participants.	Gundelund et al. (2021)

5.4 Recommendations

Use technology to think outside the box to solve common problems associated with getting complete and accurate data. Identify what general information is readily available, with permissions approved, so that personal information does not have to be reentered. Use existing tried-and-true verification technology. Plan for and incorporate emerging and evolving technologies.

Data verification is important and common. Verification can rely on common sense or by comparing with reference datasets, which may be historical data, data from similar species, or data from independent survey methods. Clear protocols should be in place for evaluating the accuracy and relevance of new data, whether they are newly added from traditional survey methods, or are being collected from newly developed methods such as electronic reporting.

6. PROBABILITY AND NONPROBABILITY SAMPLING

One of the cornerstones of estimating statistics that are representative of a population is that each member of that population has an equal or known chance of being represented in the sample. This is called probability-based sampling. Representative samples are usually achieved via random sampling, systematic approaches (e.g., sampling every 10th person in line), or stratification (e.g., sampling different habitats at different levels and then expanding the findings by area). Fishermen don't fish randomly—they choose where to fish based on cost, convenience, catch rate, etc. (Haab et al. 2012). Consequently, using catch-per-effort data from fishery catches (i.e., fishery-dependent sampling of abundance) is often considered problematic for drawing inferences about the abundance of fish scattered throughout the region—especially when fish populations may be moving or expanding due to changing climatic conditions. This is why NOAA Fisheries and other agencies dedicate significant resources to designing and carrying out statistically valid surveys, particularly for data that are critical to characterizing the fish stock, fishery, and ecosystem. However, there are nonprobability-based methods that can be used in some cases to *augment* standardized survey data. These nonprobability-based methods are usually at a different scale or are modified using reasonable assumptions, such that they can be reasonable approximations of probability-based methods.

Nonprobability-based data are attractive because they can often be obtained relatively cheaply from all places and times. On-site probability-based surveys are typically conducted over a season using one or two survey vessels. These surveys can be costly and result in hundreds of unbiased samples, despite there being tens of thousands of recreational or commercial vessels on the water at a given time. A reliable reporting method would allow any of these vessels (or individuals) to supply data at relatively low cost. Such reporting is likely to create orders of magnitude more data, which raises questions about how these data will be best stored, interpreted, and used for decision-

making. Reporting in this way can increase angler engagement and trust. Anglers may become more involved and invested in data collection and fisheries science and contribute new sources of information that result in greater insights. Increased engagement could lead to increased trust—at least in the data collection process.

Examples are helpful for highlighting the ramifications of different sampling and analysis methods, and how concerns might change with the type of information we are attempting to obtain. Consider NOAA Fisheries' estimate of relative fish abundance via stratified random sampling of catch-per-effort in geographically defined regions. Such probability-based samples (i.e., there are equal chances of sampling different habitats, temperatures, and, consequently, fish abundances within each strata), could be augmented by catch-per-effort data from fishing vessels (i.e., the number of fish per standardized tow, hook, boat, or fisherman) provided that one can make a reasonable set of assumptions about the relationships between fishery data and survey data. For example, given that the NOAA survey strata are often characterized in part by depth, perhaps fishermen could reasonably be viewed as also stratifying (i.e., choosing where to fish in these different areas) based on depth. If so, then depth can be used to combine the two measures into an improved estimate of overall fish abundance.

A significant challenge when working with nonprobability-based data—especially in the context of model-based analyses—is reconciling the risk associated with making assumptions and how straightforward it is to verify them. Consider the assumption that fishermen fish randomly within a statistical area, or that private-access anglers fish the same as public-access anglers. How likely are these assumptions? How about using other predictive factors, such as weather conditions, time of day, season, or vessel characteristics? The more assumptions one adds, the more likely it will accurately represent fish abundance by area. However, more assumptions increase the risk that one or more of the assumptions is incorrect, which can lead to misinformation. Much research is currently going on in this area, such as investigating how useful artificial intelligence approaches have been in fighting disease or for seeking useful information on the internet. Yet, computer scientists can fall into the same trap of using unrepresentative samples. Example problems are using heart studies that are unknowingly based on old, white males or U.S. Census data that do not include the homeless. While it is likely that scientists and managers will rely increasingly on nonprobability-based sampling data, and research on this is making great strides (Chen et al. 2020; Kim et al. 2021), we have a way to go.

Nonprobability-based sampling provides an opportunity to collect other important information that influences sustainable fisheries management. Examples include bycatch monitoring (amount and mortality of discarded fish), species targeting, general area preferences, port of call, gear and bait use, distance traveled from port, and other factors that motivate anglers. This choice factor is known as the human dimension, namely what motivates people to fish, and how it affects what anglers fish for, how they fish, and where and when they fish. Privacy and security come into play with the human dimension element, as well as the information gathered on the simple technical aspects of how fishing takes place and what gets caught. The point to consider here, in contrast to where boats go to fish as in the catch-per-effort example, is that the sampling frame is

now the charter boat or the individual fisherman, not the expansive ocean. This creates a different set of issues, but the nonprobability part can be greatly reduced or even eliminated if a near census is achieved. If the sample is unduly biased—for example, due to fishing off private docks or boats that dock at private locations—then there are assumptions that can be made or additional calibration data collected to address these issues.

Nonprobability-based sampling at the regional scale and new developments for probability-based sampling at the vessel or individual scale are becoming more common in natural resource management, as data collection and analysis methods become more sophisticated. Greater amounts of relevant data can be collected to address existing and emerging issues (e.g., changing climate conditions) given, for example, how electronic reporting enables more people to become engaged in the data collection process.

As stated earlier, nonprobability-based sampling, by definition, does not select samples at random, so there is a higher risk of unrepresentative data. This is a challenge for most statistical analyses, which assume a representative (i.e., probabilistic) sample. There are techniques for reducing the risk of bias when analyzing non-probabilistic data. The appropriate approach will vary depending on the type of reporting program (voluntary vs. mandatory), its goals, and the information being collected. For example, consider hybrid nonprobability-based combined with probability-based methods such as capture recapture methods, which allow the use of nonprobability-based data collection in a "capture" phase, but require probability-based sampling during recapture (Liu, et al. 2017).

6.1 Recommendations

Probability-based sampling, wherein each member of the population has an equal or known chance of being sampled, is the gold standard for gathering a representative sample of the population. However, other statistical methods such as conducting a census or careful application of model-based approaches can be used to bring in data that were collected by other means. Scale plays an important role in this approach, as does the validity of the assumptions that are made when using model-based approaches. Strive to achieve probability-based sampling where possible, but also consider (1) the mechanisms for including data collected by other means, (2) the scale and set of assumptions that are useful for integrating the information defensibly and appropriately, and (3) opportunities for expanding the data horizon.

7. SOLVABILITY AND ABILITY TO SCALE

If it is determined that a marine recreational electronic reporting effort or pilot can help to fill a data gap, or provide supplemental data to an ongoing data gathering effort, a process has been presented here for how to develop the electronic reporting program at a regional, state, or federal level. The steps include:

- Establishing data standards and identifying how the data are to be integrated into existing systems.
- Engaging anglers through recruitment, incentivizing retention, and encouraging continued dialogue to promote innovation, trust, and acceptance of the program through program development and throughout implementation.
- Clarifying early on where on the voluntary-mandatory spectrum the program lies, while recognizing that this position may change as the program evolves (e.g., from a voluntary pilot to an agreed-upon mandated program that involves all relevant participants).
- Employing processes for data verification that range from electronic checks within data collection apps to post-hoc data verification using standard analytical methods, along with supporting research that may complement or supplement the existing estimates.
- Recognizing that, while probability-based surveys are typically the gold standard for design-based fishery-independent data gathering, nonprobability-based data gathering can be informative, especially when approaching a census with regard to trip-specific metrics such as monitoring bycatch, discards, protected species interactions, and the location and timing of fishing activity.

Key elements of arriving at a successful recreational electronic reporting program are the active engagement of and dialogue with all stakeholders, including anglers, software developers, database managers, analysts, scientists, and managers. We recommend working adaptively by beginning with a small pilot program (e.g., involving selected and motivated anglers) to work out the bugs of each program regionally, and promote buy-in and peer support from the recreational community - perhaps through the establishment of an advisory committee. Issues that can be resolved through a stepwise approach relate to design and optimization. A pilot program or other actively adaptive process can also help all stakeholders to identify the value of program data for specific use cases.

Angler engagement is critical from the start. It is important to know what information is being asked of anglers, the value of that information to them and the resource, where they can go when issues arise, and what motivates their participation. Incentives to participate might include providing data summaries back to the angler regarding their own landings or time on the water, as well as a broader summary of similar metrics for the fishery overall. Care should be taken to avoid incentives that reduce data quality or introduce biases (e.g., a cash prize or expensive item for the angler who logs the most fish).

The processes discussed here are not overly complex, and generally reflect best practices for standard data collection. Communication is key, which means creating ongoing opportunities for engagement. In other words, dialogue with an emphasis on listening and responding to issues. While the math involved in the statistics can be challenging, stepwise examples of its application to realistic data collection situations, and reality checks between scientists and anglers, can enhance understanding and acceptance of the processes and the program.

The adage of running to stay in place is appropriate to consider when developing a recreational electronic reporting program. This means foresight or at least designing for

flexibility when considering how the data are and will be used. It also refers to the need to be constantly innovating to keep up with the technology and user expectations. An app can appear outdated and lose functionality quickly. Funding is needed to allow the technology to keep pace, as well as for user support, system updates, and innovation.

When thinking of scale, for example, how the resolution of data gathered will change over space or over time, recognize that managers will always want data at finer and finer scales. When designing a data collection app or a database, and in fact when designing the entire scientific and managerial process, clear identification of where change is anticipated to occur is a must. No doubt there will be surprises, but good data management and use requires foresight.

Finally, careful thought should be given to the relationship between new and existing data capture systems—especially if reporting is voluntary. Anglers already have the option to record their fishing activity through commercial, non-governmental, or, in some cases, state apps. Asking anglers who already use an app to use a different one is effectively asking them to switch apps or report on both. This creates competitive interactions that can be alleviated somewhat through partnerships that encourage standards adoption and subsequent data sharing. Another solution is to allow anglers to push data from NOAA's app to other apps.

Cost considerations

Budget and cost estimates are outside the scope of this report, and would be quickly dated if included. However, it is important to be aware of a few key approaches to software development costs.

Building and budgeting for a minimum viable product

Software can become expensive and complex quickly. To avoid going over budget, managers should seek to build a "minimum viable product," or MVP. The purpose of the MVP is to test the assumptions and theories about user needs that were uncovered during the user experience exercises with as few features as possible. By building MVPs, managers can change direction or re-assess their assumptions well within their budget.

It is wise to expect some of your initial assumptions to be off the mark. Budget for several iterations of an MVP.

Budgeting for maintenance and support

The work does not end at building a successful product. It is important to budget for angler support (e.g., reporting or getting help with issues) and ongoing maintenance and security updates. Software relies on many layers of programs and other software that will have regular updates and security patches. You'll need to ensure that you have some technical support to similarly update your software.

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