Received: 5 June 2017 | Accepted: 20 February 2018
DOI: 10.1111/faf.12285

WILEY FISH and FISHERIES

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Empowering high seas governance with satellite vessel tracking data

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Funding information
Nippon Foundation-Nereus Program

Abstract

Between 1950 and 1989, marine fisheries catch in the open-ocean and deep-sea beyond 200 nautical miles from shore increased by a factor of more than 10. While high seas catches have since plateaued, fishing effort continues to increase linearly. The combination of increasing effort and illegal, unreported and unregulated (IUU) fishing has led to overfishing of target stocks and declines in biodiversity. To improve management, there have been numerous calls to increase monitoring, control and surveillance (MCS). However, MCS has been unevenly implemented, undermining efforts to sustainably use high seas and straddling stocks and protect associated species and ecosystems. The United Nations General Assembly is currently negotiating a new international treaty for the conservation and sustainable use of biodiversity beyond national jurisdiction (BBNJ). The new treaty offers an excellent opportunity to address discrepancies in how MCS is applied across regional fisheries management organizations (RFMOs). This paper identifies ways that automatic identification system (AIS) data can inform MCS on the high seas and thereby enhance conservation and management of biodiversity beyond national jurisdictions. AIS data can be used to (i) identify gaps in governance to underpin the importance of a holistic scope for the new agreement; (ii) monitor area-based management tools; and (iii) increase the capacity of countries and RFMOs to manage via the technology transfer. Any new BBNJ treaty should emphasize MCS and the role of electronic monitoring including the use of AIS data, as well as government–industry–civil society partnerships to ensure critically important technology transfer and capacity building.

Ghoti papers

Ghoti aims to serve as a forum for stimulating and pertinent ideas. Ghoti publishes succinct commentary and opinion that addresses important areas in fish and fisheries science. Ghoti contributions will be innovative and have a perspective that may lead to fresh and productive insight of concepts, issues and research agendas. All Ghoti contributions will be selected by the editors and peer reviewed.

Etymology of Ghoti

George Bernard Shaw (1856–1950), polymath, playwright, Nobel prize winner, and the most prolific letter writer in history, was an advocate of English spelling reform. He was reportedly fond of pointing out its absurdities by proving that 'fish' could be spelt 'ghoti'. That is: 'gh' as in 'rough', 'o' as in 'women' and 'ti' as in palatial.

KEYWORDS
areas beyond national jurisdiction, automatic identification system, biodiversity, monitoring, regional fisheries management organization, surveillance

1 | INTRODUCTION

Between 1950 and 1989, industrial marine fisheries catch in the open-ocean and deep-sea beyond 200 nautical miles from shore increased by a factor of more than 10 and landed value increased by a factor of more than 17 (Figure 1A,B; Pauly & Zeller, 2015, 2016). This growth was three times the rate of increase in catch and value within national waters (i.e. within exclusive economic zones) during the same time period. Since 1990, catch and value of high seas marine fisheries has remained relatively stagnant (FAO, 2016), but fishing effort and all concomitant impacts that derive from putting more fishing gear in the water more than doubled between 1990 and 2006 (Merrie et al., 2014). In geographic terms, the greatest expansion of fishing effort during the second half of the 20th century took place primarily beyond the limits of the continental shelf and in what are now "areas beyond national jurisdiction" (ABNJ; Morato, Watson, Pitcher, & Pauly, 2006; Pauly, Watson, & Alder, 2005; Swartz, Sala, Tracey, Watson, & Pauly, 2010).

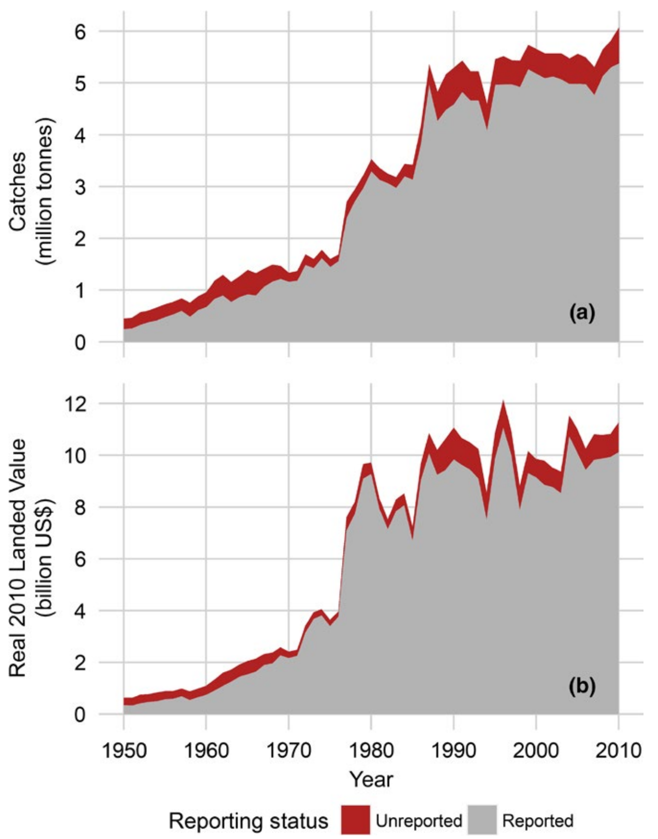

FIGURE 1 High Seas capture fisheries production (a) and value (b) from 1950 to 2010. Catches grew from ~450,000 tonnes (US$639 million) in 1950 to ~5,165,000 tonnes (US$10.6 billion) in 1989; far outpacing global growth in coastal zone catches and value during the same time period. Data downloaded from the Sea Around Us Catch Reconstruction Database (Pauly & Zeller, 2015, 2016) [Colour figure can be viewed at wileyonlinelibrary.com]

This rapid expansion of high seas fisheries has been followed, with a significant lag, by an expansion in the number of regional fisheries management organizations (RFMOs) charged with managing fishing on the high seas. In 1995, six years after high sea fisheries production levelled off, the United Nations Fish Stocks Agreement (UNFSA or "Fish Stocks Agreement") became the principal legal agreement to set performance standards and principles for the management and conservation of highly migratory and straddling fish stocks on the high seas (i.e. for the RFMOs). Article 10 of the UNFSA requires States to "establish appropriate cooperative mechanisms for effective monitoring, control, surveillance (MCS) and enforcement." That same year, responsibilities for fisheries management in general were elaborated through the United Nations Food and Agriculture Organization's (FAO) Code of Conduct for Responsible Fisheries (Code of Conduct) which called, *inter alia*, for States to "implement effective fisheries monitoring, control, surveillance and law enforcement measures including, where appropriate, observer programmes, inspection schemes and vessel monitoring systems" (FAO 1995). Furthermore, the Code of Conduct calls upon States to "deter the activities of vessels flying the flag of non-members or non-participants which engage in activities which undermine the effectiveness of conservation and management measures established by such organizations or arrangements."

Following a surge of illegal, unreported and unregulated (IUU) fishing activities towards the end of the 20th century (Agnew et al., 2009), the international fishing community, through the RFMOs and other mechanisms, started developing frameworks to regulate and monitor fishing vessels and their activities; primarily through catch documentation schemes and international lists of vessels engaging in IUU fishing activities (MRAG 2010; Österblom, 2014; Österblom & Sumaila, 2011). In 2001, these efforts were complemented by the establishment of the International Monitoring, Control and Surveillance (IMCS) network, which was further strengthened through the creation of the High Seas Task Force (High Seas Task Force 2006; Österblom, 2014). The IMCS became a platform for member States (50 by 2012) to share information on IUU fishing activities and vessels. Recent advancements such as the Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (PSMA; Flothmann et al., 2010) and the EU IUU Regulation are further promising mechanisms to monitor and deter IUU fishing activities (Marine Resources Assessment Group (MRAG), 2010).

Despite these efforts, requirements for MCS in the Fish Stocks Agreement, the Code of Conduct and elsewhere have been unevenly implemented, which has undermined efforts to sustainably use high seas and straddling stocks and magnified biodiversity impacts (Pitcher, Kalikoski, Pramod, & Short, 2009). High seas and straddling stocks are overfished at twice the rate of those within national jurisdictions (64.4% vs. 28.8% in national jurisdictions; FAO 2014). Non-target migratory species, such as some elasmobranchs, are also being heavily impacted by fisheries: 63% of the 156 species or migratory sharks listed by Fowler (2014) are Threatened or Near Threatened under IUCN standards and, according to Dulvy et al. (2008), three quarters of all oceanic shark and ray species are experiencing the same level of threat. Overfishing and IUU fishing have led to severe declines in many target and non-target species (e.g. Harley, Davies, Hampton, & McKechnie, 2014). Fisheries have also reduced oceanic biodiversity (Worm et al., 2006) and resilience of these ecosystems to other stressors like climate change (Brander, 2010). The synergistic impacts of fisheries and climate change can induce profound transformations in ecosystem dynamics (Jones & Cheung, 2015) potentially resulting in regime shifts (Daskalov, Grishin, Rodionov, & Mihneva, 2007). Together with a reduction in effort and a focus on ecosystem-based management, stronger implementation of MCS is a prerequisite for addressing any of the species, community and ecosystem impacts described in reviews of impacts of fisheries on deep-sea and open-ocean ecosystems (Clark et al., 2016; Crespo & Dunn, 2017; World Bank 2017).

The 2016 Review Conference of the UNFSA was an opportunity to address concerns and explore areas for improvement in the current management and conservation of straddling fish stocks. Among the topics discussed, MCS stood out as an area of high potential for future development, given recent advancements in technology and transboundary cooperation opportunities. The Review Conference of the UNFSA expressed the need to increase MCS for RFMO fishing States as well as for non-member States and highlighted the need for sufficient resources to carry out MCS activities. A diverse set of measures and tools were recommended, including vessel lists with complementary compliance indexes, port monitoring measures, increased onboard observer coverage, inspection schemes and electronic monitoring and surveillance. If adopted, these measures could ensure that agencies in charge of the management of straddling and highly migratory fish stocks have a better understanding of *who* is fishing *which* species, *how* they are fishing and *where* and *when*. Furthermore, MCS can also validate vessel destination, monitor trans-shipment activity and provide a history of individual vessel activity. Below, we briefly outline progress on the recommended measures and tools.

1.1 | Current status of MCS tools

Progress is being made to implement many of the measures recommended by the Review Conference. Vessel lists and compliance indexes are being developed by a host of organizations and nations [e.g. International Maritime Organization (IMO), FAO, RFMOs, the Combined IUU Vessel List]. The FAO Port State Measures Agreement (PSMA) came into force in December 2016, and its provisions for enhanced communications and information sharing are expected to allow for pre-screening of vessels entering port with fish onboard, enabling port States to more efficiently inspect or deter vessels engaged in illegal fishing activities.

Similarly, progress has been made implementing observer programmes by RFMOs and States. However, such programmes are a relatively new feature of global and high seas fisheries management and many RFMOs (including at least one tuna-RFMO) had no observer coverage as of 2013 and two-thirds of RFMOs fisheries lack adequate observer coverage (Gilman, Passfield, & Nakamura, 2014). This remains the case even though observer programmes to assess the status of fish stocks and the potential ecological impacts are considered essential elements of any MCS framework in developed fisheries (Gilman, 2011; Lewison et al., 2011). Even where it is implemented, observer coverage is not split evenly among fisheries within an RFMO or across the national observer programmes related to transboundary stocks. Allain et al. (2011) reported that while large purse seine vessels in the Western and Central Pacific Fisheries Commission (WCPFC) had 100% observer coverage, longliners had about 5% observer coverage.

Expansion of the use of electronic monitoring systems is increasingly viewed by many as a complement or potential substitute for costly observer programs. WCPFC requires the use of vessel monitoring systems (VMS) by all 43 of its member countries, participating territories and non-member countries (WCPFC 2006). Vessel monitoring systems and automatic identification system (AIS) vessel tracking data have the potential to increase the spatiotemporal coverage of monitoring programs and can help managers track the compliance of vessel in terms of the location of fishing activities (Gilman, 2011). Russo et al. (2016) and Longépé et al. (2017) provide examples of how the integration of both VMS and AIS data can inform ecological indicators of fishing pressure and enforcement of fishing moratoria (respectively). Both VMS and AIS have global coverage and have been well adopted in industrialized fisheries, although differences between the systems exist (see below). However, other forms of electronic monitoring including, for example, video and sensor monitoring have seen limited adoption (Dunn & Knuckey, 2013). While fisheries such as the tropical tuna purse-seine fishery have begun testing the reliability of these camera systems and compared their accuracy to on-board observer data, the results have been varied (Ruiz et al., 2015). Cost-efficient and-effective MCS measures across all of these categories still need to be developed, supported and expanded to provide statistically significant sampling that can track not just species-level impacts, but community and ecosystem level impacts and the necessary inputs to control and enforcement activities.

1.2 | High seas governance

The difficulties of implementing adequate monitoring, control and surveillance systems described above become an even larger problem where there is either no RFMO or the existing RFMO does not cover all the targeted fish stocks. While tuna RFMOs have almost global coverage, non-tuna RFMOs have patchier geographic coverage across all ocean basins (Ban, Bax, et al., 2014). Geographic governance gaps make up a small proportion of the high seas but taxonomic gaps, where an RFMO manages only a small number of the overall species affected by the fishing activities of its Parties, are abundant. For instance, while the International Commission for the Conservation of Atlantic Tuna (ICCAT) has established stock assessments for three shark species captured in the ICCAT area (http://www.iccat.org), that is <1% of shark species in the region. Efforts to conserve biodiversity are hindered by these fisheries governance gaps and lack of progress by many RFMOs to implement ecosystem-based management measures (Cullis-Suzuki & Pauly, 2010; Gilman et al., 2014; Juan-Jordá, Murua, Arrizabalaga, Dulvy, & Restrepo, 2018). Such obstacles to conservation of ABNJ are further exacerbated by strong divides between sectoral authorities and between governance regimes for the seabed and the water column (Ban, Maxwell, et al., 2014; Gjerde, Currie, Wowk, & Sack, 2013).

In 2015, a decade of reviewing governance gaps in ABNJ like those described above gave rise to a consensus resolution by the UN General Assembly (UNGA) "*[s]tressing* the need for the comprehensive global regime to better address the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction" (UNGA 69/292; Wright, Rochette, Druel, & Gjerde, 2016). The resolution mandated the development of an international legally binding instrument (i.e. a treaty) on a "package" of issues to be considered "together and as a whole" including, (i) marine genetic resources, including questions regarding the sharing of benefits; (ii) area-based management tools (ABMTs), including marine protected areas; (iii) environmental impact assessments; and 4) capacity building and the transfer of marine technology. To lay the groundwork for negotiations over a new treaty, the UNGA set up a Preparatory Committee (PrepCom) tasked with providing recommendations on elements of a draft text for the new treaty by the end of 2017. The final recommendations from the PrepCom were agreed in July of 2017 (UNGA 2017), and the UN General Assembly resolved to open an Intergovernmental Conference to negotiate the new treaty in 2018 (UNGA 72/249).

While a few States feel that, at most, any new treaty should simply call for enhanced coordination among RFMOs and other organizations, such an approach is unlikely to be sufficient to overcome existing governance gaps and bring MCS of high seas fisheries up to the level required to ensure sustainable fisheries and conserve biodiversity beyond national jurisdiction. The development of overarching provisions for the new treaty provides an opportunity to augment ecosystem-based management of fisheries in ABNJ through (i) the definition of a common purpose; (ii) the provision of agreed governance principles; (iii) the formation of collaborative institutional arrangements to integrate sectoral management; (iv) the development of a review and reporting process currently missing in the UNFSA; and (v) provision of a default management regime where gaps in geographical coverage by RFMOs remain (Barnes, 2012; Wright, Rochette, Blom, et al., 2016).

Conservation and sustainable use of high seas biodiversity requires an ecosystem-based approach underpinned by data collection and the use of all of the tools in our policy and management toolboxes, including vessel tracking data. A further critical but underutilized tool is collaboration between competent management organizations, academia and industry to assess and monitor the impacts of fisheries on oceanic systems (Crespo & Dunn, 2017). Here, ahead of the upcoming BBNJ treaty negotiations, we lay out how the use of AIS data via industry/academia/civil society organization partnerships can inform implementation of area-based management tools, including MPAs, the conduct of EIAs and technology transfer and capacity building. Below, we provide an overview of AIS data and three use cases to highlight the many ways vessel tracking data can support biodiversity conservation and sustainable use in ABNJ.

1.3 | Automatic identification system

Automatic identification system was initially developed to aid in vessel collision avoidance and is required for vessels of various sizes as part of the International Maritime Organization (IMO) Safety of Life At Sea Treaty (SOLAS Treaty, Chapter V; Cervera & Ginesi, 2008). Specifically, all vessels greater than 300 gross tonnes travelling in international waters, all cargo vessels >500 gross tonnes travelling in domestic waters and all passenger vessels of any size must have AIS onboard and turned on. AIS requirements for fishing vessels are highly variable depending on the organization or country mandating the requirement and can be more or less strict than the IMO AIS requirements (McCauley et al., 2016). For example, the Pacific Forum Fisheries Agency requires all registered fishing vessels that apply for good standing on their vessel registry list to have an AIS device (https://www.ffa.int/vessel_registration/howto; accessed 12/15/2017). The 28 member countries of the European Union require all fishing vessels greater than 15 m to be equipped with AIS (EU Dir 2011/15/EU). Across all countries, Kroodsma et al. (2018) estimate that one AIS tracking data set, Global Fishing Watch, contains data on 50%–75% of fishing vessels larger than 24 m, >75% of vessels larger than 36 m and 50%–70% of the total fishing effort (by kilowatt hour) beyond 100 nautical miles from land.

Automatic identification system data are broadcast by on-board transmitters linked to the vessel's GPS and communicate the vessel's identity (IMO number, maritime mobile security information number (MMSI), vessel name, call sign), current position, speed and course. These data are transmitted every few seconds and can be picked up by AIS devices onboard other vessels within range (i.e. ~50 km for a class A device), ground station AIS receivers and AIS-capable satellites. A single satellite can cover, on average, approximately 5% of the earth's surface at any given time and orbits the earth every 90–110 minutes on average. Although reception of an AIS transmission is not guaranteed, AIS transmissions are undergoing a step-change as dozens of satellites are launched over the next few years (e.g. 40 Iridium NEXT satellites in 2017; see www.iridiumnext.com, accessed 12/15/2017), and near-real time and global coverage is imminent.

Like AIS, Vessel Monitoring System (VMS) is a cooperative system whereby a transponder is placed on a vessel and integrated with the shipboard Global Positioning System (GPS). Both systems can utilize radio or satellite communications (depending on how they are implemented), however, AIS signals are also picked up by other ships with AIS transponders. There are two main differences between VMS and AIS: the propriety of the system and the frequency of transmission. AIS is open and non-proprietary with international standards, while VMS are closed proprietary systems with high barriers to data access. AIS also transmit essentially continuously (e.g. up to every 2 s), while VMS are generally set to transmit every 30 min to 2 hr. While both VMS and AIS data have been analysed, to identify fishing events and quantify fishing effort (Chang, Yuan, & Trenkel, 2014; Hu, Jiang, Souza, Pelot, & Matwin, 2016; Jennings & Lee, 2011; Lee, South, & Jennings, 2010; Longépé et al., 2017), the higher temporal resolution of the AIS data should make it inherently more useful for these purposes (McCauley et al., 2016; Natale, Gibin, Alessandrini, Vespe, & Paulrud, 2015; de Souza, Boerder, Matwin, & Worm, 2016), among other conservation science and policy objectives (Robards et al., 2016). Arguments have been made that VMS have higher spatial coverage away from shore (e.g. Russo et al., 2016), but these reflect systems where the AIS is not communicating through satellites. VMS does have higher levels of fleet coverage in nearshore fisheries, but there has been no indication that this is the case for larger vessels participating in fisheries beyond national jurisdictions relevant to the BBNJ negotiations. Regardless, direct comparisons between the two systems are limited and further studies are necessary (Russo et al., 2016).

Automatic identification system data alone do not provide information on the specific type of gear. Convolutional neural networks, a form of machine learning commonly used in image recognition, are being used to identify general fishing gear behaviour (e.g. trawling, purse seining, longlining). Limited by the availability of training data, these algorithms have not yet been used to identify more specific vessel fishing behaviour such as bottom or mid-water trawling (Kroodsma et al., 2018). However, the vessel identifiers found in each AIS data message can be combined with other data sources (e.g. the EU fishing fleet register) to identify the specific gear type of the vessel (Natale et al., 2015). Various algorithms have been developed to then calculate the probability that a vessel is fishing based on the gear type and its movements. In this paper, the presence of fishing activity at each AIS data point and the number of fishing hours exerted in a given cell were classified using the algorithm developed by Kroodsma et al. (2018).

2 | USE CASES

From questions of scope (e.g. should the treaty cover fisheries at all) to discussions of how area-based management tools, EIAs and technology transfer might be implemented, AIS data have direct relevance to the discussions of a new treaty for the conservation and sustainable use of biodiversity beyond national jurisdiction. Below, we provide three use cases, illustrating how AIS data can be utilized to inform negotiations over, and eventual implementation of, a new treaty for biodiversity beyond national jurisdiction. First, we visualize geographic and taxonomic gaps in governance. Second, we examine how AIS can be used to provide MCS for area-based management tools in ABNJ. Finally, we illustrate the utility of AIS in tracking and better understanding fishing activities that intersect multiple RFMOs and the associated benefits of globally-coordinated technology transfer and cooperation to better manage such activities.

2.1 | Use Case 1: Governance gaps in ABNJ

As discussions move towards how to incorporate fisheries into the scope of a new internationally legally binding instrument, it is evident that there is need for a more comprehensive global regime as called for under UN resolution 69/22. Fishing in much of the high seas is managed by RFMOs, but clear gaps in RFMO governance exist. We suggest that AIS, and the tools that utilize such data, has a key role to play in visualizing these geographic and taxonomic gaps in governance.

For example, while an RFMO is in place for the Southeast Atlantic (the South East Atlantic Fisheries Organization; SEAFO), the tropical waters of the South Atlantic are covered by Regional Fisheries Bodies that provide only a coordinating mechanism, and the Southwest Atlantic has no management body at all. For vessels fishing in these regions that are unregulated by a competent intergovernmental organization, it is critical that tools are in place to facilitate MCS by Flag States. AIS, combined with other data sources to identify the type of fishing vessel (e.g. the IMO Ship Identification Number Scheme or national registries), can provide evidence that fishing is occurring in these unregulated waters (Figures 2a and 3). Figure 2b displays a vessel identified as a deep-sea trawler engaged in trawling activity for the month of March 2015 outside of Argentina's exclusive economic zone.

Although much more difficult to piece together, AIS data also provide a piece of the framework necessary to examine and monitor un-managed species fisheries, providing that other sources can demonstrate what species the vessels are targeting. Here, we provide an example of six squid-jigging vessels fishing off Argentina's EEZ from 10 to 12 may 2016 (Figure 2C). Similar unregulated fishing activities have been identified in much larger number in the Western Indian Ocean where 68 fishing vessels and 21 ships likely engaged in trans-shipment activities were identified by AIS between 2015 and 2017 (Stop Illegal Fishing et al. 2017). Not only does the fishing of unmanaged species have the potential to deplete the fishery, but the lack of regulatory oversight may encourage illegal activities such as human trafficking and forced labour aboard vessels (Marschke & Vandergeest, 2016; UNODC 2011). The identification of regional and species gaps in high seas fisheries governance strongly illustrates the need for a holistic approach to the negotiation of a new international legally binding instrument for the conservation and sustainable use of biodiversity beyond national jurisdiction.

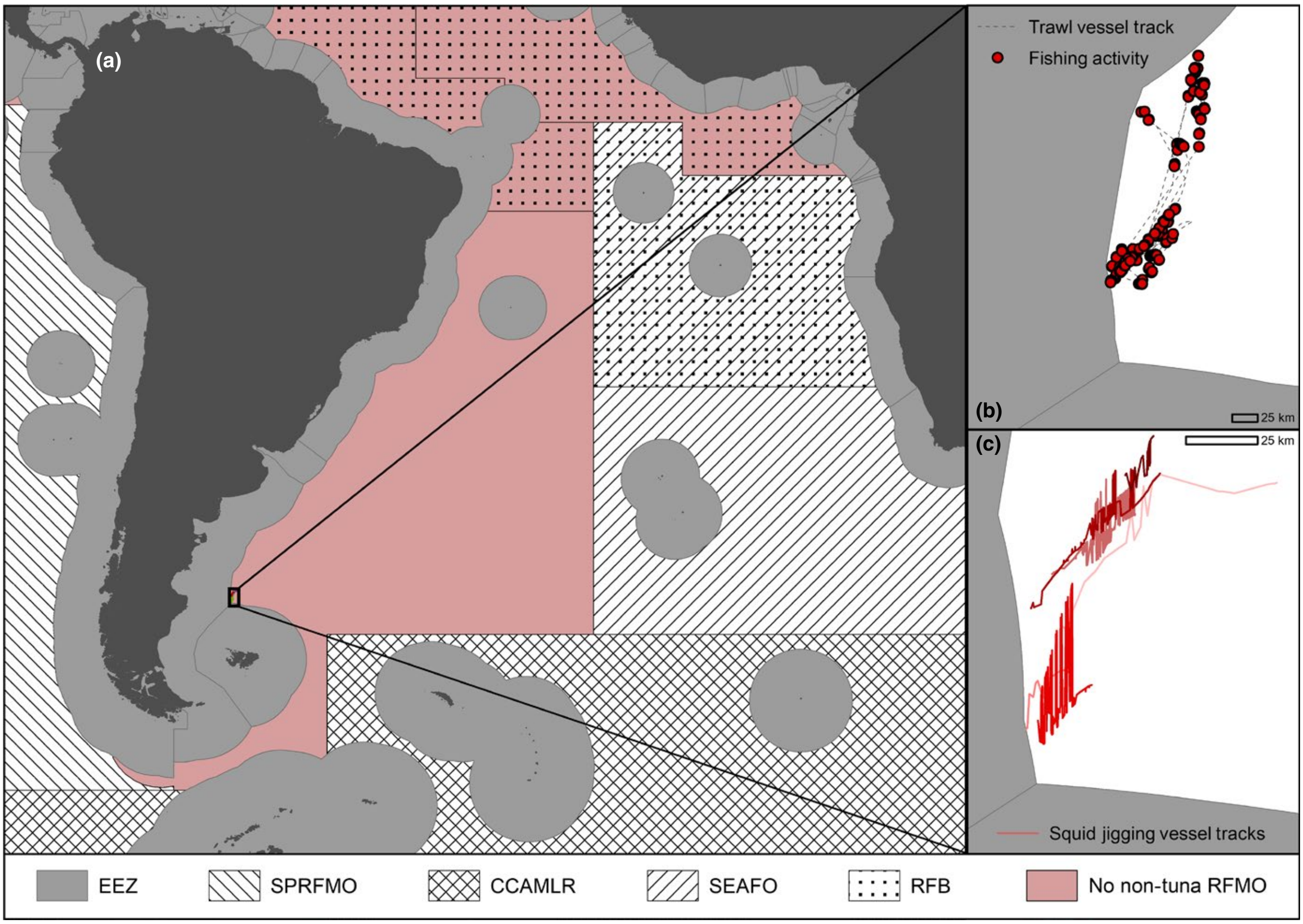

FIGURE 2 Illustration of geographic and taxonomic gaps in non-tuna RFMO management, focusing on fishing activity outside of Argentina's EEZ (a). Enlarged panels display (b) AIS tracks of a bottom trawler fishing in a regional non-tuna RFMO gap and (c) AIS tracks of six squid-jigging vessels, a taxon that is not currently regulated [Colour figure can be viewed at wileyonlinelibrary.com]

2.2 | Use Case 2: Satellite AIS as a tool for monitoring large/Remote MPAs

The ability of any State or entity to provide meaningful MCS in the high seas has been repeatedly questioned given the vast areas and long distance from shore over which States are charged with monitoring the activities of their flagged vessels. An analogous question has been raised about very large MPAs implemented in national waters (frequently those of distant overseas territories with little capacity for MCS). States have increasingly implemented such remote large marine protected areas (LMPAs) in response to international targets set for protected area coverage under Aichi Biodiversity Target 11 and Sustainable Development Goal 14.5 (Boonzaier & Pauly, 2015). 2016 and 2017 saw this trend taken to a new level as three new MPAs were established in the Northern Hawaiian Islands, the Cook Islands and in the Ross Sea of Antarctica, each at least 1.5 million km^2. The Ross Sea MPA is among the first MPAs to be established in the high seas. Monitoring, control and surveillance of such remote areas will be a key component of implementing and ensuring compliance with ABMTs. The role of MCS has been recognized by States and Observers in the BBNJ Preparatory Committee primarily in reference to the need to develop monitoring plans as part of ABMT proposal development and implementation and to monitor ABMTs against the objectives identified in the designation process. To varying degrees, such objectives will include the exclusion of certain types of activities including, among others, fishing.

The Phoenix Island Protected Area (PIPA), located in the Republic of Kiribati, illustrates how AIS can be used for monitoring fishing effort in large, remote MPAs in near-real time. Established in 2008, PIPA was closed to all commercial fishing on January 1, 2015. At approximately 410,000 km^2, PIPA is on the scale of high seas MPAs. Using satellite AIS data from 2014 to 2015, researchers found that there was a sharp decline in fishing activity within PIPA after the 2015 closure (McCauley et al., 2016). AIS data continue to be used to enforce the reserve, supplying the PIPA Implementation Office with information about illegal activity within the MPA. In 2015, action was taken against the Marshall 203 for fishing within PIPA based on information received from Global Fishing Watch (http://www.globalfishingwatch.org/), resulting in USD$2 million in payments to the Government of Kiribati (PIPA Implementation Office 2015). A

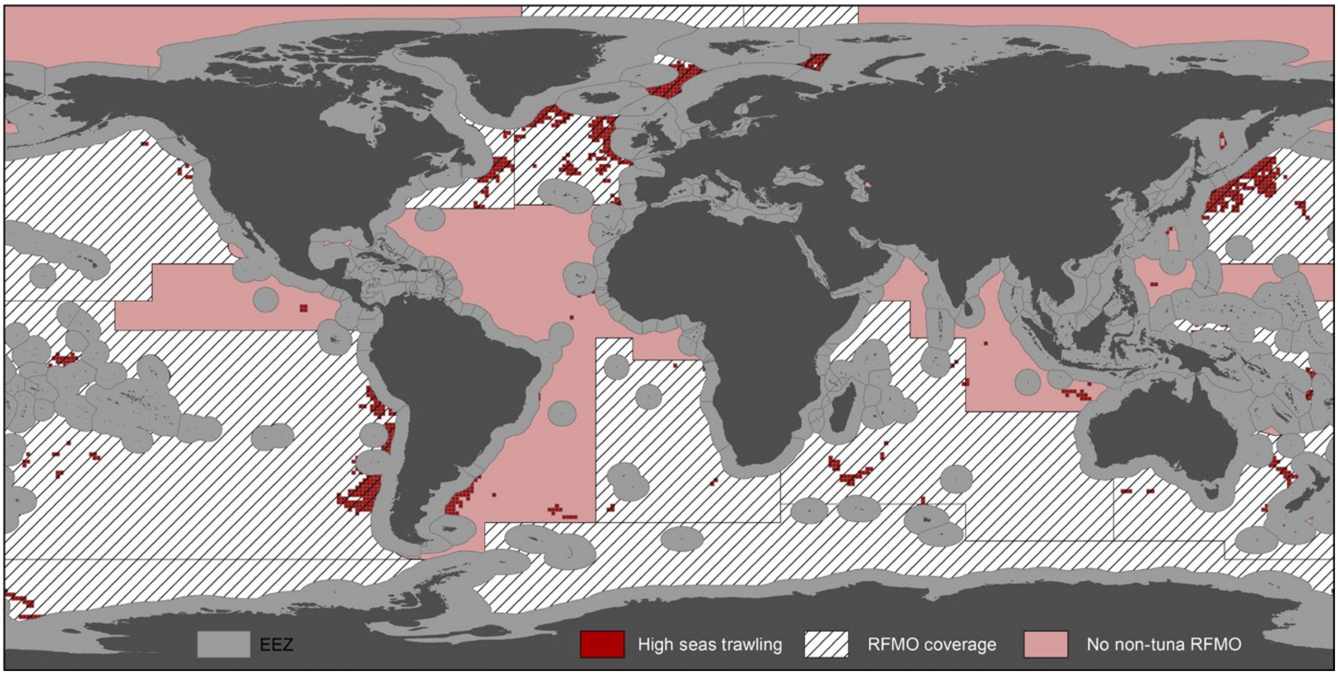

FIGURE 3 Global trawling effort (hours) in areas beyond national jurisdiction. Exclusive economic zones overlaid on trawl fishing effort in light grey. Areas of trawling in regions with no intergovernmental management organization are clear in the southwest Atlantic and eastern Indian Ocean, but also exist in the tropical Atlantic, eastern tropical Pacific, and seas of East Asia

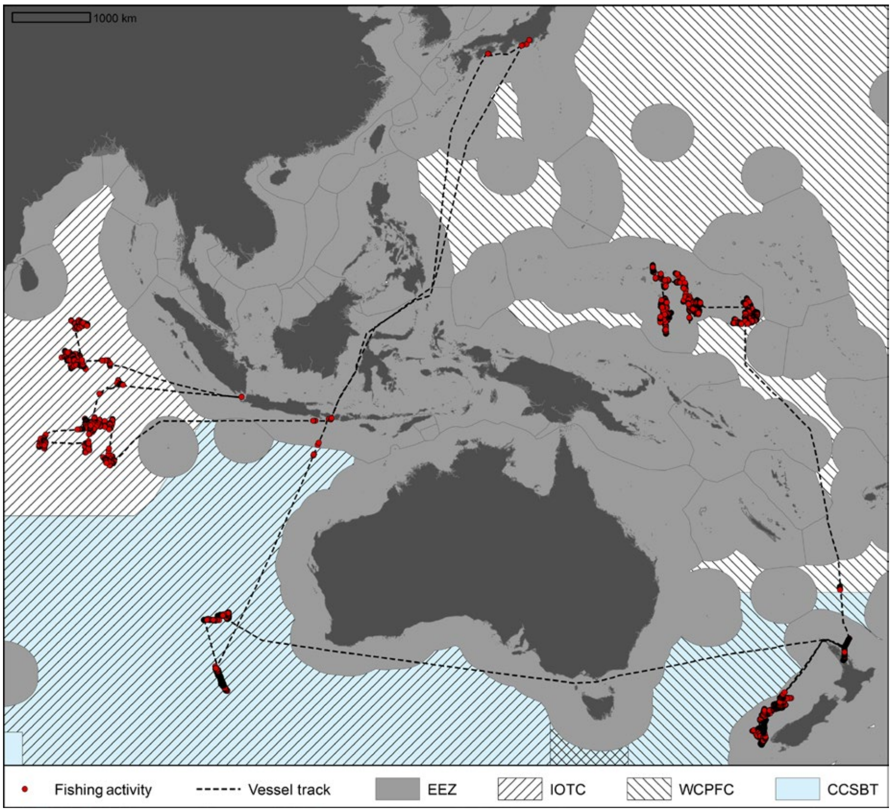

FIGURE 4 Multi-RFMO interactions illustrated by the AIS tracks of a Japanese longliner identified through the Consolidated List of Authorized Vessels. The vessel fished in the Federated States of Micronesia's EEZ for four months before heading to port at Auckland, New Zealand. It continued fishing within New Zealand's EEZ for 2 months, before returning to port in Auckland and then travelling to the high seas west of Australia. There it fished for 2 months in waters that are under management of both the Indian Ocean Tuna Commission (IOTC) and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) before it headed back to Japan, stopping at Denpasar, Bali, Indonesia. It remained in port in Japan until December, when it travelled back to the Indian Ocean to fish in the high seas south of India until March 2016 [Colour figure can be viewed at wileyonlinelibrary.com]

similar arrangement has been made between the UK government and Project Eyes on the Seas to monitor the Pitcairn Islands MPA and, when it is implemented, the Ascension Island MPA using AIS data (Pew Charitable Trusts 2016).

Satellite AIS can also be used to help document effects of MPAs on fisheries. Although the Galápagos Marine Reserve lies within an EEZ (Ecuador), study of the behaviour of tuna purse seine fishing fleets operating within and outside the EEZ is an example of how an ABMT may be monitored against a management objective. Following anecdotal reports by fishermen on purse seine vessels of preferred fishing along the boundary of the reserve, Boerder, Bryndum-Buchholz, and Worm (2017) investigated the distribution of fishing effort using long-term on-board observer data as well as high-resolution AIS data. Hotspots of catch, fishing effort and catch per unit effort all shifted closer to the reserve boundaries after establishment of the reserve. In addition, the analysis of the fine-scale AIS data revealed that fishing effort (defined as density of purse seine sets/km^2) was up to four times greater within 20 km of the reserve than in the surrounding area. This behaviour (i.e. fishing close to a reserve boundary) is known as "fishing the line" and can be an indication of fishermen benefitting from density-dependent spillover of fish leaving the reserve and has previously been identified in other areas with ABMTs as well as through theoretical modelling (Kellner, Tetreault, Gaines, & Nisbet, 2007; Murawski, Wigley, Fogarty, Rago, & Mountain, 2005).

Monitoring of large-scale area-based management tools similar in size to PIPA and the Galápagos Marine Reserve will be critical to implementation of a new high seas treaty. AIS data and the use of open-access tools developed through partnerships between government, industry, academia and civil society organizations can help scale up MCS to meet the demands of sustainably managing ABNJ. The Global Fishing Watch use case provided above is only one example of existing monitoring and enforcement activities based on AIS data. FISH-I Africa (https://www.fish-i-africa.org/), a task force of MCS personnel from Western Indian Ocean countries (Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia and the United Republic of Tanzania) together with external partners and an RFMO, utilize AIS data to address illegal fishing and associated crimes. Through FISH-i Africa, the use of AIS data has led to the detection of possible IUU fishing violations and enforcement actions, resulting in millions of dollars in fines and increased revenues for member countries (Stop Illegal Fishing 2016). Of note, in 2016, FISH-i Africa summarized its activities to date including seven instances where AIS data contributed to MCS activities and only one where VMS contributed (Stop Illegal Fishing 2016). Funding for the use of AIS data by these partnerships has been supported by civil society organizations, but long-term use of AIS data for enforcement purposes is more likely to come from fines and member countries.

2.3 | Use Case 3: Multi-RFMO interaction and technology transfer

The movement of resources and resource users between RFMO boundaries presents a challenge to regional sectoral governance and limits our ability to develop an integrated global understanding of how fishing effort is impacting biodiversity in ABNJ. AIS data can provide overarching insight into how vessels travel and fish between RFMOs and can identify the ports they visit. We illustrate this point here by describing the activity of a longliner flagged to Japan that visited four RFMOs and three ports from January 2015 to March 2016 (Figure 4). This included fishing in areas governed by the Indian Ocean Tuna Commission (IOTC), the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) and the EEZs of countries participating in the Western and Central Pacific Fisheries Commission (WCPFC) and CCSBT, interspersed by port visits in New Zealand, Indonesia and Japan. Governance of this type of cross-RFMO fishing requires very high levels of cooperation between competent authorities and strong MCS. Given differences in capacity for MCS between regions and States, capacity building and technology transfer to support MCS, as well as minimum MCS standards across RFMOs, should be major components of any new treaty.

The importance of capacity building and transfer of technology is clearly a priority for numerous Parties as reflected in the BBNJ PrepCom Chair's non-paper on elements of a draft text for the new treaty (available at: http://www.un.org/depts/los/biodiversity/prepcom.htm). To quote an intervention on behalf of the G77 (see http://www.g77.org) & China, the scope of capacity building and technology transfer in a new instrument should include: "establishment or strengthening the capacity of relevant organizations/institutions in developing countries to deal with conservation of marine biological diversity in areas beyond national jurisdiction; access and acquisition of necessary knowledge and materials, information, data in order to inform decision making of the developing countries." The Caribbean Community countries apply this more directly to MCS, stating that the scope should include: "Capacity building for development, implementation and monitoring of ABMTs including MPAs."

While much discussion of frameworks, modes and types of capacity building and technology transfer have been heard at the PrepCom meetings, little attention has been paid to the role civil society can play in implementation beyond mentions of academic engagement between States. Currently, multiple civil society partnerships exist that seek to support MCS through the thoughtful development of tools that utilize AIS data to increase transparency of fishing activity worldwide (e.g. Global Fishing Watch, FISH-i-Africa and Project Eyes on the Seas). Use of AIS data in this manner provides a common platform for sharing information between RFMOs and/or States that can improve both regional and global goals for the conservation and sustainable use of marine resources and biodiversity in ABNJ. This represents a significant form of capacity building and technology transfer by providing all Parties with direct access to easily interpreted information on the distribution of fishing effort in their (or any) region. Such access should drastically improve the capacity of developing countries, and Small Island Developing States (SIDS) in particular, to implement MCS in waters adjacent to their EEZs. The development of such tools illustrates the important role civil society can play in facilitating technology transfer and meeting basic duties that stem back to UN Convention on the Law of the Sea.

3 | RECOMMENDATIONS AND CONSIDERATIONS FOR THE FUTURE

The inclusion and promotion of the use of civil society partnerships and vessel tracking data systems would directly address concerns from the Alliance of Small Island States and others that any new agreement should "[i]nclude necessary support to implement SIDS' rights and obligations under the new instrument, including technical, scientific and funding support in the development of proposals, review of proposals, development of management measures and monitoring of ABMTs." This support can come from the civil society partnerships providing technical expertise by working directly with individual governmental or intergovernmental organizations, creating a task force of several countries that share information with each other, or by simply making the fishing effort data freely available. In fact, there are very few other non-monetary mechanisms which offer the ability to support MCS by SIDS and other developing states.

However, while AIS can be used to observe, manage and enforce fishing activities in ABNJ, it is only as effective as various international and national agreements allow. Regulations as to the carriage and use of AIS vary widely. The AIS carriage regulations as required by the IMO obligate only the largest commercial fishing vessels to carry AIS; of all the fishing vessels registered in the tuna Consolidated List of Authorized Vessels (CLAV), only 14% are required to carry AIS as per IMO regulation. Individual countries' adoption of carriage regulation also varies widely, with some having no regulations at all.

For AIS to become an effective tool for MCS, three things are necessary. First, the minimum size of vessels required to carry AIS needs to be decreased so that more fishing vessels are included. For example, if a regulation similar to that of the European Union (which requires all vessels greater than 15 m to carry AIS) was mandated, 72.7% of all fishing vessels that provided their vessel length in the CLAV list would be included. Ideally, this size requirement would be adopted on the international (IMO), regional (RFMO) and national level (individual states). Second, vessels that are required to carry AIS should also be required to register for an IMO number and include that number as part of a database, ideally an updated version of the FAO Global Record of Fishing Vessels. Finally, and most importantly, AIS should be adopted as a control tool and compliance should be enforced, assuring that the device is activated and transmitting the vessel's correct location at all times (*cf.* the aforementioned Pacific Forum Fisheries Agency requirements for listing on its vessel registry). Tools are currently being developed to identify any inconsistencies in AIS data that may indicate noncompliance, including when a device has been turned off, or is transmitting an incorrect location by several civil society partnerships. In addition, direct comparisons between regional VMS and AIS data collection will help validate the correspondence between the monitoring methods in terms of vessel tracking, identification and gear type behaviour.

Automatic identification system is an important tool to be integrated into the institutional arrangements agreed on during the BBNJ treaty negotiations. Regardless of whether a single overarching structure is developed or coordination and cooperation among existing sectoral and regional competent authorities are reinforced, mechanisms will need to be built that support a more holistic MCS system across regions and authorities with a range of capacities. AIS data, the tools described above, and the civil society partnerships that have developed them, are a critical element to improving MCS and ensuring effective conservation measures and sustainable use of biodiversity beyond national jurisdictions.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge primary support for the development of this manuscript by the Nippon Foundation-Nereus Program. CJ and DJM thank the Benioff Ocean Initiative for their support of this work. We thank H. Blondin and C. Hayes for contributing to our thinking about the scope of how AIS data has been analysed. We also thank the two anonymous reviews and T. Pitcher for their strong constructive criticism which greatly improved the manuscript.

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How to cite this article: Dunn DC, Jablonicky C, Crespo GO, et al. Empowering high seas governance with satellite vessel tracking data. *Fish Fish*. 2018;19:729–739. https://doi.org/10.1111/faf.12285