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Scoping study on cost-effective monitoring, control and surveillance data collection systems for small-scale/artisanal fisheries in the western Indian Ocean

Draft Report to WWF

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Frontispiece:

An artisanal fisher using a mosquito net inspects his catch. © Ross Wanless

Disclaimer

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INTRODUCTION

Electronic Fisheries Information System (eFIS) tools for monitoring (EM) and Reporting (ER) are fundamental to addressing illegal, unregulated and unreported (IUU) fishing[1-3]. However, despite a proliferation of technological solutions for fisheries, eFIS remains the exception rather than standard practice.[4] The obstacles and barriers to significant uptake are many and varied[3], despite a glaring imperative to address the existential crises facing many artisanal fishers.

The scale of the data and MCS challenges facing small-scale/artisanal fisheries (SSF) are daunting. For example, SSFs for tuna in the Indian Ocean Tuna Commission's (IOTC) area of competence make up *close to half* the estimated tonnage caught under the ambit of the IOTC[5]. The parlous state of data from SSFs is lamented annually in various settings at the IOTC[6]. WWF seeks to facilitate implementing and upscaling low-cost data collection systems for monitoring, control and surveillance (MCS) pilots for SSFs in the western Indian Ocean (WIO) region. This is to support States in their efforts to address IUU fishing in their national waters, strengthen States' governance with robust data, and improve national reporting of fisheries & related statistics and data to relevant intergovernmental bodies. A fundamental component of this scoping study is a WWF workshop on low-cost data collection and MCS tools; exclusively this workshop is referenced throughout this scoping study.

Robust MCS systems that monitor large proportions of landed catches and which are linked to market-incentive schemes such as Fisheries Improvement Projects, stand to

1. improve the management of marine resources
2. boost local and national GDPs
3. improve tax collection through electronic tracking of commercial transactions
4. make corrupt practices considerably more costly and difficult to evade detection
5. enhance livelihoods amongst communities dependent on SSFs
6. strengthen the resilience of marine fisheries in the face of accumulating and advancing climate change impacts.

The challenges facing national administrations with sizeable SSFs are daunting. IUU activities are pervasive and deeply entrenched. Attempts to introduce technologies with the power to disrupt entrenched systems will be met with resistance, and the law of unintended consequences makes caution advisable. The road ahead will not be smooth. However paper is a leading cause of many of those challenges[4]; it is also a critical facilitator of modes of laundering IUU catch[7,8]. If any change is to be made, it will require moving fisheries and MCS systems away from an information technology that is ~2500 years old and into the 21st century.

With any change, there will be winners and losers. Currently, many artisanal fishers experience negative impacts from increasingly challenging governance and environmental conditions, yet they persist. Will they be winners or losers? Stocks upon which fishers depend are facing or already in collapse; this leads to a cascade of consequences, including domino effects on remaining stocks and food insecurity; these work synergistically to create powerful incentives to fishers to engage in IUU, if there are no better alternatives.

Modern global seafood markets increasingly demand traceability. Fishers' access to export or premium markets is thwarted when they cannot provide verifiably legal documentation in good time. That said, the demand for sustainable products from SSFs is substantial, given the increase of Fishery Improvement Projects (FIP) for SSFs on fisheryprogress.org listing. Thus it is evident that under-resourced, stretched, paper-based MCS systems and other governance challenges are impacting the value that small-scale fishers can attain from their catches and forcing many into technical IUU fishing. Turning that around without increasing the burden that fishers must carry is ***the*** existential challenge facing SSFs. All target countries with sizeable small-scale tuna catches stand to gain substantial leverage in deciding IOTC's catch allocations (negotiations have been underway for some time) with stronger data collection and MCS systems. Demonstrable catch history is a significant factor in these negotiations.

Losers from strengthened data collection and MCS systems would hopefully include illegal fishers and the corruption networks that facilitate or enable IUU. However, many small-scale fishers have no real choice but to engage in some IUU fishing, and caution is strongly urged to not create a system that punishes fishers, but rather to create a welcoming environment that allows fishers to start improving their lot through being in compliance.

Systemic challenges

All fisheries should have a coherent IT infrastructure, and modern approaches to the scale of data that fisheries generate use the following basic approach: data are warehoused (constantly inputted live to a central repository), with different data sources of the same event carefully curated to allow cross-reference but not create confusion.

A final consideration is national inertia. Inertia, or resistance to change, is a non-trivial concern. Whatever system is currently in use is likely to remain in use unless there is substantive effort, a supportive national policy, and broad buy-in from officials. This is not a covert criticism of national efforts or officials. Inertia is simply a fact of life, and changes to fundamental things such as the database that an entire department uses, are not changed whimsically. But it is important to recognise and overcome a universal challenge to state bureaucracies wherever they exist, which is that any change brings risk, whereas allowing the status quo to be maintained does not.

CASE STUDIES ON EFFICACY IN ADDRESSING IUU

There are multiple studies that report on one or a more aspects of eFIS for SSFs – usually a narrow scope such as location tracking[9] or cost-benefit analyses at small scales[10], or with wider scope (more holistic) opt-in eFIS pilots[8]. Amongst their manifold limitations in informing whether or not eFIS is cost-effective, an insurmountable challenge is because pilots **by definition** cannot achieve economies of scale. As any start-up business can attest, speculations regarding thresholds necessary to achieve a net benefit (especially when being considered relative to status quo) cannot be done reliably, from first principles or *a priori*. That said, there are several excellent examples from industrial fisheries that demonstrate transformative potential. To clarify, this scoping study is exploring eFIS systems for use in MCS, and MCS-relevant lessons are drawn despite using some case studies that were not for MCS purposes.

The chosen examples are as close as possible to the target SSFs of this scoping study – all being from Indian Ocean fisheries, one SSF and three industrial tuna fisheries

1. Catch composition monitoring. EM onboard net-capture fleet- purse seiners, which has lessons for monitoring shrimp trawl fisheries
2. Traceability. The CCSBT's Catch Documentation Scheme impacting stock management
3. EM in Australia's tuna longliners and the subsequent impact on logbook reporting
4. Vessel tracking to characterize and then detect suspicious fishing activities

Catch composition monitoring

Camera-based EM systems giving sight of deck areas where catch operations unfold offer some of the most obvious potential improvements in MCS data. These have been widely and extensively piloted in industrial settings and the benefits, constraints and challenges with video data need not be repeated here. However, new technologies and incremental growth in machine learning and artificial intelligence solutions continue to refine and improve the beneficial aspects of EM while also addressing challenges in diverse areas such as installation, durability, power requirements, data storage/transmission, and conversion of video footage into quantitative data. These ongoing developments serve to expand the types of fisheries in which camera-based EM can be deployed, including in some SSFs.

The lessons from pilot EM in purse seine fleets operating in the Indian Ocean (and elsewhere) can reliably estimate catch composition for multiple species, with improvements in algorithms, machine learning routines and other aspects[2] building upon earlier efforts[11]. Implementing such systems in artisanal and semi-industrial shrimp fisheries would deliver many immediate benefits, including quantifying effort and catch, including bycatch proportions of various taxa, particularly endangered, threatened or protected (ETP) species.

Within the SWIO region, several boat-based gillnet and shrimp trawl fleets are classified as SSFs, have inboard motors producing sufficient current to power EM. Camera-based EM systems are already available for pilots in SSFs in the region, with solutions from service providers such as Shellcatch and Satlink being presented to and eliciting strong interest from workshop participants.

Traceability

The Commission for the Conservation of Southern Bluefin Tuna (CCSBT) manages a single species, and was established in the 1990s to help address growing concerns that the SBT stock was being heavily overfished to well below MSY[12]. Supply and demand economics led to ever-increasing prices for the diminishing stocks. This fueled a situation where increasing catching costs were offset by soaring prices (as well as various forms of subsidy to the fishery). Adherence to a stock rebuilding plan was managed through a Catch Documentation Scheme. This allowed the SBT stocks to recover such that rebuilding metrics were met and in 2018 catch allocations were increased.

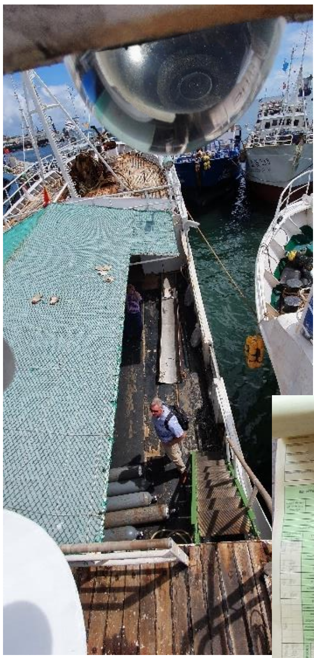
The Catch Documentation Scheme (CDS) of the CCSBT has two unusual features that offer key lessons for modern CDSs. In addition to catch records, the CDS required that all importers/buyers also submit documentation. Further, export and import records are reconciled. Buyer documentation and reconciliation are dealt with separately.

Although it might seem obvious, many CDSs only record landed catch and no commercial/sales activities. This leaves a door wide open for non-reported tuna to enter supply chains from the buyer. It is noteworthy that some countries within the WIO region already require documentation for commercial sales. Converting from paper to an electronic system of transactions should be relatively painless compared to initiating such a process where buyers are not accustomed to reporting in this manner and where processes and structures do not already exist. Reconciliation is a key advantage of electronic systems, because routines can be automated and managers do not have to uncover discrepancies, they need only verify and address flagged transactions.

During the MCS workshop several examples were discussed in which fish processing enterprises pool catches from multiple fishers. Without any reconciliation of volumes processed and sold onwards, there are no pragmatic obstacles to processors mixing legal and illegal catches, and no practical mechanisms for authorities to detect that.

EM in Australia’s tuna longliners

Australia implemented camera-based EM for its tuna longline fisheries in 2015/16. This augmented the electronic monitoring of vessel movements (via Vessel Monitoring System, VMS). Subsequently, there was a significant change in several aspects of fishers logbook reporting[13]. A known and substantial challenge with logbook data stems from it being self-reported. Without several forms of EM, the management authority in Australia had no mechanism to verify self-reported data besides quantifying landed/declared catches. The



introduction of camera systems allows robust catch quantification, including of ETP species. Critically, and similar to the process that the CCSBT CDS followed, Australian authorities implemented auditing/reconciliation of data from EM with data from logbooks. This is a critical step, because multiple sources of information are frequently (and correctly) touted as essential for fisheries management, but **critically** this is true only when two preconditions are in place

1.They are reconciled with other data

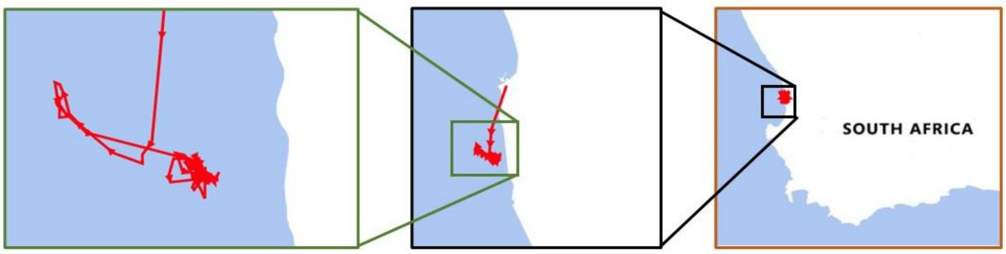
2.There is a realistic probability of censure for non-compliance

Cross-referencing discrete datasets of the same event gives authorities new and unprecedented ability to verify self-reported data. But if mechanisms to address discrepancies are weak or the appetite to improve compliance or censure non-compliant (IUU) activities is weak, then the promise of EM will likely remain deferred. The marked changes in logbook data was an unintended but very welcome consequence for Australia's management authority. Australian fishers improved their own logbook reporting because knew that any discrepancies would face censure.

Vessel tracking

The *where* of fishing has always been and will remain a fundamental aspect of fishing. Zonation of the marine environment into discrete areas where activities are permitted or prohibited is nearly universal. Spatial zonation for fisheries comes in many forms, including protected area and Beach Management Units. The zonation can be complex – e.g. allowing certain gears to be used or fish to be targeted but not others. They can also be simple, e.g. only members of a certain community may access the marine resources in a given area. But how can managers ever hope to actually manage spatial aspects of a fishery if there are no verifiable data on where fishing activities took place? The obvious answer in many instances is that they cannot, and the paper regulations remain just that.

South Africa's rock lobster fishery includes a boat-based small-scale component. The coastline is divided into sectors and fishers are authorized to catch lobster within a given zone only. In addition there are multiple Marine Protected Areas where lobster fishing is prohibited. The state does not require SSF vessels to be tracked. As a consequence, there is no mechanism to verify that once a vessel leaves port, it conducts fishing within the specified area. A private initiative from the organization ABALOBI



was established to try and bring traceability and verification to this fishery, support fishers with access to reliable, above-board sales, and simultaneously create a network of responsible buyers who do not want to support illegally caught lobster. Since there was no legal requirement or mechanism for tracking vessels, ABALOBI deployed small, battery-operated, stand-alone devices on each vessel that was used to catch lobster for sale through ABALOBI's marketplace. This information was integrated into their traceability system that surfaces permit numbers, tallies of catch against allocations, landing declaration documents AND the evidence that catches were made within authorized waters. The ABALOBI system was designed to be cheap and simple to manage. Unlike VMS or AIS systems, the devices used by ABALOBI did not transmit locations, but logged data. They had to be removed from vessels to retrieve the data and recharge the batteries. The level of effort was manageable for a small number of vessels, but would become inappropriate if attempted at scale. But the key lesson is that very simple and cheap tracking systems can still deliver market-related benefits and allow fishers to sell their catch in premium markets.

If the solution had been implemented at the scale of the entire community – i.e. all authorized vessels were tracked, then in theory any suspect behavior – such as vessels operating in very close proximity or moving in ways that are atypical for legitimate fishing for lobster – can be detected through algorithms (developed by machine learning). Global Fishing Watch has implemented such processes for industrial fishing vessels and leveraging the data from AIS, and been able to show highly suspect behavior suggestive of illegal transshipping.

All five target countries in the WIO region have VMS systems for larger vessels in the national fleet. Thus the national infrastructure to receive and manage vessel location data already exists. Multiple solutions exist for tracking SSF vessels with varying degrees of functionality, security, durability and cost. Therefore there are no technical barriers to the implementation of vessel tracking to strengthen national spatial management of SSFs.

Additional considerations

Of the examples used above, none explicitly demonstrate the power of a full traceability system. Comprehensive electronic tools are those which manage all or most regulatory aspects of a fishery with electronic systems; they utilize multiple data collection systems (e.g. smartphone apps, vessel tracking and camera systems) from multiple points (i.e. there is duplication of data collection) with dashboards to surface information and algorithms to automate many processes, including detecting discrepancies between the same data collected in different ways. Such systems have been successfully piloted in SSFs within the region (e.g. deployment of ABALOBI's tech within South Africa's West Coast Rock Lobster fishery[8]) which demonstrate clearly that IUU catch can be completely eliminated from certain supply chains. Any gap in coverage creates a mechanism for IUU catch to be laundered. And none of these systems can impact smuggling of catch. I.e. even with a comprehensive and completely watertight electronic management system in place, some processes and opportunities will remain for IUU profiteers to exploit. Nevertheless, it is clear from these examples that the more widespread the reach, the more challenging the fisheries management system becomes to IUU networks, and thus the bigger the impact will be on reducing IUU.

A clear reason for this scoping study is because there are no examples of comprehensive electronic systems being rolled out at large/national scales within the region, let alone for SSFs. Nonetheless, all the examples offer a very clear lesson – that electronic MCS systems can interact synergistically with other datasets to deliver outcomes that are greater than the sum of the individual components. Take the Australian EM example; fishers clearly understood that authorities would compare information from the camera systems with logbook records. The benefit of the cameras extended to massively strengthening another system because the data streams were used together, for cross-referencing and validation. Modest systems, such as inexpensive, low-tech solution that logs vessel movements, can address endemic problems; when those become integrated into a more and more comprehensive electronic data ecosystem, the capacity of States' MCS systems can be transformed.

COUNTRY PROFILES

Profiling is a double-edged sword at the best of times. When profiling a country and its management of sovereign activities such as fishing are concerned, the risks escalate appreciably. To mitigate this, PA shared a profile template with representatives from the five target countries, and information in the completed decks and oral presentations formed the basis for the profiles below. Where possible, gaps were filled through personal discussions or gleaning information from other workshop processes. Each profile is incomplete to some level, and there are inconsistencies between them. However the purpose of the profiles is not to become reference material for future work, name-and-shame, or have any implications for national pride; they serve to contextualise national MCS roadmaps and provide some realistic considerations for piloting electronic MCS tools.

Rather than repeat the same information in each or several profiles, where common themes have emerged those are presented first. First, South Africa is unique in the predominance (in virtually all metrics) of commercial fisheries, whereas elsewhere the SSF sector catches the overwhelming volumes and sustains vastly more livelihoods.

Existing capacity is constrained across the board, but to varying degrees. This is partly due to the expense inherent in training, deploying and maintaining a large corps of data collectors (monitors, inspectors, etc.). None of the countries has a compliance section with staffing levels that are anywhere close to appropriate. In mitigation of this, a large corps of local monitoring capacity (BMUs) exists in Kenya and Tanzania. For Madagascar, Mozambique and South Africa where the scale of coastline to be monitored is massive and there is functionally no capacity, the costs to the fiscus will be excessive unless alternative funding mechanisms can be found.

There appears to be no links between export permits and MCS systems. A broader issue is that there appears to be inadequate or no verification between different datasets, even where the potential to do cross-checking exists. Tanzania and Kenya already have some of the requisite bureaucratic infrastructure in place since they require that all buyers and sellers have permits that in theory should match. Although it is not clearly stated as such, it appears that the trade permits are paper-based, which would be an obvious impediment to verification.

Kenya

OVERVIEW OF TUNA, SHRIMP AND OTHER FISHERIES

Kenya has ~13 000 registered small-scale fishers and around 3000 registered vessels (including SSF vessels). The scale of tuna catches from small-scale fishers is not known, and there are functionally no shrimp-directed SSFs in Kenya. SSF catches make up 90% of Kenya's total fisheries landings.

GOVERNANCE

Kenya has national and county-level authorities. SSFs are divided into local sectors, termed 'Beach Management Units' (BMUs). Inspectors (both national and local) are responsible for collecting landings data using basic electronic data recording systems. Local-scale management ensures community involvement in some aspects.

DATA COLLECTION

Kenya currently uses electronic tools for data gathering, and the state acknowledges the potential that electronic systems offer and is committed to upscaling its use of electronic IT systems for fisheries. However, it is constrained in multiple spheres from achieving complete electronic coverage of SSFs. The ecosystem of CDS is only as robust as those who use and manage it, and there are substantive gaps in the process. For example, local knowledge and relationships can easily be leveraged by fishers to avoid encountering inspectors, and an unknown proportion of total catch escapes official notice. Informal estimates indicate ~5% of landings are monitored, while ~70% of landings are not declared (B. Kiilu pers. comm.).

Kenya's licensing and permitting systems include the following:
All fishers and fishing vessels must obtain a licence, but since all SSFs are open access, this is not a challenging requirement. All fish processing establishments/ vessels must also be licenced and have Certificates of Compliance. All fish trade is licenced, which in theory allows the state to manage the flow of SSF catch into the formal economy by matching seller and buyer records. However it is unclear if this validation is undertaken, and if it is, what happens to discrepancies. Finally, the scale of declared catch is dwarfed by the volumes believed to enter the informal economy.

CHALLENGES TO USING ELECTRONIC MCS DATA

Relative to the other target countries, Kenya is well positioned to implement robust electronic MCS systems for its SSF sector. It has substantial local capacity in the BMU system, and beach and port monitors already use electronic tools. However, it is uncertain how suitable Kenya's IT system is for modern fisheries management needs, including warehousing all data, sharing/serving data, generating data for reports to RFMOs, linking permit applications to MCS information, etc. Furthermore, there is no infrastructure in place for tag-and-trace of catch – a cornerstone of traceability in fisheries.

Madagascar

OVERVIEW OF TUNA, SHRIMP AND OTHER SMALL-SCALE FISHERIES

The SSF sector in Madagascar dominates catch and livelihood metrics, employing ~120 000 people directly and contributing >5% to the national GDP. The sector targets a wide diversity of crustaceans, finfish and sea cucumbers. The shrimp and tuna sectors have substantial participants (~22 000 and ~4000 fishers, respectively) and catch appreciable volumes. However, heavy reliance on gillnets in Madagascar means that finfish catch/bycatch dwarfs the catches of all other subtaxa.

GOVERNANCE

Madagascar's fisheries are open access and participatory decision-making is effected at the community level. National processes have been centralized into an integrated, multi-purpose IT system, although all supporting documentation and outputs (permits, account statements, etc.) are paper-based.

DATA COLLECTION

Madagascar uses the FAO's Open Artfish database and ODK-based smartphone application for basic data recording. The size of the MCS section and numbers of inspectors/monitors are unknown and no estimates are available on proportions of total catch that are monitored.

CHALLENGES TO USING ELECTRONIC MCS DATA

Madagascar's fisheries management is subject to a familiar set of challenges – limited human resources and budget allocations, capacity constraints and substantive training requirements for fishers and departmental personnel. That said, the existence of Open Artfish and the accompanying smartphone application do provide the rudiments of an ecosystem of electronic tools

Mozambique

OVERVIEW OF TUNA, SHRIMP AND OTHER SMALL-SCALE FISHERIES

Artisanal catch in 2021 amounted to >425 000 tons, representing 95% by weight of Mozambique's total fisheries landings. There are an estimated ~300 000 artisanal fishers and a further 500 000 livelihoods dependent on SSF in Mozambique. Fishers use a wide diversity of gears and catching a very wide diversity of marine species – crustaceans and other shellfish, reef fish, small and large pelagic species (including tunas) and more. There is a sizeable catch of shrimp by artisanal and semi-industrial fleets but very little tuna-directed small-scale effort.

GOVERNANCE

Legally the seas extending to 3 km from the shoreline are reserved for SSF, although it is unlikely that this boundary is fully respected by other sectors. Artisanal fisheries are open access and currently the SSF section of the Compliance division has ~100 staff, equivalent to one monitor/inspector for every 3000 fishers.

DATA COLLECTION

Data collection from SSFs relies on paper systems, depends on limited personnel with limited budget and very substantial geographical and access issues. As a consequence, there is only sporadic and uneven data collection, with little capacity to estimate proportions of total landings that MCS efforts cover. The national administration's IT infrastructure is currently transitioning from 'Pescart' to the FAO-promoted program 'Open Artfish', an open-source (hence free) but fairly basic fisheries database and ODK-based smartphone application for data collection. Officials have recognized the limitations of Open Artfish.

CHALLENGES TO USING ELECTRONIC MCS DATA

Mozambique's fisheries management experiences similar challenges to other coastal African states – limited human resources, no budget allocations requisite to fund additional MCS officers and technicians, as well as capacity constraints and substantive training requirements for fishers and departmental personnel. That said, the existence of Open Artfish and the accompanying smartphone application do provide the rudiments of an ecosystem of electronic tools.

South Africa

OVERVIEW OF TUNA, SHRIMP AND OTHER SMALL-SCALE FISHERIES

There are >10 000 small-scale fishers in > 200 recognised fishing communities in South Africa, but no tuna and shrimp (or prawn) small-scale fishery. Trivial volumes of smaller tunas are legally caught in small-scale handline fisheries, which is technically a mixed fishery that includes tunas.

GOVERNANCE

The Department of Forestry, Fisheries and Environment (DFFE) overseas all aspects of fisheries management, including compliance and inspection functions. Official policy seeks to co-manage fisheries, however the practical implementation of that desire faces many logistical and philosophical hurdles that have yet to be addressed. Legal minimum standards for consultation with interested and affected parties are generally adhered to, and thus there is some level of inputs to national policies. However participation at community levels is infrequent and there is a deep history of marginalization of fishers, and distrust by fishers of government. The de facto national approach can be described as top-down decision making with consultation but limited co-management.

DATA COLLECTION

Currently there is a small national cadre of inspectors, none dedicated to SSF. There are ad hoc systems for managing certain SSF catches, e.g. lobster landings have dedicated community members to record landings and submit paperwork. Tenders for service providers to provide the human capacity to undertake MCS data collection at landing sites are ongoing but not operational, and there is a long history of fisheries tenders being withdrawn, allowed to lapse without evaluating bids, or being set aside after legal challenges. What SSF landings data are collected is done on paper, forms are centralised and captured into the national fisheries database known as MAST. The MAST system is barely functional and officials are currently deciding whether to try and fix it or to start anew.

Fishers and other supply-chain actors must be in possession of permits for any species that they retain or land. Retail operations (including restaurants) must financial paperwork (invoices) for fish they sell to the public, but these are not MCS documents and cannot be used for MCS purposes. There is no CDS for buyers of fish or fish processing entities

CHALLENGES TO USING ELECTRONIC MCS DATA

DFFE must decide on whether to invest in reviving a broken IT system or start a new system. Once that has been done, tech systems to collect and accession data can be specified. There are many challenges facing the SA government in addressing IUU in its SSFs, including:

1. a severe shortage of human resources, especially monitors at landing sites
2. reliance on paper for all primary data records, issuing permits, export approvals, etc.
3. lack of any post-landing CDS requirements
4. a decrepit IT infrastructure that doesn't allow modern data inputs or remote access to live data

Officials thus have very limited ability to address IUU within SA's SSFs. Enforcement is concentrated on addressing the most egregious breaches of regulations such as being caught with species and no permits.

Tanzania

OVERVIEW OF TUNA, SHRIMP AND OTHER SMALL-SCALE FISHERIES

Small-scale fishers and aquafarming operations together account for ~95% of Tanzania's total catch of ~400 000 tons/year. Fisheries represent < 2% of Tanzania's GDP, with ~200 000 people employed directly in small-scale fisheries and an estimated 4.5 million benefiting from fishery value chains. Recent data on the relative sizes of commercial/industrial and small-scale tuna, shrimp and other fisheries are not available, but small-scale fisheries are similar to those in neighboring coastal states, targeting a wide diversity of shallow-water species with effort diminishing with distance offshore

GOVERNANCE

Tanzania's political history as a Union is reflected in there being a fishery authority for Zanzibar and one for the rest of the nation. Similarly to Kenya, Tanzania has created local structures (BMUs) to manage local fisheries. Small-scale fisheries are open access, but all landings must be auctioned at official markets at recognised landing sites, thereby centralizing all commerce. This allows local governments to record landings (on paper) and levy taxes. It is estimated that a corps of ~500 national compliance staff and a substantive contingent of BMU monitors inspect ~75% of landings.

DATA COLLECTION

Fishers are not required to complete logbooks. Most primary data are collected on paper before being captured, although BMU monitors and some national officials use simple OKD-based smartphone apps to record data.

CHALLENGES TO USING ELECTRONIC MCS DATA

Recent pilots for improved data collection included collaborations with WWF, and the existence of electronic landing data recording systems will greatly facilitate a potential transition to more sophisticated and well-integrated IT systems. However, a fairly typical list of challenges include constrained human and budgetary resources, low levels of capacity, and substantial distances and challenging accessibility of many landing sites

CRITERIA FOR SELECTING DIGITAL MCS TOOLS

Government procurement procedures are slow, risky, require a lot of upfront effort for tenders with no promise of return on that investment. Government procurement is frequently problematic in many ways. It is also unavoidable, or only avoided at potential future cost. Any government procurement of goods or services must acknowledge that different models or approaches have different impacts on how government interacts. Putting in an entirely new, electronic system for fisheries data requires careful consideration, as all relationships do. Implementing a new system will create a lot of change. One potential area for change is fishers' relationships with government and buyers; these can be enhanced or damaged, depending on what and how.

Systems thinking

All business models and eFIS systems come with costs, the component-specific quant that varies with each model. Some universal costs/consideration for electronic solutions to fisheries data needs:

1. Information Technology is a highly evolving field. Either systems are maintained and evolved to keep up with developments, or they are static and their utility has clear and short decay curves.
2. Fisheries data demands and needs only grow with time. Old systems will encounter bigger and bigger challenges to incorporating new datasets or outputting information that meets current needs.
3. Inter-operability is critical, and should be a mandatory specification for all IT systems procurement. Especially in fisheries since multilateral bodies (e.g. fishery commissions) and other partners (e.g. businesses) generate, require and curate data frequently with bespoke systems.
4. No digital system can be implemented without training administrators (who access, share and use data) and users. Complex systems, especially bespoke, specially created solutions, need field/beta testing.
5. All systems require some customization - there is a trade-off or rule-of-thumb that says the more flexible a system is, the more complex it must be.

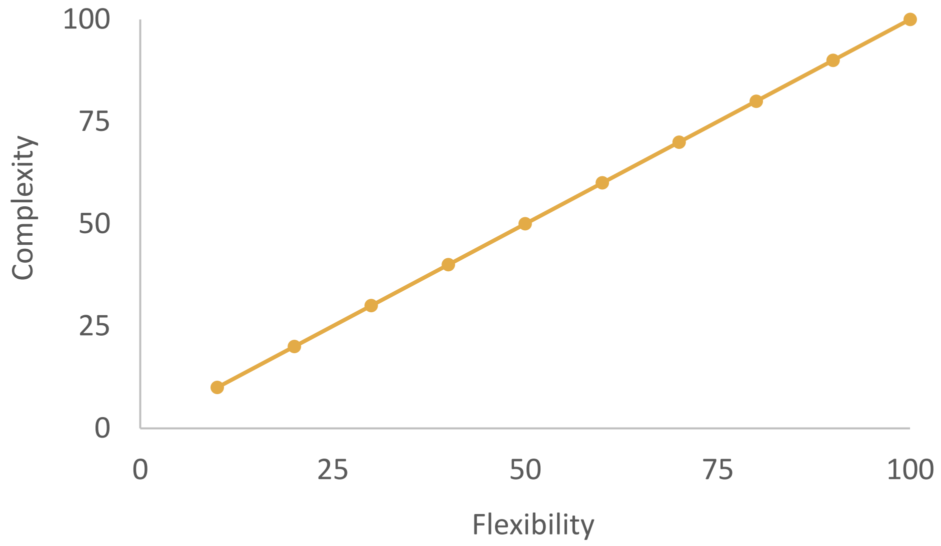


Figure 1. Visual representation of typical relationships between complexity and flexibility in smartphone applications

A decision point must be found along the continuum from simple but inflexible to flexible but complex. Innovations that allow greater flexibility without 1-for-1 increases in complexity represent very good value

1. The real costs of electronic systems lie not in licensing, customization or other fee structures, but in the time that officials need to spend managing the process, interacting with partners and users (ongoing human resource needs – often quite high-level). Often licences explicitly include support, training and maintenance fees, but these need to be interrogated carefully.
2. Unless upgrades happen continuously, with users receiving training on upgrades, a system will become obsolete within 10 years and likely replaced. This is a massive, hidden cost

Government procurement processes for eFIS will follow one of four models:

1. Custom-built: Bespoke system made to departmental specifications (ideally via tenders). Govt 'owns' the system with maintenance done in-house or via a service contract
2. Free ride: Free/Donor/NGO-funded/managed/created solutions
3. Outsourced: Tenders for established businesses/technologies
4. Standards: Taking a standards-based approach for data submission while remaining agnostic about the system used (not possible for all settings)

Custom-built

Technology partners build and/or operate a bespoke IT infrastructure. These are novel 'products' or 'solutions' that are built on existing templates or established principles, but are not systems that have been implemented elsewhere/previously. It is worth noting that the other models can evolve (or devolve) into essentially this model. South Africa's MAST IT infrastructure is an instructive example of a custom-built solution.

Advantages

1. Made to specification under direct supervision of the competent authority – what could possibly go wrong?
2. Competitive tender processes should ensure value-for-money

Disadvantages

1. The real world does not work like it's supposed to. Corruption and incompetence regularly derail well-intentioned initiatives. Reality and expectations can diverge sharply as soon as a contract is signed, including through delays, legal challenges and sub-contractor disputes
2. Custom-built infrastructure has, by definition, not been tested. Teething problems and unexpected challenges must be factored in and will add costs and delays
3. Inter-operability may not be considered or may be disregarded, so a solution becomes 'locked in' and kept in place without improvements while falling further behind.
4. National departments tends to make extremely late and poor decisions w.r.t. investing in keeping IT systems current, potentially rendering systems obsolete the day they first become operational.
5. Once a tender is secured, service providers are strongly incentivised to find ways to ensure that they are locked into a long-term or regularly renewed relationship. Examples abound of how this erodes efficiency, breeds corruption, and departments end up maintaining obsolete and barely-functioning solutions at great cost and without the needed functionality

Free ride

In this model, an agency or civil society recommends to the department a cheap/free/opensource solution. A good example of this is the FAO's Open Artfish and ODK-powered smartphone app. While these systems can certainly fulfil some important needs, they have substantive drawbacks and shortcommings. In the context of MCS data, which requires the stringent security, free systems are inadequate.

Advantages

1. Superficially/initially very light costs to national fiscus, potentially well below market rates for equivalent services
2. Requires inconsequential or no contracting
3. Can be customized quite easily

Disadvantages

1. Perhaps the most problematic issue with free solutions is somewhat intangible, almost impossible to quantify, but has been explicitly recognised in a "problem statement" during the workshop: that things that are given away free tend to have no value, or generate no 'ownership'. Cascading consequences flow from a lack of ownership in any setting, but this is especially problematic when an administration is
    a. under-staffed

   b. under-resourced
   c. subject to continuous subversion of officials and processes by IUU profiteers
2. Data security is a critical aspect of electronic systems, but free products simply cannot deploy good systems, because robust and holistic security is not free. Holistic security for MCS purposes extends to tracking user access and edits made to data. A Best Practice in this regard that is both essential for data integrity and absolutely cannot be provided through free systems includes using a ticket system to track and trace rectifications or other data editing events. Given the large sums of money that IUU activities generate, it would be naieve to think that illegal operators will not invest in ways to circumvent systems, including through hacking into low-security MCS systems.
3. Beta-testing and refining new products can have substantial opportunity costs, including time spent testing instead of implementing and using. This increases concomitantly with the increase in novelty/divergence of needs from original purpose (if system is being adapted) and with increasing complexity
4. Customisations and extent of changes will be limited, possibly severely. “Free” solutions simply cannot provide the flexibility, functionality and customisability that other systems offer, and thus will constrain the scope of what is possible. A good example is the challenges with the free, basic IT system Artfish. The mobile data collection app requires connectivity to work – which is an obvious and fatal drawback in a developing state. The entire architecture of the system would have to be rebuilt to allow off-line collection and post-hoc uploading and synchronising with the database. The costs of that level of customisation (configuring and building aspects in both the database and the smartphone app) would likely exceed the costs of securing a commercially available and tested solution such as ABALOBI or Shellcatch
5. Donor interest in subsidizing costs, let alone reinvesting in keeping solutions up-to-date with the latest technological advancements, is finite, often extremely so. Thus the ‘free solution’ ultimately becomes a paid-for solution, possibly one that cannot be cost-effectively updated (developers may not be from recognized businesses or may not be incentivized to maintain contracts)
6. Solutions may appear to be ‘cheap’ or even ‘free’ but carry substantial hidden costs The main costs for solutions are not the product license, but in training officials and users and workarounds for the inevitable limitations. Free solutions seldom offer the initial training at the requisite scale, let alone rolling training for staff turnover/expansions.

Outsourced

Outsourced service providers must tender to provide tools and systems according to government specifications and (in an ideal world) be evaluated on track record or proven technology. This model is already in use for MCS purposes – e.g. in South Africa, where the national observer program is outsourced. Third parties (i.e. the businesses running observer programs) collect and curate confidential MCS data on behalf of the state, under robust confidentiality agreements.

Advantages

1. Proven technologies require no or limited beta-testing. This creates short lead-in times and generally fewer unexpected obstacles

2. Customisation is usually not substantive because the solution will have been tried and tested
3. Service-providers should ideally be viable businesses, with multiple clients and market forces ensuring that either their offerings stay current or they lose market share. In this type of relationship, good service providers will keep pace with developments in the field and continuously upgrade services.
4. Training needs and offerings are likely already well-characterised and already developed, further reducing inefficiencies and delays in making a solution operational

Disadvantages

1. IF the service provider depends to a large degree on the state contract to remain operational, then what might have started out as outsourcing relationship quickly mutates into one that is closer to the custom-built model.

Standards

In this approach, government adopts a set of minimum standards for data submission, but leaves it to the fishing business or other entity to collect and submit the data. Government remains agnostic about the tools and who does the data collection. However, if there no solutions, or they're insufficient to provide real choices and competition, adopting this approach will come with substantive challenges.

Advantages

1. Costs government nothing, but guarantees good data (or eliminates uncooperative elements from the fishery)
2. Requires minimal preparation before implementing, so projects can be implemented very quickly
3. Training requirements can be monitored and evaluated rather than implemented or managed by the state

Disadvantages

1. Certain things, such as enforcement, are generally not outsourced by states
2. Creating the standards requires substantial effort
3. If standards are not met, it can be very difficult to address since government has no control over what tools users choose to employ to meet the requirements
4. It can become difficult to detect non-submission of data, unless interoperable systems are compared to detect non-compliance. This also raises challenges in defining the nature of the non-compliance and implementing rectifications.
5. Depending on what data is mandated for collection, there may well be a need to create and define criteria for certain tools or accredited provider

Confidentiality and security

Data confidentiality is a substantive matter, and electronic systems for MCS data must be capable of maintaining data integrity and security. Sovereignty, ownership and access must be considered carefully to ensure that the electronic system meets requirements in all these critical aspects.

The ownership or physical location data warehouses is sometimes queried. In addition to unrivalled data security and back-up systems, cloud storage leverages a critical efficiency: cloud computing. Cloud computing allows changes to HOW data are visualised or used, without requiring that the platform housing the data itself be upgraded.

Civil Society Organisations

Civil Society Organisations (CSO) can play important roles in supporting official activities or implementing pilot studies of national importance. However, since MCS processes are firmly sovereign State matters, CSO roles must be carefully considered. Evaluations were undertaken of local CSOs, to provide some guidance on their capacity to support WWF; the two responses received (Madagascar and Mozambique) can be found in the Appendix. Responses were not validated but are assumed to be accurate. Both are small (3-6 staff with annual budgets <$1 million), relatively new entities, with staff that have experience in marine and fisheries-related projects. Both entities appear to be well positioned to provide ground support for eFIS pilots despite neither having direct experience in eFIS-related projects.

ROADMAP

Before a roadmap can be developed, it is important to clarify some aspects of fisheries data, its management and the reasons they are collected. A traceable, IUU-proof fisheries IT system rests on three pillars. The types of data typically collected, the pragmatic purposes to which those data are put, and their inter-relationships are illustrated in Figure 2.

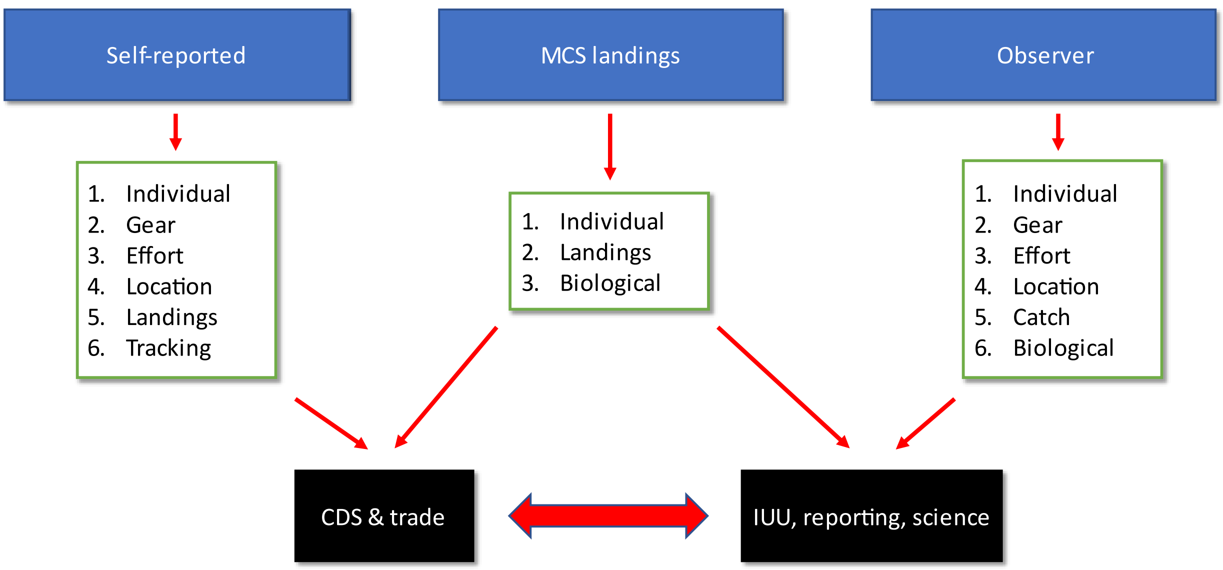


Figure 2. Constituent elements of fisheries information systems showing who (blue boxes) collects what data (white boxes), for what purposes (black boxes).

A well-constructed electronic data ecosystem can produce all the documentation (or flag up discrepancies to prevent the legal sale of IUU catch) instantaneously and painlessly. Crucially, all data must be anchored to the Individual (who, what vessel, permit information, etc). Landings data should be collected both by fishers (self-reported) and MCS officials. Self-reported data should be the basis of trade documents (CDS), but CDS docs must be legitimised by verifying details against MCS data. All landed catch that is intended for sale should be traceable via digital-physical tags (i.e. a physical representation of digital information is required – such as QR codes or RFID tags). Substantial secondary benefit of electronic information include:

1. National revenue services can track, verify and tax transactions
2. Fishers can build up a financial record that can be used to secure loans and other financial services at preferential rates
3. Financial literacy and saving programs can be implemented to help fishers start their journey from subsistence to upward economic mobility

Mapping needs to solutions

Fisheries officials from each country worked with other experts to identify the major problems in their current MCS and data environments for SSFs. Despite very different histories, population metrics, approaches to fisheries, and a huge diversity of small-scale fisheries, the problems can all be reduced to the same four challenges:

1. Reliance on paper
2. Lack of VMS for small craft
3. Limited human resources
4. Limited human capacity

All five SSF administrations currently rely on paper for most or all interactions with fishers (including data recording and permitting), and none has anywhere close to the cadre of MCS monitors/inspectors needed. The cascade of challenges that flow from paper being the basis of fisheries management are neither surprising nor unique to this region. There was universal agreement amongst workshop participants that MCS processes (and therefore the scale of IUU catches and related transactions) cannot be meaningfully improved while paper-based. Linked to this is another uncontroversial but important point: partial (i.e. uneven spatial, temporal or proportional) coverage with electronic MCS tools will simply move IUU to the areas with least attention. Therefore any roadmap towards improving MCS for SSFs should include piloting a holistic eFIS solution encompassing data warehousing, cloud computing, and dashboard interfaces, to bring clarity on potential impacts and viability.

Vessel tracking is absent from the overwhelming majority of fishing vessels (VMS or VMS-type tracking is done on some semi-industrial fleets). This represents an easy opportunity to pilot VMS-type solutions that rely on ship-to-shore (AIS-type) radio communications; the communication costs are a small fraction of the satellite-based traditional VMS systems for industrial vessels.

Table 1. Self-identified issues contributing to challenges in small-scale fisheries

	Kenya	Madagascar	Mozambique	South Africa	Tanzania

Reliance on paper	✓	✓	✓	✓	✓
Lack of VMS for small craft	✓	✓	✓	✓	✓
Limited MCS personnel	✓	✓	✓	✓	✓
Limited human capacity	✓	✓	✓	✓	✓
Existing tech (Artfish) cannot work offline	N/A	✓	✓	N/A	N/A

Workshop participants were introduced to two entities (ABALOBI and Shellcatch) that offer holistic, fully integrated and fully tested, turnkey eFIS solutions that have components **explicitly designed for data collection and MCS purposes in SSFs**. Both have proven tech (i.e. they are currently operational in multiple fisheries and jurisdictions), and besides meeting classic MCS needs, both offer vessel tracking, e-reporting and market-oriented technologies. They are primed to leverage the power of comprehensive CFIPs to bring value to small-scale fishers operating within legal frameworks.

There is a strong case for additional pilots: low-cost tracking vessels. VMS-compliant tech from S3C's "Angelfish" and Satlink's "VMS Nano" can transmit data (when within range of shore receivers) at trivial cost, or with some start-up infrastructure investment (land-based transmission stations). Additionally, Angelfish has inbuilt fisher safety features that receive alerts or send an SOS. Pilot projects will need to take the following steps:

1. Identify the budget available to support pilot(s) in each country
2. WWF or a national CSO and one or two tech company representatives/experts should engage select representatives (Senior MCS, IT and SSF sector officials) from each target country's fisheries department in a confidential 'Project planning workshop'. The objective is to understand and codify specifics of needs, challenges, institutional arrangements and no-go issues and match needs to tech solutions.
3. Ground-truth aspects of the proposed region/fishery identified in the project planning workshop, including confirming what fishers' needs the project can meet
4. Prepare communications and training materials and implement sensitization, onboarding and training amongst all fishers and officials to be involved in the pilot

COST-BENEFITS

All representatives of national administrations that participated in the workshop agreed that tech for MCS is highly desirable. While many internal challenges to implementing a new approach to MCS can be expected in any Fishery Department, as long as there is a champion with decision-making power and a team of committed officials, those challenges should not be insurmountable. The State is, at the end of the day, the final arbiter of national policies and approaches in these matters. But amongst the many barriers to the uptake of tech solutions, particularly for SSFs, are the estimates or metrics of cost:benefit analyses, especially as they relate to fishers. Only low-cost eFIS solutions have been considered here. Many of the most substantial costs for EM are for capturing data from video footage, which may not be required or which can be scaled in various ways (e.g. subsampling videos, or only capturing certain easy (cheap) elements from the panoply of possible data fields, etc.)

Co-management and similar governance models are official policy and variably implemented by all target States. But participation by fishers in pilot cannot be presumed. If short- to medium-term increases in costs *to fishers* are expected, those must be offset. Even if the tech is free to fishers (it should be), switching to fully traceable catches is only viable if there is no net loss of income to fishers. Like the revolutions from internet, smartphones, and electronic banking, tech adoption is a one-way street. This contention is reinforced with the paucity of evidence of fisheries reverting to paper (VMS, CDS, e-reporting, etc); sensible fishers will be appropriately wary of what lies down the road *for them*. If a system is imposed upon fishers, or fails to deliver benefits, a pilot project will likely fail. Attaining the requisite levels of buy-in will be contingent on both creating a conducive narrative around the projects from the start, as well as convincingly demonstrating likely or actual benefits.

The Windex effect

When the first pilots deploying on-deck EM cameras were started, fishers found ways to interfere with cameras – standing in the line of sight, hanging clothing over the cameras, or spraying salt water over the camera housing to completely blur the resulting images. Until fishers experienced benefits, at which point they began to actively curate the cameras, cleaning them daily with Windex, a brand of glass-cleaning spray. The Windex Effect is the objective for any tech deployment. In fisheries, the clearest mechanism to unlock value is the Community-supported Fisheries Improvement Project (CFIP). The FIP model is certainly no silver bullet for financial freedom and environmental sustainability. FIPs are replete with challenges (including evidence-based accusations of ‘greenwashing’ against some FIPs), and will require non-trivial effort, commitment and resources to achieive good implementation. FIPs are a recognised and fundable process for supporting transitions to sustainable practices. Appropriately structured FIPs avoid placing substantive risks and costs on fishers. Decisions on whether or not formal FIPs registered with Fishery Progress or informal projects that simply follow the FIP model without formal commitments, auditing and backing from the wider community, cannot be made or even recommended here; they must be taken with potential FIP participants.

CFIP

First, a caveat to recommending CFIPs: how it is implemented is vitally important . Not all FIPs are equal, and an objective (e.g. net financial benefits to fishers from using traceability tools) will only be met if there are strong implementation teams from all sides: tech providers, FIP managers, fishers, government structures and officials, and others. FIPs benefit from clear-eyed, realistic and well-communicated value-propositions. WWF should leverage its market transformation experience to secure market access. Initiating an MCS-directed pilot will immediately overcome one of the most challenging hurdles facing FIPs – verification, . Synergies can be greatly enhanced if participating fishers adopt market-oriented electronic traceability tools to complement the use if MCS tech. Two immediate outcomes flow from a step:

1. the FIP stands to bring fully traceable products to market and is on a highway towards sustainability certification
2. there is strong alignment of interests for a successful FIP amongst fishers and officials.

A national CFIP pilot with export-oriented components can leverage a second-order benefit: promote the national 'Made in XXX' Brand, and polish national reputations for good fisheries governance, meeting Sustainable Development Goals, etc. through branding CFIP products as 'Sustainably Caught in XXX'. South Korea has already recognised the value of this marketing approach through development and active promotion of the national K-FISH brand. Market-oriented traceability solutions allow consumers to retrieve carefully presented traceability data and information on whom, where and how the fish they are buying was caught. Most use non-fungible QR codes or implanted RFID devices that move with each (batch of) fish. Opening up national budgets for national branding interventions that simultaneously support the FIP could further mainstream sustainability into government and the national economy. Easy targets for premium, FIP-caught fish from SSFs are high-end and tourist-oriented national restaurants, and discerning markets in Europe and Asia.

Costs for setting up and running a CFIP cannot be predicted in advance – these are entirely contingent on the scale of the pilot, the types of technologies to be piloted, the timeframes involved, etc., but will include the following line items:

1. Onboarding and training fishers to use new technology
2. Technology services fees
3. Recruiting, training and deploying fisheries monitors/inspectors (noting that all target countries have identified current personnel levels to be somewhat or highly inadequate)
4. FIP oversight and management
5. Community outreach and engagement
6. Market outreach and engagement
7. Monitoring and evaluation

FIP benefits may be partially or not at all realised, depending on the objectives and quality of implementation, categorised into short (S), medium (M) and long (L) term outcomes:

1. More and better quality fisheries data (S)
2. Strengthened compliance and reduced IUU catches (M)
3. Improved human capacities and effectiveness (M)
4. Improved prices for fishers (S)
5. Improved balance of trade figures through increased export revenues (L)
6. Improved tax collection revenues (L)
7. Economic stimulation to coastal communities (L)
8. Data-driven fisheries management (L)

Another powerful benefit for fisheries departments for using comprehensive electronic tools is best illustrated with an allegory. From today's perspective it's difficult to remember the limitations and costs of messaging via SMS – each SMS had a cost, one couldn't confirm delivery or get read-receipt notifications, create groups or easily share media files. The impact of smartphone Instant Messaging apps was so transformative and disruptive that SMSs are all-but-extinct. eFIS will have directly comparable impacts: doing away with lists of emails or phone numbers. They can push notifications and deliver permits at the push of a button, and allow any authorised user to confirm what has been communicated, to whom, when.

In conclusion, the myriad benefits of eFIS have not been covered here exhaustively, not least because there's not much controversy regarding core efficiencies and benefits in the expected audiences. The gathering speed and scale of uptake of eFIS tools around the world as well as the lack of regression once adopted, lend credence to claimed benefits. However, the reasons why fisheries lag so far behind other sectors in the ongoing, digital fourth industrial revolution, are many. Proponents of technology solutions will have to grapple with the two biggest challenges – inertia and the counteractions of entities with a vested interest in the status quo (i.e. high levels of IUU fishing and paper-based systems). The challenge to achieve successful pilots is existential. All available tools and opportunities that can increase the likelihood of a positive outcome should be brought to bear on this.

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CSO Evaluations

Coalition Nationale de Plaidoyer Environnemental (CNPE)

Country and numbers of full-time staff: Madagascar, 6 staff
Number of years (and staffing levels) of

1. Legal existence/ current official registration: 2016
2. Running 1 or more marine projects: 3 currently, since 2019
3. Direct involvement in fisheries: N/A

Total annual project budgets: <$1 million
Experience (years per current personnel) in:

1. SSF management/improvement/support: >10 cumulatively
2. Direct engagement in addressing IUU issues: >10 cumulatively
3. Fisheries data collection and observer programs: Some
4. eFIS: None

FOSCANC

Country and numbers of full-time staff: Mozambique, 3 permanent staff
Number of years (and staffing levels) of

4. Legal existence/ current official registration: Not registered, operational since 2014
5. Running 1 or more marine projects: 2 currently, 6 additional completed
6. Direct involvement in fisheries: none

Total annual project budgets: <$1 million
Experience (years per current personnel) in:

5. SSF management/improvement/support: >10 cumulatively
6. Direct engagement in addressing IUU issues: Yes
7. Fisheries data collection and observer programs: Observers only
8. eFIS: Some