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Emerging Information and Communication Technologies for Monitoring India's Marine Small-Scale Fisheries, Opportunities for Inclusion, Risks of Exclusion

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Adaptive, inclusive and effective management of fisheries resources is dependent on knowledge from multiple quantitative and qualitative sources. As technology advances, there is an increasing interest in digital and automated solutions for gathering fisheries data. Small-scale fisheries (SSF) have presented a persistent challenge to many centralized quantitative data collection systems, and frequently maintain the status of 'unreported'. This unreported nature often implicates SSF in the definition and discussions of illegal, unreported and unregulated (IUU) fishing. Monitoring, control and surveillance are seen as a vital part of the solution to IUU fishing, with substantial investment being put into increasingly sophisticated technology for tracking fishing vessels. For the past few years, India has been attempting to pass legislation to require all vessels, from small-scale to industrial, to install vessel monitoring systems on the grounds of national security and combating IUU fishing. However, there are concerns that a securitized and top-down approach to implement vessel tracking is not only wasteful but risks further marginalization of small-scale fishers from the resource, and fisheries groups from governance processes. India should seek to solve the underlying causes of IUU fishing while also developing collaborative monitoring and community-based management models. In this paper, we review evidence of emerging information and communication technologies and approaches in SSF and discuss how, if introduced and managed through collaborative processes, they could be used as a platform to strengthen inclusive governance, increase sustainability and improve wellbeing in coastal fisheries in India.

(***Key words:*** *Apps, Digital, Exclusive economic zone, ICTs, ICT4SSF, Illegal fishing, IUU fishing, MCS, National security, Tracking, VMS*)

Globally, there is concern that fish stocks are overexploited, and that the benefits that fisheries provide are at risk due to climate change, habitat degradation and pollution (Sumaila *et al*., 2011). The adaptive aspect of management is now recognised as being critically important to allow adjustments in response to changing circumstances, including how these external drivers play out on the resource. Multiple sources of knowledge and learning are critical to guide effective adaptation (Nakashima *et al*., 2012; Iwama *et al*., 2021). Fisheries-dependent data, fisheries-independent data and local expert knowledge all contribute to adjusting and improving management, to different degrees in different contexts. In many contexts, fisheries present a substantial challenge for quantitative data systems because the fish stocks are mobile and, obviously, underwater, hence management relies principally on fisheries-dependent data (*i.e*., data collected from logbooks of fishing activities and landings etc.). Fisher knowledge is critical in framing and evaluating fisheries-dependent data in a social-ecological context but is still too rarely incorporated effectively into governance (Hind, 2014). Adaptive co-management of fisheries arguably relies much on local and expert knowledge sources, relative to quantitative and systematised data systems (Olsson *et al*., 2004). In the global north (predominantly), where fisheries have been intensively monitored with quantitative data systems and governed by the state, monitoring has in some cases led to effective adjustments to management and fishing capacity so that fish stocks are recovering and/or fished at sustainable levels (Hilborn *et al*., 2020). Nevertheless, the dispersed

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and diverse operations of fishing activities and the challenges inherent in measuring and understanding trends in a moving and underwater resource, place demands and limitations on both fisheries dependent and fisheries independent monitoring and assessment methods. This is especially true for small-scale fisheries (SSF), which are often informal, dynamic and even more widely dispersed.

Small-scale fisheries are broadly defined as non-mechanised, non-industrial fisheries but precise definitions are context dependent and constructed from socioeconomic and cultural conditions. SSF supplies two-thirds of global fish catch for human consumption, but the unreported nature of many SSF, often inadvertently implicates them in the definition and discussions of illegal, unreported and unregulated (IUU) fishing. The concern is that being unreported in formal accounts (*i.e*., national data on landings, fishing effort and economic values) further marginalises women and men fishers and fish workers from governance (Kelleher *et al*., 2012), and more broadly that this invisibility might, ultimately, exclude them from the ocean and coastal spaces (Cohen *et al*., 2019).

Fishing activities can hold one or all three of these IUU characteristics. IUU fishing is considered by some to be amongst the most urgent threats to marine ecosystems and fisheries sustainability (FAO, 2019) and maritime security (Song *et al*., 2019). Ending IUU fishing is prioritised by the Sustainable Development Goal 14 on 'life below water', where target 14.4 seeks to "*effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics*".

By extension, SSF are often inaccurately considered as being environmentally exploitative and destructive, and by extension criminal, simply because there is no system in place to report catches or when government knowingly leaves the fisheries unregulated (*e.g*. due to resource and capacity limitations relative to the scope and scale of the fisheries). This outcome of marginalisation from governance, and potentially resources, is not the fault of the fishers themselves but reflects a failure of centralised monitoring and governance efforts to account for informal sectors, and even overlook the existence of alternative, non-hierarchical governance mechanisms such as community-based management (Song *et al*., 2020). The impacts of a securitized[1] response to combating IUU fishing, based on physical deterrence and sanctions, have shown to be punitive and demoralizing to fishers in many cases (Balint, 1999; Song *et al*., 2020). The negative 'fish wars' rhetoric is also likely to obstruct collaborative management approaches that require resource users and governments to work together (see Pomeroy *et al*., 2016). There is an urgent need to understand and address the root causes (and concepts) of IUU fishing that leads to overexploitation and develop greater clarity around the disaggregation of SSF with regards to IUU fishing.

One of the options to disentangle SSF from IUU fishing, and those efforts to "eradicate IUU", is to improve reporting and the flow of quantitative data and local social-ecological knowledge of fishing activities to national accounts. The need for specific data measures for SSF in terms of IUU has been stated for more than a decade (FAO, 2009, chap. 15) and more recently formally acknowledged through the establishment of the FAO's Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication: "*States should establish systems of collecting fisheries data, including bioecological, social, cultural and economic data relevant for decision-making on sustainable management of SSF with a view to ensuring sustainability of ecosystems, including fish stocks, in a transparent manner*." (FAO, 2015). However, the rhetoric surrounding IUU fishing has created an environment in which SSF has become collateral damage in the global fight against more organized and industrial forms of IUU fishing (Song *et al*., 2020), with SSF being unduly incriminated due to its unique data characteristics. Drawing on the case of Indian fisheries, this paper explores ways in which data and ICTs can be used as part of multiple knowledge systems, in ways that avoid securitization of fisheries management and strengthen SSF voices, visibility and agency in governance.

[1]Securitization is the transformation of political issues into matters of "security" to increase the attention, means and resources to be used in the name of security or existence.

Small-scale fisheries in India

India is one of the largest fishing nations of the world by catch volume, with ~3.5 million MT landed per year (CMFRI, 2019) and approximately 14.5 million people employed by fishing and fisheries value chains (FAO, 2021). Fisheries represent nearly one per cent of the country's gross domestic product (approximately USD 30 billion). The ways of harvesting, the fisheries habitats and the species caught are all relatively diverse. As with many diverse fisheries, effective management of stocks is challenged by difficulties in understanding the status of "stocks" and in the capacity of management structures to effectively govern the full scope of fishing operations, particularly when they are informal and dynamic (Ghosh *et al*., 2015). India does not have a de jure definition of SSF, and numerous descriptors such as artisanal, traditional, indigenous, subsistence or community-based can imply SSF.

The government classifies fishing vessels into mechanised, motorised and non-motorised craft (Jadhav 2018). Almost all vessels (fishing or non) are built under 20m long to avoid coming under central government rules and remain subject only to state regulations on boats and licensing. For the purpose of this paper, SSF is considered to include all fishing (harvesting activities, as well as pre and post-harvest labour and activities) using non-motorised and motorised craft (excluding the larger sized fishing vessels with inboard engines) (Jena and Grinson, 2018). Indian fisheries policy to date has focused on enhancing production through fuel subsidies, loan discounts or incentives for deep sea fishing which has benefited large capital owners (Gunakar *et al*., 2017) and exacerbated the vulnerability of small-scale fishers (Cisneros-Montemayor and Sumaila, 2019) by overfishing stocks and driving coastal fishing communities into a poorer status (*i.e*. 'social-ecological traps') (Heymans *et al*., 2011).

Traditional fisheries governance at the level of fishing communities has declined since the 1950s due to intensification and commercialisation of fisheries fuelling increased state control, and India has been considered complacent in meeting their commitments under the SSF Guidelines (Gunakar *et al*., 2017). The Government of India's recent draft National Fisheries Policy (NFP) 2020 makes it clear that the reduction of IUU fishing is an important target, not only to protect national food supplies but also for national security (Bhatt, 2020). It states that the national and state governments "will establish a sound and effective monitoring, control and surveillance (MCS) system". Additionally the draft Indian Marine Fisheries Bill 2021 (GOI 2021) states that all fishing vessels must be equipped with "suitable transponders/communication systems when out at sea which reveals the latitude-longitude of vessel adequately". Making satellite-based vessel monitoring systems (VMS) compulsory on vessels less than 20 metres in length has been advocated in the past decade following the terrorist attacks in Mumbai, in November 2008, as the terrorists utilized small fishing vessels to approach and alight undetected at the Gateway of India (Bhalla, 2020).

The type of illegal fishing that is arguably of main concern to countries, including India, is from foreign vessels entering their exclusive economic zone (EEZ)[2] and exploiting marine resources without permission or license. Illegal fishing can also be the use of a gear for which the vessel is not licensed. If VMS were to be installed on all Indian fishing vessels, it would still not be possible to see foreign vessels entering the EEZ, or detect gear violations. To detect foreign vessels, an aircraft or satellite-based surveillance would be required, though their identity or origin would still be unknown. For the Indian national fleet, there is little advantage in real-time monitoring for enforcement purposes. It is much simpler and cost-effective to impose fines and license revocation based upon a body of evidence of fishing activities compiled over time, with the greater location precision that comes from archival tracking (see section 4). Furthermore, the big data from high resolution tracking allows for faster development of machine learning algorithms to detect abnormal fishing activities with respect to the licensed fishing gear (Marzuki *et al*., 2018). Any benefits of real-time tracking in terms of safety-at-sea from VMS are also negated by much cheaper and more effective EPIRB (Emergency Position Indicating Radio Beacon) technologies as part of an effective maritime safety policy (Maritime New Zealand, 2018).

There is concern by fisher leaders and allied agencies (*e.g*., National Platform for small-scale fish

[2]The exclusive economic zone is the marine area extending 200 nautical miles from the nation's coasts, in which it has special rights to resources.

workers - NPSSFW, 2021; Dakshinbanga Matsyajibi Forum, 2021) who propose that MCS regulations in the draft NFP (2020) are not principally motivated by concerns for safety at sea and sustainability of fishery resources. Rather, they see it as a move towards securitisation, focused on protecting and securing the interests of private players investing in mariculture and other blue economy projects. Furthermore, concerns of over dilution of environmental laws in conjunction with the Sagarmala project and other blue economy based plans have created an atmosphere of distrust amongst small-scale fishers (Counterview.org, 2016).

Reporting infrastructures and data flows that reach national and state accounts are often not in place for catch and effort data from SSF in India. Without broader knowledge of fisheries, the absence of disaggregated SSF data within state and national databases can exacerbate experiences of exclusion from decision-making processes about how resources are used and managed, and how the rights and uses of coastal and marine spaces are recognised or divided. In addition to thinking about the management of the EEZ at large, there is a need for coherence of Indian fisheries policies with international and regional legislation, to allow for tenure reform, improved rights and responsibilities in international fishing agreements, and strengthened community-based management of coastal and small-scale fisheries (Kurien, 2017).

In building a body or authority specifically for SSF, India's government and SSF actors would have the opportunity to leverage their world-leading technology sector and establish a platform that makes fishers the owners and co-generators of the data upon which decisions are based. This transparency and accountability builds trust and can initiate the two-way flow of information. This is crucial in developing a knowledge system that incorporates social and customary dimensions and can bring about improved gender equality, well-being and empowerment. Furthermore, such a platform would represent a gateway to connect fisheries actors to new financial and information services, such as digital marketplaces, e-wallets, microcredit, and training opportunities or advisory services.

Data from multiple knowledge systems

Sustainable fisheries management is possible given sufficient catch and effort data on which to base decisions (Hilborn *et al*., 2020), but SSF have long been considered data-poor due to their number, diversity and geographic and economic isolation from formal markets (Smith and Basurto 2019). The decreasing size and cost of ICTs means they are increasingly applicable and accessible to small businesses and operations, such as SSF. In India, the competition between small-scale fishers' and mechanized boats for near-shore resources is ongoing and widespread, despite state-level regulations in India that restrict mechanised vessels from fishing inside the coastal zone set aside for small-scale fishers (the zone extent varies by state). These competitions with illegal mechanised vessels impact the livelihoods of small-scale fishers (Bavinck 2005). By not distinguishing sufficiently between small-scale and mechanised fisheries and the different values, challenges, limitations and opportunities from their experience in Indian waters, the draft National Fisheries policy and the draft Indian Marine Fisheries Bill 2021 (GOI 2021) risk further marginalising SSF, pushing them deeper into a social-ecological trap.

Quantitative data can play a role in supporting certain fisheries management decisions (Hilborn *et al*., 2020), and in the SSF context, particularly where those data are considered alongside the knowledge and observations of women and men working in the sector daily. Multiple knowledge systems that consider fishers' observations and knowledge of equal validity, accuracy and value as quantitative data, are legitimate and effective in monitoring and governing SSF in the face of climate change (Gianelli *et al*., 2021). Building capacity and infrastructure for (primarily western notions of) good data, monitoring, management and governance should be balanced with less patriarchal, top-down but equally legitimate governance pathways.

High resolution, co-generated catch and effort data at the level of individual fisher can and should be the foundation for inclusive governance, as has shown potential in other comparable country settings, where information flows from and to the resource users, who are considered resource stewards, are supported by hierarchical government and/or other agencies (Tilley *et al*., 2019, Nthane *et al*., 2020). In South Africa, the submission of catch data (species, size and number of individuals etc.) by individual fishers into the Abalobi app suite was originally incentivized through marketplace and transactional elements, where fishers

obtained much higher prices for their catch by accessing end-consumers directly (FAO and World Fish, 2020, Box 9). Yet, their active engagement in data collection has further led to collective action and greater institutional sustainability of SSF (Nthane *et al*., 2020). In Taiwan, when a container ship ran aground in 2016, destroying an important local fishing ground, landings and tracking data were the evidence that local fisher organisations used to estimate their loss of revenue and to leverage reparations from the shipping company (FAO and WorldFish, 2020, Box 13).

By enabling more democratised access to information on SSF activities, governments can simultaneously invigorate the sector through improved revenue and market opportunities, while facilitating data-driven fisheries management. The following sections present and unpack some local and international examples of opportunities presented by emerging ICTs.

Low cost, non-satellite vessel monitoring systems

The ability to track the global position of vessels by satellite has existed for decades in the fisheries sector, but the costs of satellite communication are still prohibitive - especially when these costs filter down to individual fishers and boat owners over time. In Asia, VMS has been criticised as inefficient due to the lack of suitable software elements causing delays and functionality issues with dashboards and analytics (Suhendar, 2013). However, new tracking technologies can store the data offline then use cellular networks to communicate archival positional data from vessels in real-time when connected. Figure 1 shows the tracks, fishing activity and effort heat map of a single vessel off the coast of Odisha State in India in 2020, using one archival vessel tracking system from Pelagic Data Systems Inc. (USA). This system is fully automated, charging and running continually by solar power, it cannot be turned off. If the solar panel is completely covered, the device battery sustains positioning for approximately one month.

Due to the lower cost of transmitting data over cellular networks compared to satellite data, these technologies can provide much higher data resolution, with vessel positions as frequent as 600 records per hour, compared to VMS which is generally one position per hour. These advances in vessel tracking enable analyses of spatially explicit behaviours in SSF and the design of robust and equitable management strategies (Tilley *et al*., 2019; Behivoke *et al*., 2021; Frawley *et al*., 2021) as well as the development of big data approaches such as machine learning algorithms and predictive analytics of fishing patterns and catch rates, according to gear types or activity when combined with catch data. Tilley *et al*. (2019) illustrated this utility of high-resolution vessel tracking in measuring the return (increased catches) on investment (materials and deployment costs) from the use of nearshore fish aggregating devices in Timor-Leste.

Vessel tracking could present a value proposition for fisheries management stakeholders that is greater than merely identifying where fishing is taking place and how intensively. If fishers can generate, contribute and hold their catch data, along with visualising the 'effort' they are putting in to catch it, they have a wealth of information on which to base sound business decisions or access new markets from a better insight into their supply patterns (FAO and WorldFish, 2020, p. 70). Furthermore, small-scale fishers are largely excluded from visions and negotiations of the blue economy (Cohen *et al*., 2019). Quantitative evidence of activities and the food production, income generation and environmental stewardship values they generate from particular marine spaces, will help valorise SSF in the blue economy. These very same data may be used in the Blue Economy's preferred tool, marine spatial planning, to allocate, constrain or buy-out marine spaces. Maintaining genuine commitment and accountability to SDG14b[3], the SSF guidelines, and the FAO guidelines on tenure[4] (FAO 2014), will be critical to ensure that the India blue economy model is inclusive and does not undermine the foundations that SSF provide to livelihoods, food and nutrition, and ways of life. These risks are apparent in the Sagarmala port-based development (Ministry of Shipping, GOI, 2019) and the heavily subsidized deep-sea fishing models (that also require coastal spaces for their operations) that are key components in the draft policy framework for India's Blue Economy (Economic Advisory Council to the Prime Minister, 2020).

If women and men that fish and work along fisheries value chains are involved in decisions about

[3]The application of a legal / regulatory / policy /institutional framework which recognizes and protects access rights for small-scale fisheries.
[4]Voluntary guidelines on the responsible governance of tenure of land fisheries and forests in the context of national food security.

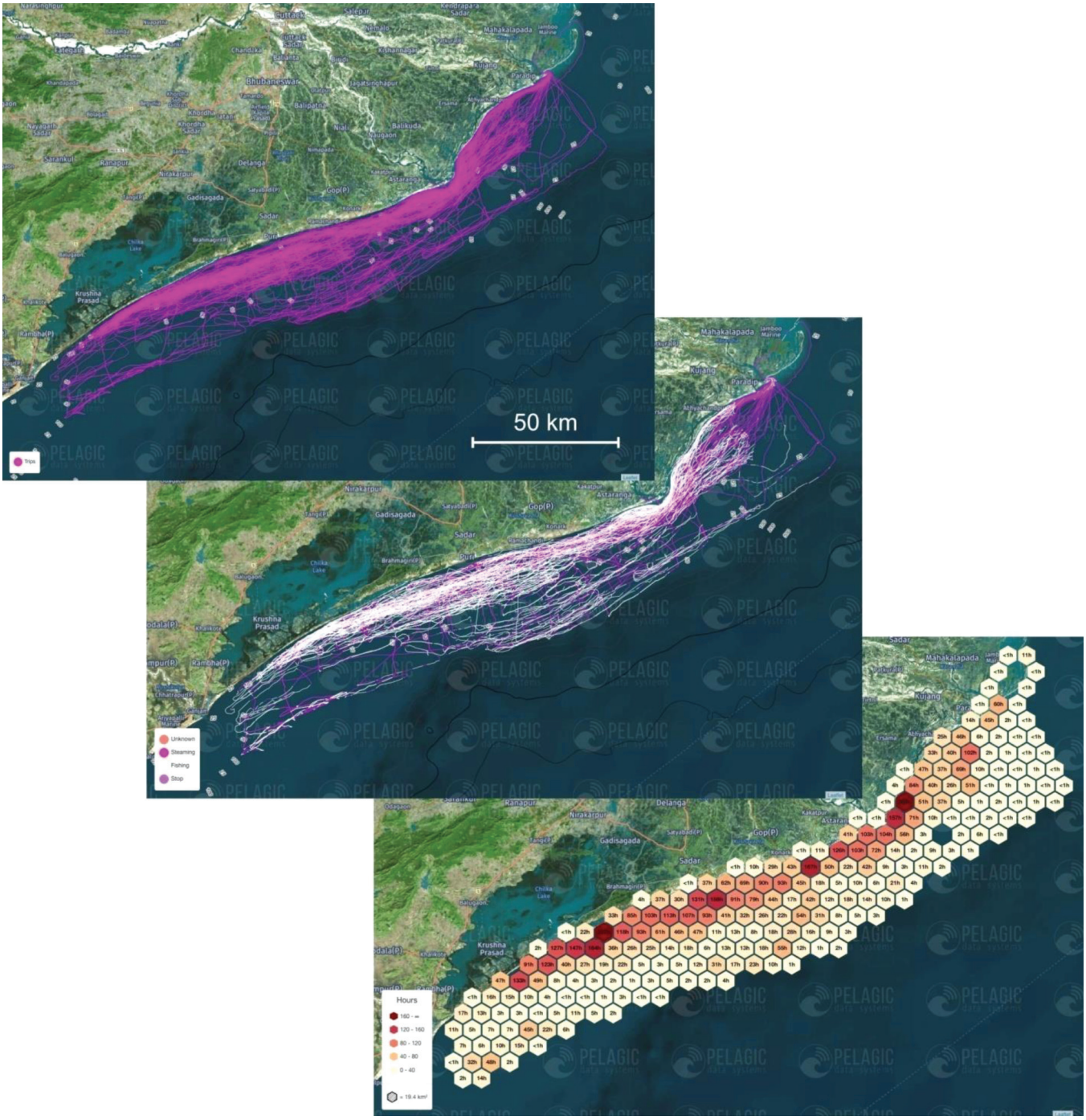

Fig. 1. *An example of one year of vessel tracking data from a coastal fishing vessel in Odisha State in 2020 using a solar-powered archival GPS tracking system. Data are sent via cellular networks. A machine-learning algorithm is used to detect fishing activity (white lines) from steaming (purple lines) using track characteristics such as the speed of movement, turning frequency and tortuosity (middle image). These data can then be used to create heat maps of effort or catch per unit effort for particular vessels, fisheries, species or gears (bottom image). © Pelagic Data Systems. Satellite Imagery ESRI-Leaflet 2021*

vessel tracking or the design of ICTs, and this design incorporates their unique knowledge of the system, its local legitimacy will lead to better uptake and sustainability. There is even the potential for fishers to serve as civilian partners of the state to reinforce shared security objectives in Indian territorial waters, a scenario being played out elsewhere such as in Korean border disputes (Song, 2015). However, the current relationship between SSF actors and their associated social movements and civil society groups, with the national and state governments is tainted by distrust. To overcome current suspicions and pave the way for equal power relations and more inclusive governance in achieving international commitments (*e.g.* SSF Guidelines), state governments will need to invest substantially in hearing from, and consulting with, fishers and fish workers (NPSSFW, 2021).

Towards beneficial fisheries information systems

The digital revolution of mobile technology, sensors and machine learning enables the generation of data required for the predictive and optimised management of aquatic food systems, but SSF are traditionally data-poor, and better data will not translate directly into better management without significant investment into awareness raising and digital literacy. The fisheries sector contains formidable barriers to the use of technology, including the lack of power or connectivity at sea, the harsh operating environment, the corrosive nature of seawater on electronics, the low incomes of most fish workers, and in some cases the relatively low literacy of users (FAO and World Fish, 2020). Despite this, there has been a dramatic expansion of the development and testing of ICTs for fisheries monitoring, management and traceability (Fujita *et al*., 2018; Bradley *et al*., 2019; FAO and WorldFish, 2020). Recent digital interventions have: enabled new income streams for women in SSF communities in Bangladesh through digital financial inclusion (FAO and WorldFish, 2020, chap. 7); brought about improved social cohesion through community-supported fisheries in South Africa (Nthane *et al*., 2020; Stone, 2020); have automated faster, cheaper and more accurate scientific guidance for fisheries management (Tilley *et al*., 2020); and provided high-resolution coastal zoning for co-management (Tilley *et al*., 2019). However, these systems and interventions need not cost the earth. Tilley *et al*. (2020) describe PeskAAS, a decision support tool built in the open-source R coding environment that provides near-real-time, automated catch analytics, and that has been adopted as the national fisheries monitoring system of Timor-Leste. The PeskAAS system makes use of a free platform to collect data through webforms[5] called Kobo Toolbox built on the Open Data Kit (ODK) framework. This is widely used to collect data, and has been trialled for community fisheries monitoring in the Lakshadweep Islands in India (FAO and WorldFish, 2020, Box 5).

There are several interesting uses of ICT by small-scale fishers in the case of South India. Some fisher apps have been developed by external agencies namely fisher friend (M.S. Swaminathan Research Foundation) and mKrishi (Tata Consulting Services) (Fig. 2). Both these apps provide an early warning system for severe weather and potential fishing zones for fishers based on wind, weather and other environmental parameters provided by the Indian National Centre for Ocean Information Services (INCOIS) (Singh *et al*., 2016; FAO and WorldFish, 2020, chap. 3). Instant messaging apps like WhatsApp and Telegram are popular among fishing communities and have even been utilised by the Fisheries Department of Tamil Nadu to create fishers groups for distress calls, being used to some success during Cyclone Ockhi in 2017 (Lakshmi, 2018). There are also various reports of WhatsApp groups used to share fishing and market information with friends and family, without revealing the information publicly (FAO and WorldFish, 2020, chap. 3.).

As early as 2011, mobile phones were already enabling new modes of cooperation amongst SSF in Kerala, particularly in the exchange of information on the location of fishing grounds, real-time uptakes on the movement of fish stocks and concerns or responses related to safety at sea (Sreekumar, 2011). Climate change impacts the movement and productivity of fish stocks (Sumaila *et al*., 2011), but also makes predicting sea conditions and extreme weather events much harder, which has implications for fisher safety at sea (Sainsbury *et al*., 2018). The ability of fishers and managers to understand and respond to social and

[5]Open-source software that allows for custom survey form creation, offline data collection in remote areas on mobile devices, and submission of the data when connected to the internet.

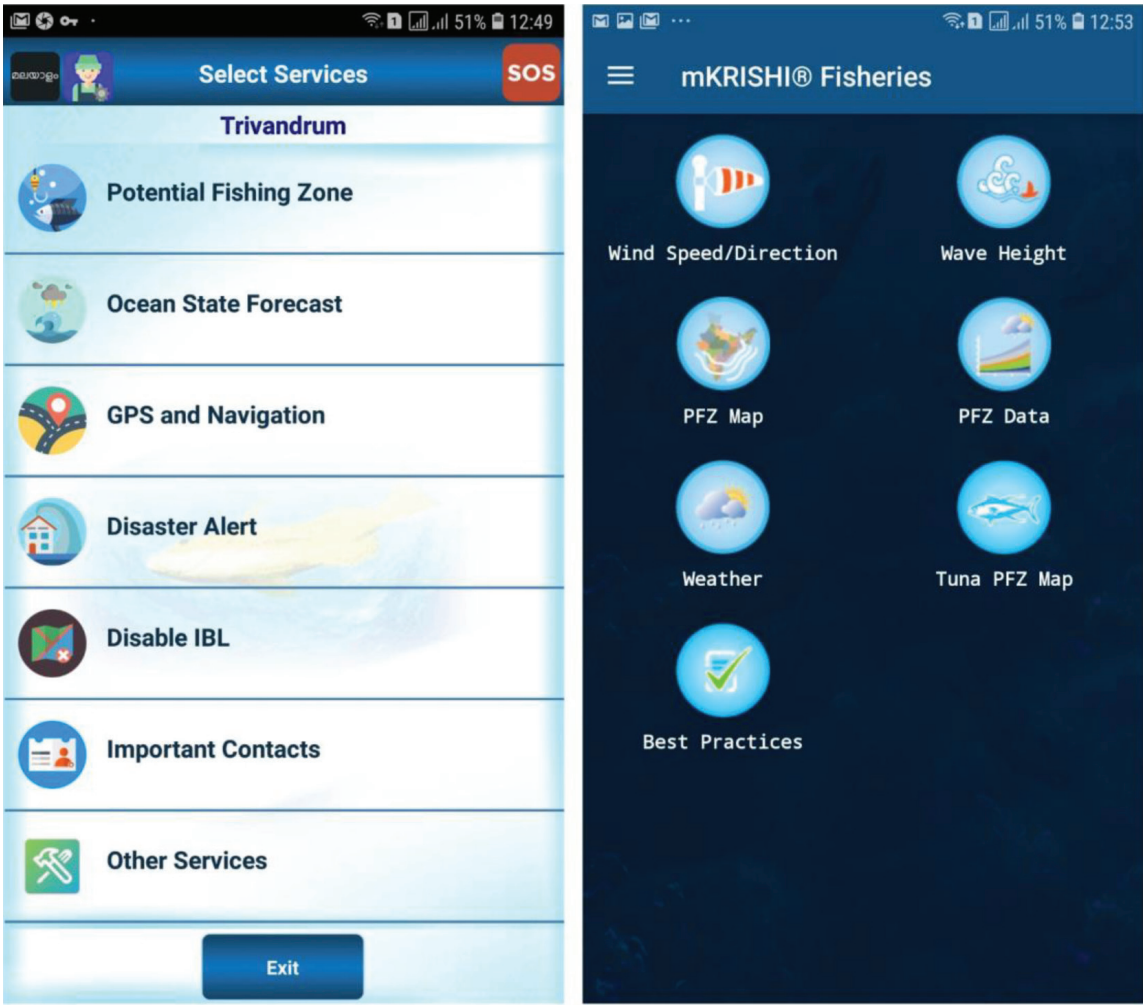

Fig. 2. *Screenshots from Fisherfriend and mKRISHI apps developed for Indian fisheries to provide information on weather and potential fishing zones (reproduced with permission from FAO & WorldFish 2020)*

ecological changes driven by climate change will be influenced by the incorporation of weather data into fisheries monitoring systems (Pinsky and Mantua, 2014), which allow for adaptive management according to non-stationary population processes (Szuwalski and Hollowed, 2016). Towards inclusive, climate adaptive fisheries management, it must be understood by policy makers that Indian fishers' perceptions of wellbeing are strongly rooted in safety and risk reduction, rather than solely focused on increasing income (Srinivasan and Burrell, 2013; Steyn and Das, 2015). Hence, if MCS systems have cross-sectoral support (coast guard and emergency response), and are coupled with awareness raising campaigns, these new data systems may represent an attractive proposition for fishers facing increasingly variable catches and stormy seas.

Opportunities and risks for value chains, livelihoods and wellbeing

Legal frameworks and data privacy

The opportunities that ICT might bring for fishers, fisheries management, and greater wellbeing of actors along value chains will only be realised if governance regimes remain inclusive, and targeting commitments to SDG14b, the SSF guidelines, and the tenure guidelines. As ICT develops and proliferates in fisheries and for fisheries governance, innovation in legal frameworks will also be required to keep apace. Legislation must be designed to limit government and corporate abuse of data privacy, to decentralise power, and make decision-making transparent and accountable. This implies a mechanism such as: 1) fishers and traders are given the

right to hold and use the individual data they contribute to the government, 2) analyses of aggregated fisheries data are aligned to agreed publicly transparent baselines and shared resource management objectives of all stakeholder groups, 3) analysis results are transparent and open to public comment and 4) new regulations are decided upon with all stakeholders and are traceable to specific data trajectories.

Enhancing ICTs use for SSF (ICT4SSF) will only bear fruit if, simultaneously, there are checks put in place to regulate the mechanized sector and ensure that aquaculture, and specifically mariculture, another focus of the blue economy vision, does not come at the expense of SSF. A recent study by Scholtens *et al*. (2020) illustrates how the fishmeal industry for aquaculture is increasingly dependent on the same fish that small-scale fishers catch, reducing available stocks for the latter. There are examples of the detrimental fishmeal industry practices from elsewhere in the world that not only deepen the poverty of small-scale fishers and traders but also cause chronic environmental harm (Urbina, 2021). Improved ICTs for SSF must be, therefore, part of a vision that sees the future of sustainable fisheries largely in terms of the small-scale sector as envisaged in the SSF Guidelines.

Data innovations can represent one pathway to move away from the unhelpful conflation of IUU fishing, but SSF must be approached differently. Song *et al*. (2020) provide three strategies as a starting point for potential alternatives to global IUU regulations that recognise that illegal, unreported and unregulated fishing are not the same thing. Besides making exceptions for SSF in global IUU policies and allowing flexibility in multilateral frameworks to fit the realities of SSF, we should try to create bespoke solutions to IUU fishing that truly work for SSF. This will need to be grounded on the recognition of SSF's contributions to national and local economies, as framed by the SSF Guidelines (FAO, 2015). Various efforts are underway, including a recent technical report, which presents guiding questions to frame the development of ICT4SSF by governments and agencies. These are mapped to the objectives of the SSF Guidelines in three major use areas: 1) Management, tenure and ecological sustainability; 2) Well-being, decent work and gender equality; and 3) Value chains, benefit distribution and poverty alleviation (FAO and WorldFish, 2020).

Value chains and the potential gender digital divide

The use of smartphones and apps in SSF offers the opportunity for commonly marginalised communities to connect to financial services such as banking and microcredit, which is often the pivotal factor in the development impact of microenterprises in rural areas (FAO and WorldFish, 2020, chap. 7). COVID-19 and the associated movement restrictions imposed on people and markets worldwide since early 2020, have brought deleterious impacts to fisheries value chains (Campbell *et al*., 2021), increased vulnerability of fisher groups, and increased occurrences of illegal fishing (Bennett *et al*., 2020). However, in response it has also driven the rapid growth and diversification of e-commerce in fisheries, with the emergence of new digital marketplace platforms and apps, a refocusing of existing platforms into community-supported fisheries (Stone, 2020), shorter value chains (Bennett *et al*., 2020, Harper, 2020, UNCTAD, 2020) and an increase in microcredit availability for new ventures and shifts to alternative livelihoods (UNCTAD, 2020). In addition to the cursory consideration of women fishers in the draft NFP (Vohra, 2020), this nascent digital transition in fisheries represents potential risks for women and other vulnerable groups with little or no access to digital services. If ICTs become the social or economic norm or a legislated requirement, and efforts are not made to balance the playing field, these groups will face further exclusion from markets and supply chains (Madgavkar *et al*., 2019). In India, women are often the primary household breadwinners, so the need for digital literacy and capacity building, as part of digital transformation, must be recognised not only for women's inclusion in value chains but for household incomes and wellbeing in general (Rethinam, 2020).

Distributed technologies and applications such as blockchain provide a decentralized mechanism for transparent and immutable transactions in finance, public services and governance. There is evidence that digital trust tends to be higher than personal trust in small-scale cooperative arrangements, so there is the potential for blockchain to increase transparency and accountability in financial transactions (Xiong *et al*., 2020). Blockchain for fisheries has been realised most dramatically in enabling traceability and chain of custody evidence to support high-value seafood certifications (Blaha and Katafono, 2020). To date, traceability has been of limited

application to SSF, except those who exclusively target billfish and other very high-value species or for niche markets (Sterling *et al*., 2015; Project Provenance Ltd, 2016; Future of Fish, 2019). The reason being that profit margins in fisheries are already low, so accessing new markets in which demand is high enough for traced, certified products to cover the costs of digitizing the process, is extremely challenging.

Enabling conditions for inclusive governance

The digitalization of the fisheries sector in India has commenced largely through weather and fishing advisory services, although also instant messaging apps are increasingly used for communication between fisher and value chain actors (FAO & WorldFish, 2020). The draft National Fisheries Policy (2020) implies that the scaling of digital tracking of fisheries vessels and commodities in seafood value chains is imminent (Draft National Fisheries Policy 2020, 31 p, 21.1). This signals increased requirements for data systems in both mechanised and SSF sectors in India, but this appears contrary to the political and infrastructural situation on the ground. With extensive awareness raising and digital capacity building at fisher and fish worker level, this digital transformation could represent an opportunity for data-driven decision making that brings improved fisher wellbeing and resource management. However, if data systems and requirements are established as a top-down decision without appropriate discussion and inclusion of resource users, it is likely to alienate and disaffect these most critical actors.

The use of ICT for fisheries should be considered in the context of a social-ecological system – where the purpose is not only to support the sustainable use and management of fisheries resources, but to strengthen and maintain the relationships between resources and people, and governance across different levels (Nayak, Oliveira and Berkes, 2014). Without this reform, multidimensional factors, particularly institutional ones, including the current push to make VMS compulsory on all vessels, will risk mislabelling SSF as IUU fishing, delegitimise their work and will drive impoverishment in Indian SSF systems.

Establishing new or more inclusive data systems will present multiple technical, institutional and bureaucratic challenges, but by providing opportunities for collaborative learning and cogeneration of data from multiple systems and actors to achieve shared objectives, fishers and fish workers can become stewards of their resources alongside the government.

The Government of India must invest in and support the development of a platform of fisheries monitoring tools and provide customisable solutions and options for state governments to improve reporting of SSF, while integrating existing knowledge such as the Central Marine Fisheries Research Institute landings database and censuses (CMFRI, 2020), and apply strong data protection and ownership for fishers. Fishers and fish workers must be integral in the design and development of this platform, and this process should be combined with awareness-raising campaigns and digital literacy and capacity building activities in the sector.

CONFLICTS OF INTEREST

The authors declare that there is no conflicts of interest.

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