



Article

Overcoming Catch Data Collection Challenges and Traceability Implementation Barriers in a Sustainable, Small-Scale Fishery

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Abstract: The seafood sector faces both socioeconomic and environmental sustainability challenges, as well as pressure to demonstrate progress from governments, NGOs, retailers, and consumers. To document data elements necessary in verifying key sustainability attributes and fishery progress, the sector needs to implement traceability systems accessible to fishers and other vulnerable near-shore actors. Implementation must overcome a suite of technological, social, and economic barriers. We assessed and reviewed the efficacy of several approaches attempted in a Philippines yellowfin tuna (*Thunnus albacares*) fishery. The current prevailing approach is a centralized, analog method of catch recording, both broadly across the Philippines and specifically in this MSC-certified fishery, where they have implemented enumerator-facilitated catch certificate recording. The fishery has begun developing, testing, and piloting new decentralized digital models, including NFC cards, RFID tags, and an app-based smartphone catch data capture. All approaches encountered barriers to uptake, and the most recent estimates suggest up to 44% of the catch in the Philippines remains unreported. We discuss additional systemic considerations necessary to advance sustainability outcomes and their documentation through traceability systems in the seafood sector originating with small-scale fishers.

Keywords: traceability; small-scale fisheries; supply chain (SC); sustainability; environmental impact; economic, environmental and social benefits of end-to-end SC traceability; sector-specific SC traceability for improved sustainability; context-aware SC sustainability; SC provenance and sustainability



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1. Introduction

Design, implementation, and evaluation of effective sustainability programs is contingent upon accurate data. Without accurate catch data, basic attributes of fishery health such as stock size, catch volumes, fish sizes or maturity, and catch geography are impossible to ascertain. However, of all seafood supply chain stages and data, none are more critical or difficult to capture and transmit than catch records. These challenges are particularly acute in the Philippines among municipal fishers practicing hand-line methods to mitigate bycatch issues in yellowfin tuna (*Thunnus albacares*).

In the Philippines, the problem of poor data plagues both municipal and commercial scale fisheries, as well as government policy and enforcement at all levels, from local/municipal, to provincial, to regional, to national. Nationally, data is not being collected systematically across the country [1]. Natural geography, current policy, the prominence, and diffuse nature of the municipal (small-scale, <3 T) fishery sector, and the lack of a functional centralized registration system at the local government unit (LGU)-level all contribute to the poor data problem. Together, these issues result in 583,000–907,000 metric tons of fish going unreported or misreported, a volume equivalent to 30–50% of the total reported catch in 2019 [1]. Further, the diffuse nature and geography pose additional barriers. As an archipelagic nation with more than 17,000 km of coastline, and a prominent small-scale, or municipal, marine fishery sector characterized using boats less than 3 gross

tons in weight; accurate catch data documentation is especially difficult. Physical barriers include the municipal fishers' frequent use of informal landing sites dispersed across the country's expansive coastline, as opposed to formal landing centers. Furthermore, even formal landing centers are far more numerous and spread out for municipal fishers (>8000 community landing centers) compared with commercial landing centers (~500), further complicating catch data capture [2]. Technological, economic, and social barriers to effective or efficient catch data capture include poor cellular service; limited WiFi access; low levels of income, literacy, and technology access or adoption; and limited formalized economy participation. Together these factors hamper the documentation, monitoring, and improvement of this yellowfin tuna fishery by various governmental and non-governmental actors, including local governments, the national government, international NGOs, and interested private sector entities such as downstream processors and retailers.

This paper explores the observed and potential efficacy, cost structure, and equity of two approaches to first-mile traceability data capture: the currently dominant centralized analog approach, and small-scale pilots of democratized digital approaches (Table 1). The centralized analog model is the prevailing approach both for governmental fishery statistics as well as for catch recording the specific MSC-certified small scale yellowfin tuna fishery operating in two regions of the Philippines. That MSC fishery has also worked to develop, test, and pilot a few democratized digital approaches to catch recording, including NFC cards and, more recently, the smartphone-based Tracey app that was also paired with a Binance incentive [3,4]. We are focused on comparing these two approaches because they represent the prevailing status quo, which we hypothesize is incomplete due to systemic shortcomings, and new options, which we hypothesize may mitigate some of those geographical and economic challenges and result in more complete and enduring uptake.

Table 1. Approaches to catch data capture employed and under exploration to enhance first-mile traceability in small-scale fisheries.

Attribute	Centralized Analog	Democratized Digital
Who	Enumerators or Traders	Fishers
Where	At Landing Centers	Anywhere with Internet
What	All species caught	Major fish species
How	Paper-based, key data element (KDE) forms provided by WWF	Smartphone-based app, NFC cards, or RFID tags
Funders	USAID, German Development Bank	USAID, WWF Germany, Downstream processors, and retailers (EU-based)

Each model of catch data capture offers its own set of benefits and drawbacks, which further differ across specific iterations or applications of the two general approaches. Both models are constrained in their efficacy by policy or regulatory frameworks. Without sufficient market access, cost savings, or regulatory incentives to report catch data—or disincentives for failing to report, such as fines and even prison penalties—neither a centralized analog model, nor a democratized digital model is likely to be effective [5,6]. Other efforts to implement traceability with smallholders in Latin America, the Caribbean, Fiji, and Ghana that have achieved sufficient technological capacity have ultimately failed due to insufficient regulatory or enforcement support [5,6]. An effort to implement two different traceability software solutions with smallholders in Colombia, the Dominican Republic, El Salvador, Honduras, Peru, and Haiti also received USAID funding and ultimately failed to achieve traceability system uptake [5]. However, unlike this effort, which was most specifically motivated by trying to achieve a sustainability certification from the Marine Stewardship Council (MSC) to maintain access to European and American retail export markets, this other effort was motivated by the anticipated implementation of a new regulation, namely the United States' Food Safety Modernization Act (FSMA) and the launch of the U.S. Foreign Supplier Verification Program (FSVP). In the U.S., prosecution for noncompliance includes not just corporate prosecution, where businesses may face multi-million-dollar

finances, but also prosecution of noncompliant companies' CEOs [7,8]. Criminal penalties can include imprisonment [7]. There are at least two cases in the last 10 years with prison sentences: a 28-year sentence for a peanut company CEO responsible for a Salmonella outbreak and a 6-year sentence for melon farmers responsible for a Listeria outbreak [7,8]. However, in the case of these two failed traceability software systems launches in Haiti and Latin America, the regulatory body did not adhere to their originally communicated implementation deadline. Furthermore, the regulatory body also announced in 2018 that "it would exercise enforcement discretion for certain FSMA provisions, including FSVP for foreign horticulture suppliers," which eliminated the strongest incentive for adoption [5]. After this regulatory announcement, "exporters rightly assumed it would be unlikely for them to be found non-compliant, and therefore opted to risk regulatory violation and one-time fines rather than invest in an expensive digital solution" [5]. Full traceability system implementation often requires closing regulatory and enforcement gaps in tandem with technological and economic challenges.

Both models assessed in this paper require initial and ongoing investments of time and resources in traceability tasks and systems that have not historically been necessary for participation in either domestic or EU-oriented seafood export markets in the Philippines. Case studies of other traceability implementation efforts with small-scale producers serving export-oriented markets motivated by regulatory drivers have repeatedly demonstrated that regulation alone is an insufficient motivator, even when the law is clear, if the enforcement is lax and/or the level and likelihood of fines for noncompliance do not exceed the system acquisition, implementation, and transactional costs of compliance [5]. Another meta-analysis identified 4 main barriers: (1) operator incentives, (2) operator capacity, (3) operator access to technology, and (4) interoperability and/or willingness to share data [6].

Centralized, NGO-funded analog models skirt the operator incentive, capacity, and technology access issues by providing salaried enumerators, who they give the time and tools to record catch data, although enumerators must still collect data from fishers. The key drawbacks of the centralized model are poor alignment between enumerator locations and catch landings by municipal fishers, and the disconnect between the catch data, which is recorded and maintained by NGOs external to the supply chain and downstream actors. Democratized digital models attempt to lower the burden of data capture and transmission, but still require some degree of economic incentive or regulatory disincentive for operators to procure the necessary hardware, software, and service; to invest time and effort into learning the platform(s); to dedicate time to using the system; and to agree to share the data necessary to use them. Democratized digital models paired with direct compensation for use may, like the smartphone-based Tracey app, begin to address the incentive issues necessary to drive beyond adoption when market access is insufficiently restricted for non-adopters [4].

Food safety and trade management use cases originally motivated seafood traceability system adoption, but now environmental and social use cases increasingly motivate adoption. Over the last six years, foundations, NGOs, and leading seafood businesses have made major investments in developing global interoperable traceability across seafood supply chains with the aim of creating the visibility necessary to leverage market forces to root out illegal, unreported, and unregulated (IUU) fishing [1]. In March 2020, the Global Dialogue on Seafood Traceability (GDST) published a standard to support end-to-end seafood traceability from boat to retail shelf around the world [9]. More than 70 global companies have already committed to implementing GDST, motivated in part by the clear positive return on investment (ROI) for large-scale processors, manufacturers, and retailers [10,11]. The business case and the path to adoption and implementation is more challenging for near-shore actors due to a variety of factors including the low incomes of fishers relative to system costs and little to no cost savings from things such as information management, liability, and recall management [12]. However, whether traceability can be used as a

tool to drive desired social and environmental outcomes for fisheries hinges on first-mile fisher adoption.

While a desire for positive environmental and social outcomes may motivate the drive for traceability adoption, that drive largely emanates from large-scale retailers in the global North [12,13]. This dynamic has raised concerns that traceability may be yet one more method of exacerbating an already problematic power dynamic between both fishers and downstream supply chain actors, as well as between the global North, where many traceability systems are designed and where provenance-sensitive seafood markets are located, and the global South, where most seafood is caught [13]. Despite these risks, traceability and catch data stewardship from fisher to consumer carry tremendous potential to improve global seafood governance [13]. To tap into this promise of traceability, objectives and incentives for traceability adoption must be aligned not just across global and regional public and private actors, but first and foremost with the needs and objectives of fishers [12]. Yellowfin tuna fishers in the Philippines engaged with a ‘bottom-up’ Fishery Improvement Project (FIP) led by the WWF (that became MSC-certified in October 2021), providing an opportunity to explore the extent to which first-mile traceability system design can either improve or exacerbate issues around efficacy, efficiency, and equity [14].

Fishers in the Philippines are classified based on groupings defined in The Philippine Fisheries Code of 1998, also known as RA 8550 [15]. Originally adopted in 1998, RA 8550 defines the classification of fishing vessels and regulates their operation. Under RA 8550, vessels in the Philippines are classified as either municipal, weighing 3.0 gross tons or less, or commercial, weighing 3.1 gross tons or more [15]. RA 8550 further classifies commercial vessels as small-scale (3.1–20 gross tons), medium-scale (20–150 gross tons), or large-scale (more than 150 gross tons). This paper focuses exclusively on the smallest-scale operators, essentially municipal fishers, and the efficacy, equity, and economics of alternative approaches to recording their yellowfin tuna catch data.

Municipal vessels are largely exempted from regulation under RA 8550 and were granted protection in the form of exclusive access to all waters less than 15.1 km from the shore [15]. Registration and licensure of municipal vessels is still voluntary, and while 265,753 municipal vessels have registered in BoatR through LGUs, approximately 80,000–125,000 or 30–47% of municipal vessels remain unregistered [1]. Thus, at best, there is a localized registration system, but there is no national, globally unique identification scheme for vessel registration. LGU staff cite poor internet connectivity in their offices as a barrier to inputting data on vessel registration, leading to the under-reporting of municipal vessels [1].

Additional regulatory changes that motivate the adoption of enhanced traceability systems in the Philippines include EO 154 and RA 10654, both of which were driven by pressure to maintain access to international markets [16,17]. Executive Order 154 was signed in 2013 due to the Philippines’ membership in the UN-FAO and the UN-FAO’s endorsement of the International Plan of Action to Prevent, Deter, and Eliminate Illegal, Unreported, and Unregulated Fishing (IPOA-IUU) in 2001 [16]. The EU placed sanctions imports from nations with high rates of IUU fishing in 2010. In 2014, the EU issued a yellow card threatening to ban Philippine seafood imports valued at PhP 9.3B, motivating the Philippines legislature to pass RA 10654 in 2015 [17]. RA 10654 increased fines for illegal fishing and enhanced record-keeping and reporting requirements for commercial fishers under a system to be administered by DA-BFAR [17]. Together, these policies, particularly with the amendments made in 2015 and the addition of FAO 198-1 in 2018, enhance the monitoring and reporting of fishery data, particularly in the commercial sector, while the diffuse structure, lack of reliable internet access in LGUs, and voluntary policy governing the municipal sector continue to challenge complete catch data collection from municipal fishers.

Over the two decades that these policies have been in place, the structure and relative importance in terms of volume and value of municipal and commercial fisheries has shifted. In 2001, municipal and commercial fishers each represented about 31% of the fishery sector

in the Philippines [2]. Commercial fishers dominated the Philippines tuna sector in 2001, catching over 60% of reported tuna across all species [18]. By 2019, the municipal catch dominated the fishery sector both in terms of volume (969k metric tons vs. 932k metric tons) and value (90.96B PhP vs. 63.48B PhP) [19]. At the latest estimate, municipal vessels outnumber commercial vessels by more than 30:1 [1].

The prominence of municipal fishers motivates the development and implementation of traceability systems accessible to these actors to better monitor and manage yellowfin tuna fishery health as well as the livelihoods of municipal fishers [14]. Additionally, while municipal fishers have increased the volume and value of their catch to a greater degree than commercial fishers over the last 2 decades, commercial fishers dominate the yellowfin tuna catch in the Philippines [20]. In 2019, commercial fishers caught nearly twice as much yellowfin tuna as municipal fishers, and have been suspected and accused of poaching yellowfin, particularly in Lagonoy Gulf, for many years [20,21]. These issues further underscore the importance of good quality catch data, particularly regarding yellowfin tuna catches from municipal fishers in the Philippines.

This work aims to contribute to the ongoing effort to improve the deployment of traceability as a tool to enhance the equity and sustainability of fishery policy, particularly for small-scale, near-shore actors, such as the municipal yellowfin tuna fishers in the Philippines. We address this objective through the following research questions: What is the cost and efficacy of the current model of centralized catch data capture and management? What are potential explanations for different data capture rates over time, both between fisheries and between fishers? How could a democratized model of direct data capture and incentivization facilitated by mobile technology change the economics and efficacy of traceability adoption compared to the baseline centralized model? Why might one model or the other be preferable to near-shore stakeholders and/or downstream actors in the supply chain?

We have two related hypotheses. First, we hypothesized that yellowfin tuna catch records in the Philippines collected via centralized analog means both by the government and by an NGO were incomplete. We explored this through a retrospective analysis of more than 30,000 catch records collected by WWF-Philippines between 2014 and 2019, informed by publicly available data on the national and regional economy and tuna catch. Second, we hypothesized that certain structural factors undermined the efficacy of the centralized analog model and that a democratized digital model might mitigate these issues and result in more complete catch records and enduring uptake by small-scale tuna fishers in the Philippines. To evaluate this, we looked to two pilots of democratized digital catch data collection models recently conducted in the Philippines: (1) NFC cards/tags [3] and (2) a smartphone-based app paired with direct compensation for fisher and trader users [4].

2. Materials and Methods

National, regional, and provincial-level reference data, if available, were retrieved from the Philippine Statistics Authority (PSA) on sector size, catch quantities, value, and trends from 2001 through 2019, the most recent year for which data is available [2,19]. WWF-Philippines FIP (now MSC-certified fishery) is active in two regions: Bicol and Mimaropa. In the Bicol region, work is concentrated in 3 provinces, namely Albay, Catanduanes, and Camarines Sur, so that when province-level data was available it represented a compilation of those three. Mimaropa region activity is focused on fishers active primarily in the Mindoro Strait and landing in Occidental Mindoro province, so only data from that one province is used as reference for that region. Official public fishery data in the Philippines is collected through quarterly surveys conducted in the third or fourth week of the final month of each quarter [19]. In 2015, state-employed statistical researchers gathered these data at 282 commercial landing centers and 840 municipal landing centers through interviews with fishers, other center operators, fish brokers, barangay officials, or anyone who could give information on fish unloaded and prices paid at the landing center [19]. In 2001, state-employed statistical researchers obtained the data through quarterly surveys at

68 commercial and 217 municipal landing centers [2]. In addition to fishery-specific public data, we also relied on public data from the Family Income and Expenditure Survey (FIES) to assess economic indicators including median income, poverty incidence rate, and the subsistence rate for both the general population and fishers in 2015 and 2018 [20].

WWF-employed enumerators recorded FIP-specific catch data at municipal landing centers in the Bicol region adjacent to Lagonoy Gulf between 2014 and 2019 and in Occidental Mindoro adjacent to the Mindoro Strait from 2017–2019. Enumerators relied on standardized paper catch reporting forms to collect data on fish catch. WWF field staff provided costs associated with this enumerator-enabled model of data capture, which was intermittently deployed from 2012 through 2021 in the Bicol region and 2015 through 2021 in Occidental Mindoro. Most recently, USAID funded the employment of two enumerators in the Bicol region and WWF-Switzerland funded the employment of two enumerators in Occidental Mindoro, although funding of both enumerator-based data capture programs ended in April 2021. Interruptions in funding sourced from outside the supply chain motivate exploration of alternative models that better internalize the costs of catch data capture and recording, which should result in a more sustainable, consistent, and reliable model of data capture.

To understand completeness relative to public estimates and test our first hypothesis that records were incomplete, we summarized historic, enumerator-derived catch data by region, species, and vessel, as well as by catch and reporting frequency by fisher through time. Additionally, we calculated mean yellowfin tuna catch weights and variance through time by region and year. WWF partners also provided a small dataset from a survey conducted with 33 fishers or wives of fishers in the Bicol region on household finances and technology access, which was used as a reference [22].

To test our second hypothesis that democratized digital models of catch recording might mitigate systemic barriers to uptake, specifically economic barriers, we created scenarios based on the catch data frequencies observed in the enumerator-derived data to assess their economic performance. We then calculated the cost and returns to fishers of both the enumerator model and a democratized digital approach with direct fisher compensation at various rates per record. We developed the potential data payment rates through conversations with regional processors on their willingness to pay, as well as by bounding with the calculated cost efficiency of the centralized model. Costs to the full fishery were calculated by extrapolating costs based on PSA-derived (2020) estimates of total municipal and regional yellowfin tuna catch [19].

Potential efficacy and equity impacts of the democratized data capture model were evaluated qualitatively relative to the centralized enumerator data capture for near-shore stakeholders in and adjacent to the supply chain. Factors used to evaluate the efficacy and equity impacts of each catch data collection model include incentive/disincentive size relative to typical regional fisher incomes [20], data capture beneficiary/ies, and ease of data transfer to downstream stakeholders. This evaluation enables a directional assessment of where one model may perform better or worse than the other with respect to efficacy (assuming the chief uptake barrier is economic) and equity.

3. Results

WWF-Philippines has been actively engaged with yellowfin tuna fisheries situated in two regions: the Bicol region adjacent to Lagonoy Gulf, which abuts the Philippine Sea on the eastern side of the country, and Mimaropa's Occidental Mindoro province, adjacent to the Mindoro Strait, which abuts the South China Sea on the western side of the country. Together, these communities are home to 140 fishing villages and about 6000 hand-line fishers [23]. The WWF asserts that hand-line fishing reduces by-catch and catch of juvenile tuna compared with purse-seine methods used by larger-scale commercial fishers [23]. However, the problem of juvenile catch may persist with municipal fishers in Lagonoy Gulf [21]. WWF-Philippines has been engaged with fisher communities in both regions since 2011 as part of a FIP officially recognized as starting in 2014 [23,24]. These small-

scale yellowfin tuna fishers were part of the Philippine Tuna Handline Partnership (PTHP) that received MSC certification in October 2021. The goal of both the original Philippine Yellowfin Tuna FIP and the current MSC certification is to improve the economic position of small-scale fishers by improving access to European and North American retail markets. Those markets require the successful implementation of traceability to uphold the chain of custody requirement.

Based on WWF's catch records, 479 vessels participated in the FIP from the Bicol region between 2012 and 2019, though more than 85% of records are from 2014–2019. In Occidental Mindoro, 806 vessels participated between 2015 and 2019, though 99% of catch records are from 2017–2019. In both regions, few vessels are regular participants (Figure 1). Only 55 vessels operating in Lagonoy Gulf recorded more than 100 trips over the 6-year record available from that region, with most vessels recording fewer than 10 catches per year through the program (Figure 1a). In Mindoro, catch records suggest an even more concentrated structure, with only 4 vessels recording more than 100 trips over the duration of the recording period, suggesting both infrequent reporting and/or infrequent catch success. Most vessels in Mindoro also reported fewer than 10 catches per year (Figure 1b).

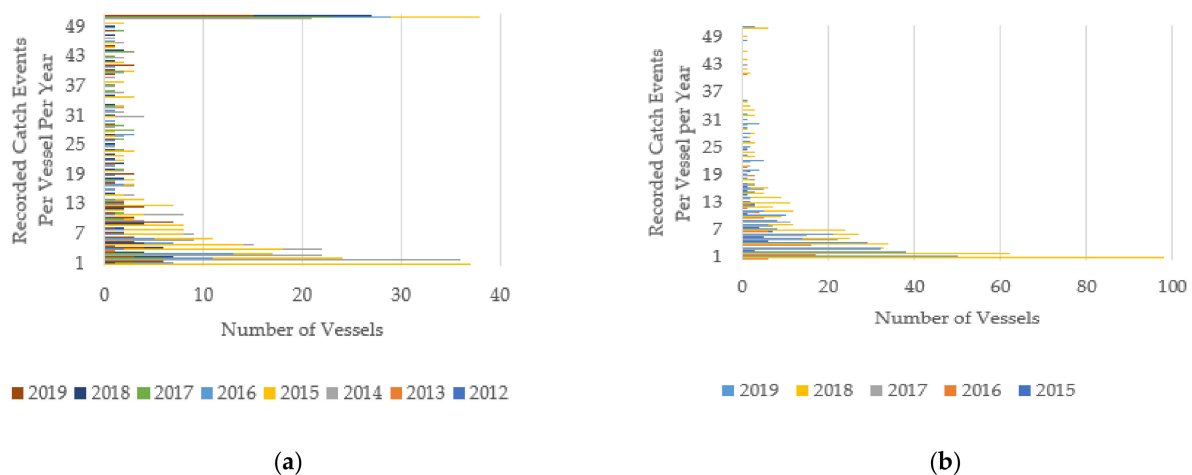


Figure 1. Frequency of catch data recording by vessel under the centralized enumerator model implemented by the WWF in the Bicol region (Lagonoy Gulf) and MIMAROPA (Occidental Mindoro/Mindoro Strait): (a) Lagonoy Gulf catch records; (b) Mindoro catch records. Records reveal catch data incompleteness with most vessels only recording 8 or fewer catches per year.

3.1. Trends in Yellowfin Tuna Catch Data

Since this WWF-led FIP (now MSC-certified small-scale handline fishery) was first implemented across these regions in 2015, there has been a decrease in yellowfin tuna catch (Figure 2) [19]. Nationally, the catch has fallen by approximately 30% since 2015, with even more drastic decreases in the Mimaropa (Mindoro Strait/Occidental Mindoro) region, where the catch has fallen by approximately 50% [19]. Ironically, the Mindoro area is where two sustainable tuna fisheries operate: the MSC-certified fishery covered in this paper, and the Artesmar yellowfin tuna FIP [14]. The decreasing trend in the Bicol Region (Lagonoy Gulf/Region V) is less extreme but still significant: a >10% drop in 5 years (Figure 2). This supply contraction has been accompanied by an increase in yellowfin tuna prices. Since 2015, Yellowfin tuna prices in the Philippines increased 25% nationally, but increased even more in the Mimaropa region and the Cataduanes province in the Bicol region (43–70% increases) [19].

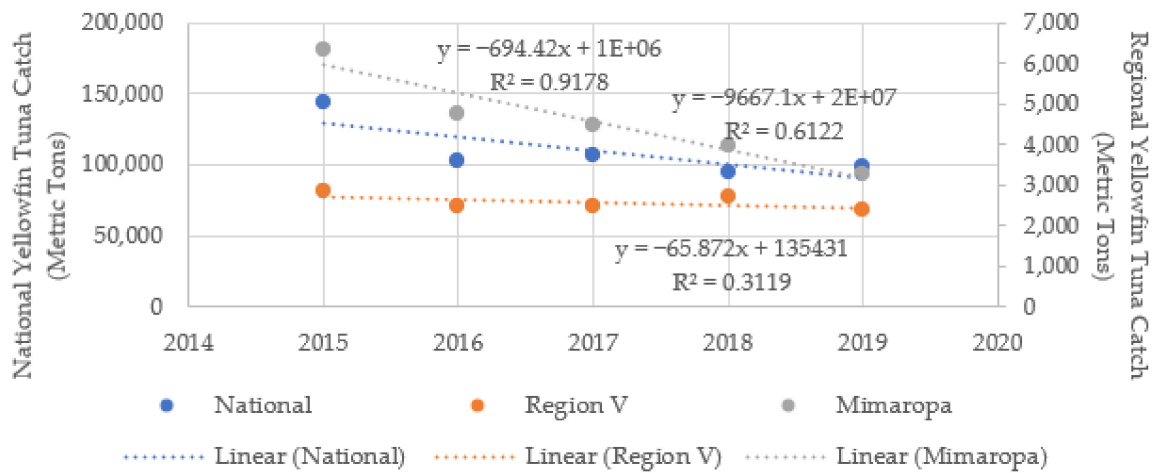


Figure 2. Yellowfin tuna catch volume is down ~30% nationally, and 15–50%, depending on region or province [15].

As total catch has declined nationally and regionally, catch data from WWF enumerators suggest juvenile harvest; even among municipal fishers this remains a significant portion of the catch (Figure 3). Climate change is expected to further exacerbate these issues and further strain the health of tuna fisheries in the Philippines [25].

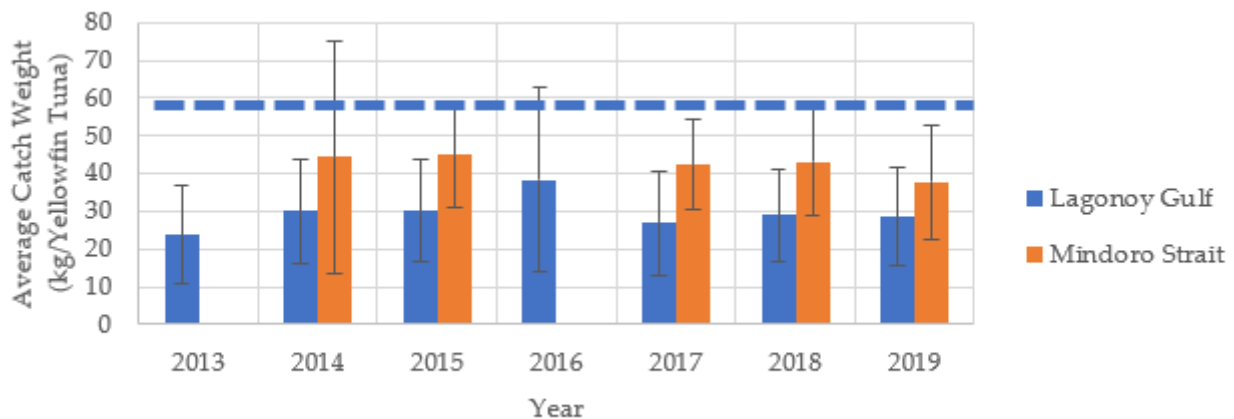


Figure 3. Yellowfin tunas caught by municipal fishers in the WWF-led FIP have mean weights indicating that juvenile tuna are prevalent in the catch, particularly in Lagonoy Gulf. The dotted reference line indicates the expected minimum weight of a reproductively mature tuna based on Zudaire et al. [26].

3.2. Cost and Efficacy of a Centralized Catch Data Collection Model 2012–2019

Given the diffuse and expansive geography within which municipal fishers operate in the Philippines, a centralized model driven by a single enumerator per region has some obvious limitations. However, to meet the MSC requirements for fishery monitoring required for certification, the WWF hired one enumerator per region to capture catch information from municipal fishers. Since each region contains multiple municipal landing centers, and even multiple provinces in the case of the Bicol region, and municipal fishers do not always land their tuna at landing centers at all, these data are understandably patchy. However, even given those multiple handicaps, a single enumerator in the Occidental Mindoro province was able to record as much as 17% of the annual tuna catch and more than 10% on average (Figure 4). These data suggest that simply hiring 4–9 additional enumerators (at a cost of ~\$15,000 to \$30,000 USD for all additional enumerators) would potentially be sufficient to record all tuna catch data for the regions. Conversely, in the

Bicol Region, which includes 3 provinces, catch data were reflective of ~1% of tuna catches in all years (Figure 4).

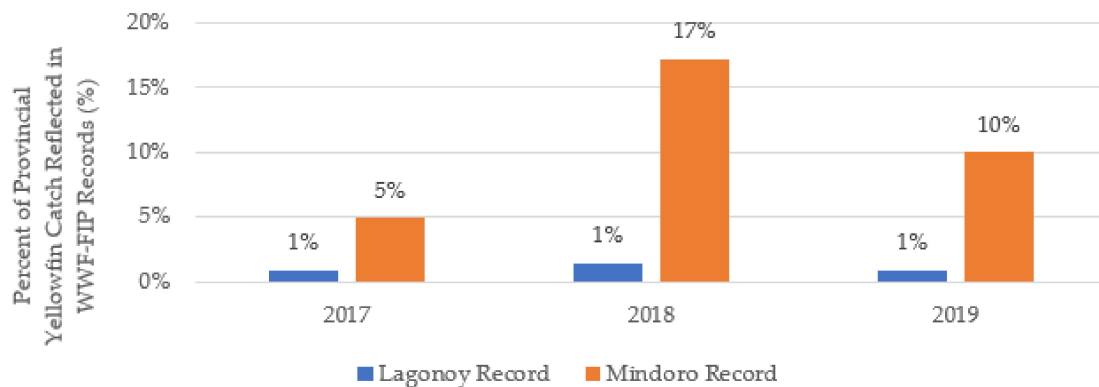


Figure 4. Percent of Regional Yellowfin Tuna Catch Included in Record. Comparison of volumes recorded under the centralized model to regional (Lagonoy/Bicol) or provincial (Occidental Mindoro) catch data estimated by the Philippines Statistics Authority suggests gaps.

This suggests that capturing 100% of yellowfin tuna landings in those provinces would require a minimum additional investment in enumerators of about 330,000 USD yr⁻¹ on enumerator compensation alone. These data suggest this model of data capture would require significant additional investment to capture all tuna capture in the region. While initial costs were higher, the typical cost per record of this model is about 40–50 PhP per tuna (0.8–1 USD/tuna recorded, Figure 5). Direct beneficiaries of this model are limited to the few enumerators employed, and transmission of data to downstream supply chain partners is not currently supported or possible, nor do those supply chain actors currently bear any of the cost of implementation, despite some processors and retailers accruing market access benefits related to selling FIP- or MSC-certified tuna.

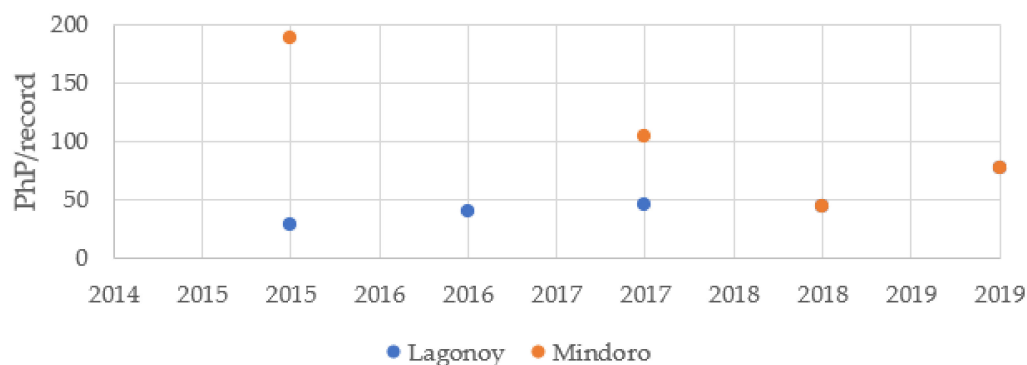


Figure 5. Cost of primary data capture via the analog enumerator model.

The expansive structure of municipal fisheries, including their use of unofficial landing sites, make it challenging to capture catch data from fishers under the enumerator model, as many fishers simply land outside of official landing centers, or land at landing centers where there is no program enumerator present. The most recent estimates of unreported or misreported catch volumes in the Philippines are 583,000 to 907,000 metric tons, worth PhP 50–75 billion, or about 28–44% of the total value of the commercial and municipal fisheries' catch reported in the Philippines in 2018 [1]. Barriers to improving this data include an unclear policy for municipal reporting, the difficulty of monitoring catches landed outside of designated landing centers, and the lack of a proper catch validation system and incentive structure [1]. Many municipal fishers even perceive dis-incentives to registering their boats, obtaining licenses, and reporting their catch. Perceived dis-incentives include

the time required to register and report in the LGU offices and the fact that the data could be used for taxation [1]. Democratized, digitized data capture paired with a direct payment for data offers a means of countering at least some of these concerns and disincentives.

3.3. Potential Performance of a Democratized Data Collection Model and Remaining Challenges

NGOs working in partnership with local government units and with support from international aid organizations are working to develop and deploy digital, democratized data capture methods. These methods include hardware-based methods, smartphone-based apps, and SMS-based approaches, each of which enable fishers to record their own catch data and digitally transmit it to downstream supply chain actors. Downstream actors are interested in this approach because of the potential cost savings offered by these approaches compared with the current process, which typically consists of paper catch report forms that traders photograph and email to downstream processors (pers. comm., JAM Seafoods; Figure 6). However, the appeal of these digital, democratized approaches to fishers has been less clear.

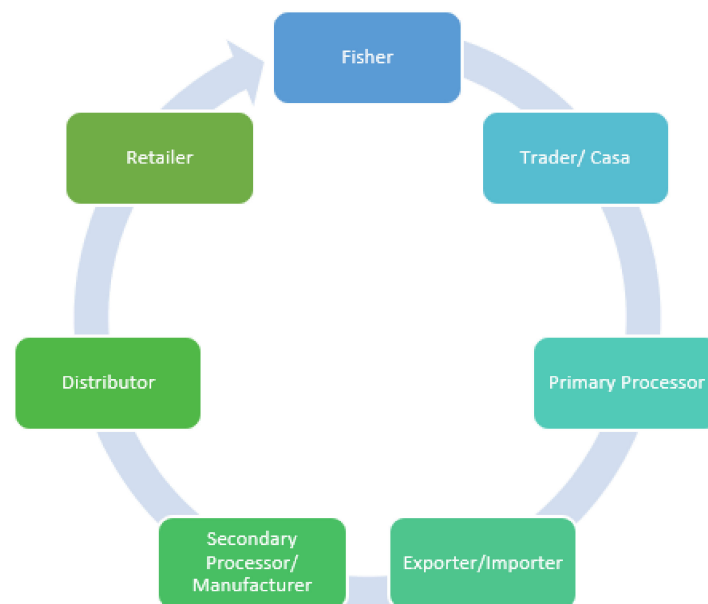


Figure 6. Digitization can enable traceability across long supply chains and enable retailers at the ends of supply chains to access catch data from fishers. New apps also enable processors and even far downstream actors such as retailers to compensate fishers directly for their catch data.

Each of the three digital models has a different suite of benefits and drawbacks. The hardware-based approach included an electronic catch documentation and traceability (eCDT) system comprised of on-boat Futuristic Aviation and Maritime Enterprise (FAME) transponders paired with Near-field Communication (NFC) cards to support electronic catch data [3]. The primary appeal of this system was the security or safety value of the transponder, which, in addition to recording fish catches, could also be used if the vessel were lost or in danger to transmit distress signals [3]. While this system theoretically supported the democratized, remote capture of catch data by fishers, the exact configuration piloted did encounter numerous challenges that thwarted full implementation [3]. First, procurement of the hardware required was expensive and outside the means of typical municipal-scale tuna fishers [3]. This barrier was initially overcome through outside subsidy from financial institutions in the Philippines and foreign aid [3]. A second barrier encountered in the preliminary pilot was power for the transponders [3]. While solar panels were supplied to allow fishers to charge the transponders, tuna fishers typically fish at night, and many of the transponders ran out of charge prior to fishers catching the tuna [3]. Additionally, the NFC cards provided during the pilot were not designed to

withstand the wet working conditions of the fishing vessel and were often unreadable or otherwise damaged [3]. Finally, the transponders were damaged by a typhoon, delaying further deployment of that system [3].

While the eCDT system encountered some setbacks, it still offers enough advantages to both fishers and downstream actors to merit additional effort [3]. To fishers, these benefits are safety, accessibility, and, potentially, compensation [3]. For processors, the savings from digital data management and more accurate data are enough incentive for them to purchase more transponders, so that fishers may access them at no cost, and to provide payment to the fishers for tuna when those tuna meet export grade [3]. Thus, this eCDT system, while still not yet widely adopted, illustrates the potential for information management cost savings at the downstream processing stage to fund the implementation of more effective digital data capture at the harvest/catch stage of the supply chain.

Phone-based apps are another alternative that may ease the collection of catch data, empower fishers to share their own data, and better connect the resources of the downstream beneficiaries of that data with fishers—providing fishers with additional compensation and downstream actors with cost savings and enhanced market access. A small survey of 33 fishing households in the Bicol region found that fishers or members of their households increasingly have access to a mobile device, with 63% having some type of phone [22]. Most have a feature phone (text only), but 15% have access to a smartphone [22]. Leveraging this technology, which fishing households have other uses for, would eliminate the issues related to hardware access inherent within the eCDT system. Additionally, some of these platforms have the additional benefit of connecting fishers with payment for these catch data [4]. We explored the potential value of this smartphone-based Tracey app model under different frequencies of tuna catch and rates of pay and compared potential data revenue to the typical debt burden carried by municipal fishers in the Bicol region.

3.4. Cost, Potential Returns, and Structure

Catch records compiled by WWF Philippines and official catch records reported by the Philippine Statistics Authority suggest that municipal tuna fishers in Mindoro typically catch 3–5 tuna per fisher per year, while those in Bicol catch 10–11, rates which local experts believe are indicative of chronic under-reporting (*pers. comm.*, WWF field staff). At the rates (25–50 PhP) currently experienced by WWF for collecting catch data under the centralized enumerator model, tuna fishers would only expect to receive 125–500 PhP annually for providing catch data (Table 2). This amount of remuneration is 1.7–10% of the typical annual debt burden of 5000–7000 PhP reported by municipal fishers in the Bicol region [22]. Processors have reported a willingness to pay a higher rate per record of 100 PhP, based on information management cost savings they expect to experience from a transition to digital traceability record keeping (*pers. comm.*, JAM Seafood). Even at that higher rate, however, the value to individual fishers of reporting their catch data is of limited economic value relative to their monthly income from fishing, which includes catching other types of fish reported as <3000 to 15,000 PhP [20,22]. However, if pay prices were increased to 300 PhP per record, approximately 5% of typical 2019 pay prices for tuna in the Philippines, the value of data entry and sharing begins to become more significant, particularly for municipal fishers in the Bicol region catching 10–50 fish per year. At that rate, fishers catching 20 or more fish start to make enough from data capture to alleviate typical debt burdens and allow them greater options for marketing their fish than fishers carrying debt from their traders have, potentially further improving their incomes (Table 2).

Table 2. Projected returns to individual municipal tuna fishers of a democratized digital data capture model at various compensation levels and catch frequencies. Bold indicates levels of revenue equivalent to or greater than typical fisher debt levels. Asterisks indicate typical tuna catch frequencies in *—Occidental Mindoro and **—Lagonoy Gulf.

Annual Catches Recorded	Payment per Record, PhP				
	25	50	100	200	300
5 *	125	250	500	1000	1500
10 **	250	500	1000	2000	3000
20	500	1000	2000	4000	6000
30	750	1500	3000	6000	9000
40	1000	2000	4000	8000	12,000
52	1300	2600	5200	10,400	15,600

While digitized data capture may not be a pathway to complete poverty alleviation, it could address efficacy and economic concerns around fish traceability. Continued development of these alternative models of data capture and transmission may offer additional cost savings across the supply chain that motivate their adoption. Ensuring they are also designed to transmit at least some of the value derived from that data by downstream actors back up to the fishers themselves is a step toward a more equitable, collaborative management of fisheries. Given the willingness of processors to pay at least PhP 100 to fishers to obtain this data, based almost entirely on their anticipated (not yet experienced) potential cost savings in information management, downstream actors may be willing to offer an even larger incentive to fishers to digitally collect and transmit their tuna data, if their experienced cost savings are higher than expected.

4. Discussion

We found support for our hypothesis that yellowfin tuna catch records collected via a centralized, analog approach are incomplete, both within NGO-collected datasets as well as in official PSA estimates [1]. We identified numerous systemic issues that impede the collection of complete yellowfin tuna catch data from small-scale handline tuna fishers in the Philippines, including geographic, economic, and regulatory.

Geographic challenges in the two yellowfin tuna fishing regions that we focused on in this study, Bicol and MIMAROPA, stem from two factors. First, both regions have an extensive coastline and limited formal landing centers; second, the scale of the municipal fishers' boats means they often land them on beaches near their villages rather than near landing centers. These geographic factors mean there are practical limitations to a catch record collection model that is dependent on the regions' ~6000 tuna fishers encountering 1–2 enumerators at landing and filling out catch reporting forms.

The second systemic issue is economic. Current catch data collection has been supported by extra supply chain actors, such as USAID, whose support has allowed NGOs to hire enumerators to record catch data [3]. However, when there are lapses in that funding, the already impoverished fishers have been unable or unwilling to take on this new additional administrative cost. Additionally, even when enumerators are funded, the analog format of the catch-reporting forms they generate creates a substantial administrative handling cost burden on the processors who need to digitize the records and maintain them for their importer customers demanding FIP or MSC-certified tuna. While these processors would benefit economically from the fishers adopting a digital catch recording system, unless that system incentivized fishers, it would represent a transfer of costs from *casas* (traders who often first record the fish) and processors who must receive digitize and maintain those records to fishers. This makes further expansion of the analog system economically unpalatable to fishers. However, simply digitizing the current centralized recording process may offer a middle way that is less burdensome and more complete than

the current analog approach, but more palatable than a complete shift to a democratized, digital model that increases the cost and infrastructure burden on fishers.

Finally, the regulatory landscape in both the Philippines and critical importing countries in Europe and North America is insufficient to adequately incentivize either fishers, processors, or importers to adopt traceability systems that would ensure the collection of complete and accurate catch records. In the USA, an important export market for yellowfin tuna from the Philippines, the FDA's 2018 announcement that they would "exercise enforcement discretion" for the key regulation was meant to drive traceability adoption among foreign producers and suppliers [5]. Additionally, strengthening domestic fishery policy, specifically by extending RA 10654 to include requirements for national vessel registration and catch recording for municipal fishers, as well as implementing appropriate fines and enforcement, could help address this systemic regulatory weakness [17].

4.1. Economic Considerations

There was less support for our second hypothesis that a democratized digital model might mitigate some of the systemic issues that undermine complete catch recording.

A digitized, democratized approach to catch data collection is unlikely to be more economically efficient than the centralized model at the catch/harvest stage of the supply chain. However, when considering costs incurred related to data entry, management, and transfer of that data incurred at later stages in the supply chain, the approach may still offer some economic advantage relative to the centralized enumerator model. The democratized model, especially when paired with direct compensation at the level of 5% of current tuna prices or greater, does redirect an amount of downstream value back up to the fisher that could be economically significant to the fisher when catch frequencies exceed 20 tunas annually (Table 2). This value transfer would also enhance equity between first mile actors and their downstream counterparts in the supply chain by giving fishers some degree of agency and control over primary data capture and transmission.

4.2. Efficacy Considerations

Digitization and democratization offer advantages over the centralized model in terms of accessibility and potential efficacy by enabling fishers to directly record and transmit their catch data, even when landing outside formal landing centers, to downstream actors in the supply chain. These factors suggest that digital, democratized traceability may offer an effective, equitable catch data solution for improving catch data record keeping with municipal fishers in the Philippines. These technological advances in traceability systems offer important opportunities to enhance sustainability data capture without unduly increasing the burden on either fishers or the state.

4.3. Regulatory Considerations

Adoption and implementation could be further improved with regulatory support, for example, if the government were to require catch recording and reporting for municipal fishers. Without this clear requirement, a functional centralized catch-reporting system, and digital, democratized methods of data capture accessible to fishers, having adequate quality data to meet trade requirements and effectively manage the health of the fishery, may continue to elude the Philippines.

4.4. Suggestions for Practitioners

Invest in enabling infrastructure. Internet access is still a limiting factor in these regions of the Philippines. This impedes the adoption of digital recording, including both democratized recording by fishers (on smartphones many lack access to) and centralized digital recording, perhaps by casas or traders at community landing centers where the first change in custody occurs.

Consider baseline conditions, including the cost and incentive structure of current systems and the appropriateness of potential solutions given physical, climatic, technological,

and economic factors. For example, any physical identifiers used in fishery systems should be able to persist in wet conditions for extended periods of time. Additionally, consider the resilience of any hardware required in the face of both routine challenges (e.g., if it requires power, consider that fishing frequently occurs at night and size solar panels and battery storage appropriately) and episodic disruption (e.g., typhoons that may require the more frequent replacement of hardware than would be otherwise dictated by the product's expected lifespan). Additionally, if the current costs of recording and digitizing are borne by actors downstream of fishers, consider pursuing centralized digital models that would provide cost savings to those actors, further incentivizing adoption without resulting in new costs for fishers.

Advocate for an effective and enforceable regulatory framework. Many traceability systems fail not due to lack of technological capacity, but due to regulatory or enforcement weakness [5]. Ensure all supply chain actors and relevant markets have sufficient regulatory and enforcement capacity to drive the adoption of traceability.

4.5. Conclusions and Future Research Needs

The current analog catch reporting system in the Philippines is incomplete, challenged by geographic, economic, and regulatory factors. Pilots of democratized, digital systems have shown that they may mitigate some of the geographic challenges but may also introduce new economic ones. Undertaking additional socio-economic research on the fishers, casas, and processors as detailed by Pinello et al. is necessary to more clearly enumerate these challenges and design systems that could effectively mitigate them [27].

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Data Availability Statement: Data analyzed in this study includes publicly available data, extended versions of certain publicly available data available on request from the corresponding author, and 3rd Party Data available on request from the corresponding author with the permission of project funders. Publicly available datasets on the volume and value of Philippine yellowfin tuna catch by province and region from the Philippine Statistics Authority were analyzed in this study. This data can be found here: <https://psa.gov.ph/content/fisheries-statistics-philippines> (accessed on 14 January 2022). Additionally, a consolidated publicly available dataset on the catch in now MSC-certified yellowfin tuna fisheries in Lagonoy Gulf and Occidental Mindoro can be found here on pages 396–398: https://fisheries.msc.org/en/fisheries/philippine-small-scale-yellowfin-tuna-thunnus-albacares-handline-fishery/@assessment-documentsets?assessment_step=Initial+assessment&documentset_name=Final+draft+report+and+determination&assessment_id=FA-02519&phase_name=Final+Draft+Report+and+determination&start_date=2020-09-30 (accessed on 14 January 2022). An extended version of that publicly available data on catch (with finer resolution to region and season) within the now MSC-certified small scale handline yellowfin tuna fishery is available on request from the corresponding author. It is not hosted in full on the MSC assessment site for the fishery due to length. Finally, we utilized 3rd party data from traceability solution provider, TX, who developed and piloted the smartphone-based Tracey app reported in this paper. A subset of that data is available here: <https://tx.company/wp-content/uploads/2020/10/Tracey-Whitepaper-2019.pdf> (accessed on 14 January 2022) and additional data is available on request from the corresponding author with approval from the project funder.

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