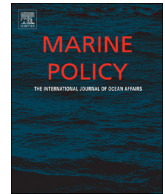




ELSEVIER

Contents lists available at ScienceDirect

## Marine Policy

journal homepage: [www.elsevier.com/locate/marpol](http://www.elsevier.com/locate/marpol)

## Sea of possibilities: Old and new uses of remote sensing data for the enforcement of the Ascension Island marine protected area

Thomas Appleby<sup>a,\*</sup>, Matthew Studley<sup>b</sup>, Brendon Moorhouse<sup>a</sup>, Judith Brown<sup>c</sup>, Chad Staddon<sup>a</sup>, Emma Bean<sup>a</sup>

<sup>a</sup> International Water Security Network, University of the West of England, Frenchay Campus, Coldhardbour Lane, Bristol BS16 1QY, United Kingdom

<sup>b</sup> Engineering, Design and Mathematics, University of the West of England, Bristol, United Kingdom

<sup>c</sup> South Atlantic Research Institute, Falkland Islands

## ARTICLE INFO

## Keywords:

Conservation  
Enforcement  
Law  
Remote sensing  
Management. Fisheries

## ABSTRACT

Very large marine protected areas are in danger of becoming 'paper parks'. This paper uses an interdisciplinary team to investigate the use of remote sensing technologies to provide sufficient evidence for effective fisheries management. It uses the intended marine protected area around Ascension Island as a case study. Satellite technology provides opportunities to detect the presence of fishing vessels but because of difficulties with data interpretation, it is unlikely to be a sole source of evidence for prosecutions. Developing drone technology and traditional over-flights by aerial surveillance may supplement satellite technology with 'eyewitness' evidence. Well-crafted regulations will be able to make some use of this data, but the evidential requirements of criminal courts make prosecutions difficult to pursue. There is some scope to expand management opportunities through vesting the fishery in a public body and pursuing offenders through civil law, this approach having a different suite of remedies. Other opportunities lie in giving very large marine protected areas legal personality which has similar advantages and additional reputational benefits. Using remote sensing data in the civil court poses evidential problems. An alternative approach is to collate data around frequent infringers and, by negatively impacting on their reputation, restrict their ability to obtain insurance, finance, access to fisheries and market access. This is exemplified in port state measures by fisheries authorities and chain of custody requirements by labelling bodies. Data sharing raises challenges with intellectual property and coordination. The paper demonstrates that there are opportunities to make VLMPAs work more effectively.

### 1. Introduction

It is widely known that many marine species are under threat from human activity. A number of actions have been suggested and measures implemented worldwide to help address this, including the establishment of marine protected areas (MPAs). Although many factors have been shown to impact upon the effectiveness of MPAs, 'protection' of the resources within the MPA is a *sine qua non*. With a number of recent announcements of very large MPAs (VLMPAs) in remote parts of the world, scholars are questioning the worth of VLMPAs if there is no effective enforcement mechanism. At the same time there has been significant developments in remote sensing technologies, and these are increasingly seen [1] as a means to combat illegal unreported and unregulated (IUU) fishing activities and enforce management measures. This paper uses an interdisciplinary team to explore the relationship between remote sensing technologies and enforcement mechanisms. The paper examines the current state of the literature on VLMPAs. It

then investigates the range of remote sensing technological measures which may be used to manage and enforce VLMPAs and how these technologies may be integrated into the legal system. The paper focusses on an example of the VLMPA (to be designated in 2019) around the British Overseas Territory of Ascension Island. The paper then proposes technological and legal developments needed to improve management and enforcement.

### 2. Prior work

In 2002, Jameson et al. [2] posed the question, "Can Marine Protected Areas be effective?" and noted that the majority of factors, which would impact on their effectiveness, are beyond the local control of the individuals and bodies tasked with their management. Such factors could be directly or indirectly caused by human activity, for example, climate change or agrochemical runoff, or they might be the result of natural variation. The authors stated that the great majority of

\* Corresponding author.

<https://doi.org/10.1016/j.marpol.2018.06.012>

Received 9 January 2018; Received in revised form 22 June 2018; Accepted 22 June 2018  
0308-597X/ © 2018 Published by Elsevier Ltd.

Caribbean, and almost all Indo-Pacific, MPAs were failing to meet their stated aims, and were “paper parks’ which lack compliance on the part of resource users and monitoring or enforcement on the part of management agencies” and argued that a change in management culture to focus on delivering against meaningful metrics was the key to improvement.

A series of publications echo the concern that some MPAs are ineffective. In some cases, management objectives are not met [3,4] and in many cases it has been shown that positive ecological change and fish stock recovery is correlated with strong surveillance and enforcement mechanisms. However, in one study only 20% of the MPAs were adequately subject to surveillance [5].

In their recent paper, Pieraccini et al. [6] discuss the complex web of interlinked regulatory, normative (tending towards a norm) and social motivations which impact upon users’ compliance with the intentions of MPAs. In their case study area, the second largest Italian MPA (Penisola del Sinis-Isola di Mal di Ventre MPA), the user community was local and aware of the MPA status and restrictions. In these users’ own assessment, their failure to comply with the restrictions stemmed, in the most part, from the belief that the area was a self-replenishing store from which resources could be taken with no thought of tomorrow, and from a real understanding of the lack of surveillance and enforcement activity. The authors suggest that enforcement measures would not provide a long term solution to the problem, and that education and trust-building between the user community and regulator are more likely to deliver in the long term. It is noteworthy that these same users report that even where regulation may be beneficial, they are unlikely to report illegal activity for fear of reprisals.

VLMPAs have come under particularly close scrutiny [7]. Jones & De Santo [8] make the critical point:

“..... the pace at which remote VLMPAs are being designated exceeds the pace at which enforcement capacity is being developed, and that some remote VLMPAs are at risk of being ‘paper parks’ that provide only an illusion of marine conservation.”

This is a very real concern, and as Jones & De Santo point out, has implications well beyond the individual MPA, by creating a false impression that global targets set out in international regulation, such as the Convention on Biological Diversity and its Aichi Target of 10% global coverage by 2020 are being met. Lack of enforcement is one of a number of key issues they identify with VLMPAs which may hamper effective conservation (the others being representivity, connectivity and equitable management).

The ability of an MPA to meet its objectives depends in part on whether fishing pressures can be controlled at appropriate levels. In many MPAs, IUU fishing has compromised this, and enforcement and compliance have been unsupported and under-financed [9]. Where interactions with IUU fishing communities can be established, behaviour change can be effected through social intervention such as establishing alternative sources of food or economic sustenance [10]. However, governance based upon social capital and trust is unlikely to be directly effective in controlling the activities of IUU fishers where that community is not cohesive, local, or identifiable. Cost-effective and timely detection and enforcement are therefore likely to remain an important element in MPA management. History, economics and game theory (rational behaviour in context) [11] suggest this is likely to continue to be true while people eat fish and fish remain to be caught. Effective MPA enforcement is one of the five key attributes (along with governance and stakeholder engagement mechanisms) identified by Di Franco et al. [12] for increasing MPA performance for small-scale fisheries management, and the effectiveness of enforcement was found to be associated with an exponential increase in conservation benefits by Edgar et al. [13] in their study of 87 MPAs worldwide. Combatting IUU fishing does not only address conservation goals; there is considerable evidence that crewmembers may be trafficked, beaten, enslaved and trapped in a deepening cycle of criminality [14].

In summary enforcement is an essential part of MPA management and there are widespread concerns that, despite encouraging developments, significant cost effective advances need to be made to create effective enforcement of MPAs (and VLMPAs in particular). The absence of effective enforcement does not just create paper parks but undermines the reputation of MPAs and the international legal framework which underpins them, it even contributes to the cycle of criminality. Without enforcement an MPA is doomed to failure.

### 3. Legal Engineering

#### 3.1. Approaching the problem

As long ago as the second century, the Roman poet Oppian [15] said of attempts to understand the marine environment:

“Foolish th’attempt; none can the space define. The depth retires beneath, and mocks the sinking line. Three hundred fathoms founded at the most, Such is the knowledge which our labours boast. To comprehend the whole we fruitless seek; our souls are finite and our reason weak.”

The same could be said of attempts to regulate fishing [16]. Yet for the first time technology has started to produce effective mechanisms for tracing the activities of the fishing industry. New technology has inevitably had to contend with the evidential requirements of the courts in order for it to be used satisfactorily in a prosecution. Oduntan [17] examined the difficulties posed by the introduction of a fisheries computer aided managements system (known as FishCAM) which captured logbook data, global positioning and appropriate environmental data. Oduntan concluded encouragingly that:

“There is sufficient basis to conclude that electronic logbook records and evidence derived from the satellite vehicle monitoring systems may be legally valid and admissible in the courts of the EU member states.”

For the first time technology is providing a potential solutions to IUU fishing [18]. However, new technology poses a challenge to the legal system itself. The absence of established precedent creates difficulties for the legal system to make full use of the newly available data, and the (often impenetrable) language and process of the law itself are obstacles for the design and development of new technology. How then to get all actors to relate to a system designed to protect the broader values? Everard et al. [19] have explored challenges to effecting a similar regime transformation with respect to air quality management and have noted that critical to effective management is a comprehensive analysis of the rights and responsibilities set out in the legal structures (and identification of any gaps) of the management of use of air. This paper only explores the enforcement mechanisms but it is important to recognise that regulatory mechanisms exist within the broader context of public law and other civil legal relations (such as contract and tort law). These too must be considered as part of ‘the law’ and form a valuable part of the civil society enforcement mechanisms identified by Newton et al. [20]. So it is important that this paper does not confine itself to traditional criminal enforcement mechanisms only.

In theory remote sensing data will generally be admissible in criminal proceedings. In reality it is difficult to rely on remote sensing data alone to mount a successful prosecution [21]. This arises from challenges in discovering not only presence of a ship but also acquiring sufficiently detailed evidence. Purdy went on to conclude, when investigating remote sensing earth, data:

“The greater use of [remote sensing] data in legal and regulatory strategies, therefore, demands significant shifts in the mindsets of environmental lawyers. Strong advocates for these new technologies who can persuade others of the utility of the data and information will be needed. Generally, the success of introducing new forms of

technology relies upon establishing a confidence base amongst those who might use it. This can sometimes take time. Precedents will be needed as further evidence of effectiveness, reliability and cost. Models of cooperation, towards sharing information and experiences with [remote sensing] data should, therefore, be established between national regulatory bodies and other environmental enforcement networks worldwide.”

It is self-evident that effective enforcement must comprise of five processes, namely:

- (1) Building a regulatory structure that is adapted to modern enforcement methods;
- (2) Creating mechanisms to gather evidence to support that regulation;
- (3) Gathering evidence that identifies a particular vessel engaging in illegal activity; and
- (4) Using this evidence to underpin successful actions which deter further illegal activity.

This paper, has used an interdisciplinary team in a ‘model of co-operation’ such as Purdy outlines. The team, comprising lawyers (Appleby, Moorhouse and Bean), an engineer (Studley), a fisheries manager (Brown) and a geographer (Staddon) have investigated how best to optimise both remote sensing technology and the legal system to act as an effective deterrent to IUU fishing. We have chosen an iterative process by which remote sensing data and its utility are set against the three operating legal frameworks: criminal law (prosecution), civil law (litigation) and other civil society legal frameworks. We have called this process ‘legal engineering’.

These three frameworks are interrogated in order of apparent restrictiveness of the use of remote sensing data. Criminal procedures are more restrictive in their use of evidence data than civil procedures, which in turn are more restrictive than the general rules of data use.

### 3.2. The Ascension Island case study

Undertaking this task in abstract sense could lead in turn to abstract rather than practical answers. The legal process is based on precedent, in scientific terms this is similar to using a case study; the judge decides in a certain direction (and thus develops law) in a certain set of circumstances and in response to a certain set of written rules. It is therefore possible to generalise from those circumstances. It would seem appropriate therefore to use a case study to explore the effectiveness of remote sensing data to deter IUU fishing.

The researchers have chosen the Ascension Island intended MPA as an area of study. It has 50% of the entire EEZ as a no take zone and was identified as part of Jones & De Santo's investigation into VLMPAs. The Ascension Island exclusive economic zone (EEZ) has no median line with its neighbours, covers an area of 445,390 km<sup>2</sup> and is surrounded by the high seas. Around 800 people live and work on the island. Travel links are either via the Wideawake Air Base or by ship. It is a remote place (located in the South Atlantic Ocean approximately 1600 km west of the African continent) and fisheries enforcement of such a huge area has its challenges. The closed area is due to be designated as an MPA in 2019 once further scientific research has been conducted to determine final size and location of the MPA, and viability of different enforcement and monitoring technologies have been further trialled to find a long term solution for effective management.

The Royal Society for the Protection of Birds investigated the enforcement mechanisms [22] that would be needed for an Ascension Island MPA and assessed some of the available technologies. This assessment included useful redrafting recommendations of the legislation and permitting arrangements and listed some of the remote sensing mechanisms currently available for deployment to assist traditional fisheries enforcement vessels and provide additional evidence. These were:

- Bespoke Vessel Monitoring Systems (VMS);
- Automatic Identification Systems (via satellite and VMS);
- Radar and Satellite Surveillance;
- Aircraft coverage.

In addition research has indicated autonomous vehicles and acoustic devices [23] and social media [24] also have a potential role to play in remote sensing enforcement.

The utility of remote sensing data for enforcement in Ascension Island's waters depends on whether that data can ultimately lead to a prosecution or provide an effective deterrent to IUU activity. The researchers interrogated the remote sensing data by using their legal engineering approach and maintaining that dialogue between the engineering team and the legal team to optimise the effectiveness of both systems. The team devised a brief followed by assessing different legal frameworks to test the interrelationship between the legal system and technology and assess how successful legal enforcement measures might be obtained. The framework starts at criminal prosecution but also seeks to determine whether there are other legal frameworks which may be able to make effective use of technological developments.

## 4. The first iteration of the legal engineering process – Criminal legal framework

### 4.1. Brief

The brief from a lawyer to an engineer using remote sensing technology to deter IUU fishing could be framed as: provide enough evidence to enable a successful prosecution. The ultimate demonstration of effectiveness is prosecution in the court with a commensurate fine [25]. An example is the prosecution, impoundment and substantial fine of the IUU vessel *Elqui* in South Georgia [26]. The vessel was scuttled to prevent her being used for further IUU activities [27]. Such an action sends a powerful message to IUU fishing businesses. However the *Elqui* prosecution was ultimately reliant on eyewitness evidence, which in remote areas is often difficult to obtain. The first iteration of the legal engineering process is to assess the effectiveness of remote sensing technologies to mount a successful criminal prosecution

In the Ascension Island case study remote sensing technology may be the only means of effective enforcement; the sheer size of the Ascension Island EEZ and shortage of appropriate vessels means eyewitness evidence, though possible on some occasions will, for much of the time, be difficult to obtain. Different technologies can provide various data and it is important to have a sense of the available options. These are set out below.

### 4.2. Vessel monitoring and automatic identification systems

There are various vessel monitoring systems (VMS) available from satellite and mobile phone location modelling systems to on-board cameras. All of these systems suffer from the same basic issue: they are not tamper proof (though systems are improving) and they involve the potential offender collecting evidence against themselves. This can be moderated by the presence of on-board observers and cameras, but even then this raises issues of safety, sleep deprivation and intimidation of the observers [28]. It is also possible to create specific offences which relate to not having functioning VMS on a vessel, indeed this is the case with Ascension Island (section 6 (3), the Fisheries (Conservation and Management) Ordinance 2015).

Australia is perhaps the most advanced jurisdiction in the developments of successful prosecutions using VMS data [29]. As long ago as 1998, in the case of *Bagnato v Australian Fisheries Management Authority* (Administrative Appeals Tribunal Decision No. 12568, 30 January 1998), the court supported the integrity of VMS as evidence. Other

jurisdictions have been slower to adapt, for instance in Fiji cases have tended to use VMS evidence as a means of ensuring that the vessel should have known where it was when it was apprehended by other means [30], but there is an increasing trend to accept the robustness of VMS evidence (see for instance in the USA the case of *Lobsters, Inc. v Evans*, 346F. Supp. 2d 340 (D. Mass. 2004).

Much VMS data also requires interpretation before it can be presented to the court. This raises additional hurdles as the data requires interpretation by experts [31] which can be expensive and open an avenue for cross examination.

#### 4.3. Radar and satellite coverage

There are a number of ways of using terrestrial and satellite radar, and satellite imagery, to detect fishing vessels. Terrestrial radar detects a vessel in a given area, but provides no identification. A further disadvantage of using radar is the high cost of building and operating the infrastructure; for example, the Jindalee Operational Radar Network (JORN) which monitors Australia's Northern borders comprises 22 physical installations and cost in excess of \$1billion [32]. Satellites have the advantage that it is likely that an existing satellite will provide coverage of a specified area, and a variety of sensor modalities are available. As sensor acuity increases, the area covered in a scan decreases, driving up the cost of covering a large area through the process of scanning a large area by 'stitching together' the results of many satellite passes, which itself introduces delays on the frequency and reliability of the data. Satellites can take optical images (in daylight and with no cloud cover) but the commercially available images, although they may show an identifiable ship, may not be sufficient quality to successfully demonstrate fishing activity. They can also deploy synthetic aperture radar (SAR) to detect the presence and size of likely fishing vessels, but again these images are not sufficiently detailed to be able to detect if a vessel is fishing or to identify it. It may be possible to demonstrate a technical prosecution if there is sufficient evidence to identify the vessel and there are appropriate restrictions on passages (see Section 4.9 below), but this would not be straightforward and any evidence provided is likely to require human interpretation for a case to be successful. Moreover, obtaining those data can be expensive since satellite data would need to be bought from commercial operators and monitored, and terrestrial radar data only captures a limited area and again requires human agents to monitor the data. The costs can be moderated by aligning observational data with fisheries data, since many fisheries are seasonal and therefore monitoring would only need to take place when there are commercial species projected to be in the waters of Ascension Island.

It can be a two-step process. Satellites could be used to both detect intrusion as well as identifying perpetrators of illegal fishing [33]. It is then possible to gather identifying evidence by using optical instruments on satellites, which have a very high resolution but cover a concomitantly small area of the Earth's surface. The workflow for using satellite SAR and optical data might look like this:

- (1) Do scheduled satellite scan;
- (2) Assign Automatic Identification System data to ships on satellite scan;
- (3) Investigate whether there is a ship for which the identity is unknown, and or which satisfies other criteria for investigation;
- (4) Get optical imagery of the area; and
- (5) Use optical imagery to identify the ship.

Unfortunately, there may be a long time delay in between steps 3 and 4, above. Once an area has been flagged for optical investigation, the satellite operator has to be tasked with gathering data. This is likely to take hours rather than minutes. A ship can move a long way in that time, and may change its activity. In addition, it may not be a trivial problem to identify vessels from the optical imagery, and the vessel

may be marked with false identifiers (ie a fake call sign). Moreover the gathering of the data itself is likely to require human interface, both to direct the satellites, then interpret the data in a form which can be used to mount a prosecution and then potentially defend the data in court.

As yet the researchers are unaware of any successful prosecution solely reliant on radar, SAR or satellite optical data alone, and the devices would at this stage appear to be best used as a trigger for obtaining other evidence.

#### 4.4. Aircraft, traditional vessel and remote autonomous vehicle coverage

Ascension Island currently requires fishing vessels to register passage across its EEZ (Section 5, the Ordinance). There are also requirements for stowing fishing gear during any innocent passage (at section 9). Visual evidence of a fishing vessel engaged in fishing activities, accompanied by such 'lash and stow' regulations is admissible in court and would provide good evidence for a prosecution. Image data, backed up by GPS location, also has the additional benefit that it requires little interpretation for a court to mount a successful prosecution. The Australian case of *Aregar v Australian Fisheries Management Authority* [2015] NTSC 61 demonstrates the power of eyeball evidence in association with GPS location. In the *Aregar* case, despite an appeal, aircraft evidence was used in association with a GPS location to 'certify' the location of a fishing vessel inside Australian waters.

Obtaining those data presents technological challenges however. Aircraft are expensive to operate and of limited range, particularly for a VLMPA. Drones and autonomous vessels are also of limited utility because of their range, and because they require significant maintenance. Ascension Island has an airport and some maintenance capability and therefore some drone and aircraft coverage is feasible; military drones have been operated from the airbase there as part of a training programme but this has since been completed [34]. It might be possible using military technology to create an effective robust prosecution system reliant using current drone technology, but at present that is likely to be prohibitively costly. If a suitable platform can be procured at a reasonable cost, with the capability to patrol an entire 200 nm EEZ it is possible to see utility in this approach.

#### 4.5. Acoustic data

There is an increasing use of acoustic devices to monitor marine activities and systems based on acoustic technology have been long employed in the detection of marine activity, first as hydrophones, and from 1917 as SONAR. Such devices are useful to indicate whether there is a vessel in an area of interest. While these sensor modalities might serve to indicate a potential infraction, an acoustic signal is unlikely to be able to produce evidence identifying a vessel. At present it is possible for experienced human operators to identify with some accuracy what class of vessel has produced a signal, and it might be possible to detect the noises associated with the deployment of fishing gear or seabed trawling. If a human operator can discriminate in this way, we might expect a suitably-trained combination of digital signal processing and artificial intelligence to be at least equally good, and indeed, some considerable progress has been reported [35,36]. There have been significant developments in automated acoustic signature recognition [37], though there are still practical hurdles: from anchoring hydrophones in deep water (Ascension Islands waters are over 2000 m), to changes in acoustic signatures during fishing, to calibrating any acoustic technology to match the vessel. Acoustic evidence may be useful to indicate whether a vessel is in an area (and thus trigger the use of some other remote sensing technology), but at present, on its own, is unlikely to be able to provide effective evidence and even then would need significant human interpretation to meet the evidential requirements of a court.

#### 4.6. Social media data

Self-published data is available from fishers regarding their activities available via social media platforms. The usefulness in prosecution arises in everything from location data, to visual images, to confessions. In the US, where there has been use of social media evidence than the UK, problems have been noted regarding the accuracy of the data, the actual source of the information and authentication by social media providers [38]. The sheer volume of data also poses logistical problems [39]. It is difficult to see how a systematic use could be made of SNS data except, perhaps, as ancillary to other activities or as supporting evidence.

#### 4.7. Combining data sets

These systems are particularly powerful when used in collaboration together and with other available datasets, as they enable fisheries managers to build a full picture of the fishing pattern and target enforcement. OceanMind [40] combined SAR data with VMS data, both within Ascension Island waters and on the adjacent high seas with vessel data sets from the Regional Fisheries Management Organisation and the International Maritime Organisation. From this data OceanMind researchers were able to build up a picture of suspicious activity (ie where VMS data had gone ‘dark’ or where were vessels transiting in or near the Ascension Island EEZ). The increasing ability of these data sets to ‘communicate’ with one another either through human intervention or neural network machine learning enables managers to assess the risk of illegal activity, and where it is likely to take place, if the individual technology is not sufficient to lead to a prosecution.

#### 4.8. Enforcement through criminal law

Remote sensing is capable of technical prosecutions in relation to speed of vessel and breach of lash and stow regulations. There will still be major weak points in the legal system for areas such as prosecutions at night (for images), in poor weather, or when remote sensing data is simply too expensive to obtain or unfeasible due to the location of the VLMPA. VMS systems in tandem with strict requirements for their use can provide a feasible legal measure.

There is an increased awareness that sharing data between enforcement agencies is a key aspect of regulating IUU fishing. Flag states have an obligation to mount VMS on their vessels (under the 1993 Compliance Agreement [41] and the 1995 Fish Stocks Agreement [42]) but ensuring that data can be accessed by prosecuting authorities may not be straightforward. Increasing co-ordination with flag states and port states through the Port State Measures Agreement (PSMA) [43] shows encouraging developments in the sharing information between prosecuting authorities, though even these developments have been criticised for lacking sufficient teeth.

The PSMA establishes a framework to refuse access and require information from a suspected IUU vessel. The loss of access to port facilities from IUU vessels is clearly a significant threat, but starting point for any prosecution still remains with the flag state where the vessel is registered. This means that such prosecutions will meet similar admissibility of evidence requirements (though subject to the different needs of that particular jurisdiction) as prosecution by the Ascension Island Government. Furthermore the poor application of regulations by ‘flags of convenience’ states and the potential for the development of ‘ports of convenience’ with lax standards means the impact of the PSMA is yet to be fully felt [44]. However these developments in information through organisations such as Interpol and through regulations such as EuroSur [45] within the European Union improve the enforcement landscape significantly.

#### 4.9. Inferences from criminal sanction

There are some recommendations however which can be made from this assessment:

Satellite technology does show some potential for effective enforcement, particularly when allied to other forms of evidence gathering, which can provide unequivocal evidence of illegal fishing.

Traditional overflight by spotter aircraft or vessels are still useful means of providing the necessary “eyeball” evidence but these may be supplemented through the use and development of drone technology.

Acoustic technology provides more problematic evidence (because of the requirement for interpretation) but could be useful particularly when allied to other technologies or if developments in technology permit better automated interpretation of acoustic signatures.

The aggregation of different data sources enables a fuller picture to develop about fishing effort, thus enabled targeted enforcement.

In terms of legal development, there are hurdles relating to the prosecution of criminal offences per se and in particular obtaining sufficient evidence for an effective prosecution. Problems can be ameliorated through drafting of effective regulations such as:

‘Lash and stow’ obligations which deem fishing equipment to be deployed and therefore makes observation evidence easier to obtain (section 9, the Ordinance);

Transit provisions which require pre-registration of fishing vessels (Section 5, the Ordinance); and

Certification of evidence to minimise extensive technical arguments on admissibility (*Aregar*).

Because fishing prosecutions are relatively rare, there needs to be a sharing of best practice in the use of remote sensing evidence across similar jurisdiction and within the same jurisdictions, and also using different remote technology platforms (such as speed cameras in road traffic offences).

There is always a risk that even with a successful prosecution the size of the fine is not an effective deterrent. The Ascension Ordinance contains the potential for large fines and there is growing international recognition that many IUU vessels are part of organised crime groups, and Interpol is active in supporting investigations and prosecutions through their ‘purple notice’ and other systems, there may be the necessary international will to support such applications. This approach would require relatively minor amendment to current Ascension Island law which already incorporates the Proceeds of Crime Act 2002 by virtue of the English Law (Application) Ordinance 2005. This could be supplemented by the designation of IUU offences as ‘lifestyle’ offences (which for example apply to drug supply offences as much as breaches of Consumer Protection law in the form of the Consumer Protection From Unfair Trading Regulations 2008) and the burden reverses onto the convicted person to show that all of their income/expenditure/gifts are not the proceeds of crime. Indeed such prosecutions can lead to substantial financial receipts.

There is also a risk, that prosecution of a strict liability offence, such as a speed restriction, lash and stow regulation or VMS requirement, captures the accidental criminal rather than the more calculated and habitual IUU offender. This has been ameliorated by the imposition of ‘on the spot fines’ where IUU was not suspected but rules were broken and such ‘strict liability’ offences may encourage a culture of compliance within MPAs (section 28, the Ordinance).

Mounting a successful prosecution of vessels is still difficult and there are weaknesses in current remote sensing technology as its

application as a tool for effective prosecution. Developments in technology and regulation will ameliorate some of these weaknesses, but there are still evidential hurdles in place to restrict the use technology in the courts and to restrict the level of fines. This can be supplemented by data being collected by different authorities, through states sharing information through the operation of international regulations such as the PSMA, EuroSur or through third party agents such as OceanMind.

## 5. The second iteration of the legal engineering process- Civil legal framework

### 5.1. Brief

This time the brief is reversed. Having displayed the evidence which engineers can produce, can the legal framework itself be altered to make better use of the available data to penalise IUU fishing? To date fisheries enforcement in the academic literature has been considered in the context of criminal prosecutions of offenders breaching technical regulations. But there is another legal disincentive through the civil courts. This is where a wrongdoer is sued, usually for damage caused through some action which causes harm to another person (rather than prosecuted by the state and fined). This uses the civil rather than criminal process and approaches the issue as a dispute between two parties rather than as the state operating as regulator. It has some advantages. The burden of proof in civil proceedings is generally less: it is based on the balance of probabilities. In a prosecution the lead authority must demonstrate its case ‘beyond reasonable doubt’ for many cases, but in civil proceedings a court is seeking to balance two competing narratives: those rights of the claimant versus those of the defendant. Civil proceedings also give rise to a different suite of financial remedies based around financial loss (known as ‘damages’).

### 5.2. Enforcement through civil law

There are two potential ways for the civil proceedings to be used in the Ascension Island example. The first is via ownership of the fishery. Fish are ownerless until captured (*ferae naturae*) but the right to fish is potentially a valuable property right if managed properly. In the UK, in rivers and some tidal waters fishing rights can be bought and sold, but for the vast majority of UK waters (and thus in many common law jurisdiction) there is a public right to fish [46] which permits its citizens to fish its waters. As it stands the ownership status of these rights are unknown, they may belong to the public but they also may be ownerless [47]. Before a civil action can be taken the right to fish would need to be ‘vested’ or established in a particular legal body to establish the ‘boundaries’ over the resource (formal common property rights set out by Ostrom [48]. That right would need to be harmed before a civil action could be taken. However, the harm need not just be related to the loss incurred by the owner of the right (in the example this would be the Ascension Island Government), the court can award damages which is equivalent to the market value of the goods (*Kuwait Airways Corp v Iraqi Airways Co and another* [2002] UKHL 19) and potentially ‘special damages’ relating to additional costs incurred (*Simms, Re.* [1934] 1 Ch. 1). The researchers were unable to find case law relating to the use of remote sensing to protect marine fishing rights in a remote area, but (in legal terms) the approach is similar to that adopted by a submarine cable company, Tele Greenland, operating in Canadian waters seeking to recoup their costs after their infrastructure was damaged, allegedly by fishing vessels [49].

Civil remedies have, however, been used in fisheries actions. Under US legislation (the Lacey Act) officials were able to apply both criminal and civil sanction in the case of *United States v Bengis* [2006] WL 3735654 (SDNY Dec. 19, 2006). This resulted in an award of ‘restitution’ by the US Southern District Court for New York to South Africa of over US\$ 29 million for the illegal harvest of tons of rock lobster from South African waters and exporting it to the United States of America.

[50] Restitution in this case was based on the (higher) market value rather than the (lower) costs of remediation.

It is likely that changes would be needed to the Ascension Island legal system. Ascension Island, like many jurisdictions, does not currently expressly claim ownership of its fishing rights or have use civil remedies for such activities. The Fisheries Limits (Licensing of Fishing) (Offshore Zone) Order 2015 gives Ascension Island’s Director of Fisheries the power to authorise the activity, but as a regulator not as an owner. It may be that ownership is implied, but the safer course would be to expressly claim public ownership of fishing rights or to expressly reserve other civil remedies. The UK already reserves civil remedies for other environmental prosecutions under the Regulatory Enforcement and Sanctions Act 2008.

Tort remedies can also be claimed through granting legal personality, sometimes referred to as ‘standing’ [51]. Companies have long claimed legal personality (*Salomon v Salomon & Co Ltd* [1897] AC 22 (HL), 51) and recently this approach has been extended to natural features. The Whanganui River in New Zealand was granted legal personality as a means of both redressing native title claims and also securing the future of the river itself [52]. Having legal personality means that the resource (in this case it would be the fishery or even the marine space itself) would have a representative appointed both to protect it, which brings an additional suite of tort remedies (such as trespass) but also to promote it [53]. This would also permit a wider degree of protection than simply looking at illegal fishing, but also secure against other issues which may assume greater significance over the forthcoming decades when environmental pressures are likely to increase. Jameson et al. [54] identified that many of the threats to MPAs were wider: citing atmospheric (in his example dust from Africa, global climate change), terrestrial, (perhaps of a lesser concern in Ascension Island) and oceanic (through pollutants being carried to the area). Legal personality, particularly in the area of the Ascension Island MPA which is likely to be highly protected, would have an additional currency in relation to its narrative and thus its reputation. This is a move away from approaches which are simply based around bureaucratic structures, such as property rights [55] or ‘black letter’ enforcement law. Legal personality places the ecosystem at the heart of the MPA; its whole management would need to be reconsidered from that perspective.

### 5.3. Inferences from civil sanction

In both cases access to remote sensing data poses problems. Prosecution authorities only have access to VMS data with permission from the vessel/flag state and under the auspices of the PSMA and other international information sharing agreements (such as the 1993 Compliance Agreement, the 1995 Fish Stocks Agreement). If these agreements work effectively, such information may be available to a criminal prosecuting authority. It does not, however, automatically follow that the information can be used for civil purposes (ie non-criminal sanction), particularly where the fishery was owned by a third party (such a charity or other fishing business). It is notable the first of the Canadian legal actions by the Tele Greenland was an action against the Canadian fisheries authorities to force the disclosure of the VMS data for civil use [56]. There is clearly an issue even with remote sensing data collected by public authorities over the use of those data. Where those data are collected by private bodies (or for civil purposes), there is bound to be further questions of cost and intellectual property rights.

Even outside the notoriously litigious US, there are plenty of examples of the use of tort law [57] to protect private fisheries (*Pride of Derby and Derbyshire Angling Association v British Celanese* [1953] Ch 149) and it is not stretching that precedent too far to cover vested public fisheries, expanding civil remedies through statute or to grant legal personality. There are, of course, costs risks attendant on any court proceedings, but again there are opportunities for costs to be

reclaimed from the defendant, moreover there are reputational advantages, from being seen to be taking all effective measures possible. Justice not just be done, but be seen to be done.

However the basic problem of the utility of the remote sensing data in court proceedings still remains.

## 6. The third iteration of the legal engineering process – Civil society legal frameworks

### 6.1. Brief

From the engineer's perspective the court process still struggles with the best way to use the data it can provide. The third iteration interrogates the legal system still further to investigate whether there are other legal frameworks which can make better use of those data.

### 6.2. Enforcement through civil society legal frameworks

The laws governing human behaviour extend further than the direct adversarial activities of the court room. There are a plethora of further contractual and other relations which are governed by choice rather than process. The reputation of an activity or an individual will affect whether businesses chose to operate in a particular sector. Much as the grant of legal personhood would enhance the reputation of an MPA so it is possible for data to be used to affect the reputation of a fishing business. Ships are noticeable, obtrusive and slow moving objects and there are a limited number of operators in the sector. It is therefore possible for an individual ship or business to acquire a poor reputation which can be informed through the use of remote sensing data. This is something which is already starting to happen [58] and leading to successful prosecutions of vessels fishing illegally. The UK's Marine Management Organisation mounted a successful prosecution for quota offences against Ocean Rover Limited in 2016, at the same time as a prosecution using VMS data, reporting that the fishing vessel was in a real time closure area at speeds consistent with fishing activities, contrary to a condition in its fishing vessel licence [59].

“In this case fisheries patrols and Vessel Monitoring System data were combined to detect and provide evidence to the court of these offences. Fisheries offences of this nature do not allow for a level playing field amongst operators.”

Such data reporting suspicious activity need not just drive enforcement, particularly in remote VLMPAs, where data from boarding vessels or even radar or image data may be difficult to obtain. The PSMA potentially restricts port access to vessels on the basis of their reputation and provides a framework to obtain hard evidence by boarding a vessel when it comes into port at articles 8 and 9.

There are also other areas where a business reputation is important for legal or quasi-legal arrangements. These include:

- (1) Obtaining vessel insurance – insurers check the reputation of the insured to assess their risk;
- (2) Obtaining bank finance for vessels – banks, as a rule, check their borrower's ability to repay;
- (3) Selling fishery products – there are increasing chain of custody requirements from food buyers;
- (4) Accreditation schemes relating to sustainable fishing – the reputation of the accreditation scheme itself is imperilled fishing is permitted to continue by vessels with a poor reputation;
- (5) Obtaining a licence to fish in a coastal state's waters – coastal states will want to assess the reputation of any business obtaining a licence to operate in their waters;
- (6) Obtaining a quota/licence from the Regional Fisheries Management Organisations – RFMO's hold blacklists of IUU vessels; and
- (7) International reputation – Flag states representing distant water fleets over fisheries access agreements or on Regional Fisheries

Management Organisations on the high seas will be live to the reputational risk of representing poor business practice.

Such measures can be at least as powerful as an effective prosecution, as these directly affect the ability of a poorly operated fishing business to trade. For instance strict chain of custody requirements are increasingly commonplace in the UK supermarket [60]; fishing business reputational data is likely to have a major impact of the sector's buying policy. Indeed the reputation of the assessors themselves is vulnerable if unsustainable fishing is permitted in a sector they assess [61]. The reputation of the large corporations which own fishing businesses has also been under scrutiny through operations such as the Fish Tracker Initiative; this highlights the danger of unsustainable fishing practice to investors in fishing businesses with revenues of around \$70.6 billion [62].

### 6.3. Inferences from civil society legal sanction

The food buying sector has been using chain of custody approaches for many years and this is undoubtedly effective, the broadening of the approach to include more reputational data in other sectors (such as the banking and insurance sector) is to be welcomed.

In engineering terms many of these data sets may already exist, but co-ordinating the data, dealing with intellectual property issues and interrogating the data requires a centralised effort from a multitude of potential users. Reference agencies have long provided such commercial information and there is an intrinsic connection to the commercial market. However the ownership and use of remote sensing data will present logistical problems for those civil users seeking to use it: the data may exist, but they may need to pay to use it or face a difficult struggle acquiring it from public authorities.

## 7. Further discussion

It is clear from the Ascension Island example that there are still many improvements which can be made in the liaison between remote sensing technology and the legal system. However such an approach involves looking at the legal system as a whole rather than simply treating prosecution as the only effective legal deterrent. Prosecutions such as the *Elqui* send out a grave warning to IUU fishing businesses, but then so do prohibitive insurance premiums.

At Fig. 1 we have attempted to describe the various mechanisms and assess their cost and effectiveness. This is not an exact science (and never can be) but it is clear that there are relatively cheap solutions to make better use of the remote sensing data. However, the use of data to effect reputations, while it may be cheaper in overall terms, suffers from some weaknesses in that it involves a pooling of commercial resources to pay for it and requires co-ordination of intellectual property rights in the remote sensing data. The challenge is as much about developing the technology as it is about ensuring the social systems are in place to make adequate use of the data that technology provides.

There is a further point to be drawn from this. Much criticism has been levelled at VLMPAs, in their current form that criticism is not unfounded, but like the church of Sagrada Família in Barcelona, the work of developing VLMPAs is incomplete. There is an acceptable pathway for the creation of MPAs which has the steps of designation, regulation then enforcement. Information sharing through the PSMA, Ocean Mind and EuroSur demonstrates progress along that transition. This paper demonstrates that there is still some distance to travel before appropriate enforcement is in place, but that there are still many actions which can be taken before VLMPAs can be written off as a failure [63], as long as designation is not seen as the end point but the start of the journey.

In the particular Ascension Island example, the Island itself has proved to be an exceptional testing ground for the effectiveness of remote VLMPAs. The governance arrangements, of what is effectively a

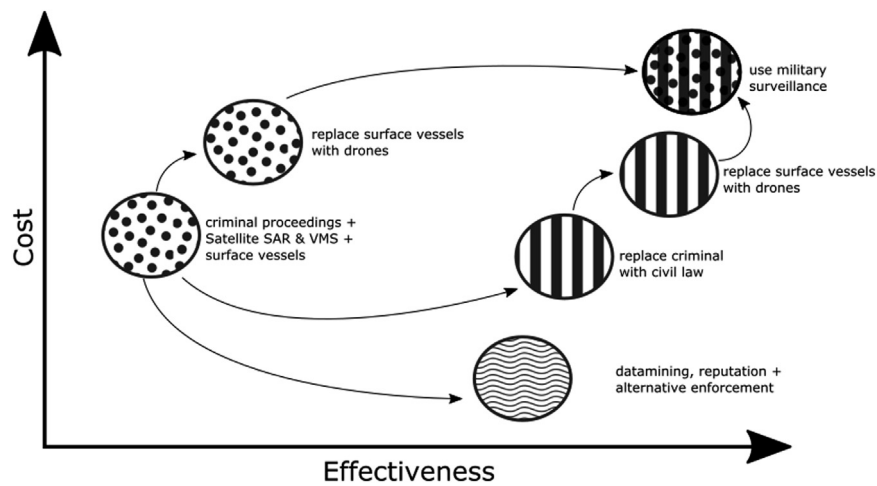


Fig. 1. Differing enforcement mechanisms rated on cost and effectiveness.

microstate, mean that changes to the regulatory system are not particularly difficult. As it is surrounded by the high seas, protection of the Ascension Island VLMPAs lends a currency to any arguments for further protection on the high seas. It would be insupportable if the UK, following its international commitments to marine conservation, were to be undermined by overfishing on the high seas of the straddling stocks which the Ascension Island VLMPA protects. Frustratingly, once again, this leaves further actions to take before the VLMPA is at its most effective, but those actions are identifiable and feasible.

## 8. Conclusions

It is clear that VLMPAs create challenges in terms of enforcement, however there are clear signs that the current system is beginning to generate effective technical solutions. The increasing development of tamper-proof devices and use alongside strict liability offences have started to give officers a suite of effective measures for prosecution. At present not all vessels carry these devices and the devices themselves are still in the process of development. This strand continues to be an important area of development.

While engineering research will inevitably continue into remote sensing technologies, the most promising developments seem to be in terms of the use of drones. Fixed wing, solar powered devices are able to remain aloft for increasing periods and such ‘eyewitness’ data is exceptionally useful for a prosecution. Their potential could be particularly effective when deployed in tandem with other remote sensing data (such as SAR) and scientific data which could show anomalous behaviour of fishing vessels and the likely presence of commercial fish species.

In legal terms there is a need to share best practice so that well-crafted regulations make the best use of data for prosecution in the courts. There is also the possibility through the ownership, civil sanctions or legal personality to craft a further suite of civil law remedies. The development of civil remedies in this area is in its infancy and represents a significant prospect for development, using established terrestrial practice. Legal personality, giving the MPA a legal voice of itself, would have the additional benefit of a reputational, almost philosophical, narrative often lacking in the dry application of science to real world issues.

Underpinning all these developments lies a ‘grand challenge’ to pool remote sensing data and use commercial reputation as a means of driving IUU out of the global market. There are clear steps in the right direction with EuroSur (though Brexit may have negative consequences here) and the PSMA, but this approach faces challenges in terms of co-ordination and the use of data: it could turn out to be the most rewarding method of all. Prosecution will always need to be conducted by

national authorities, but national (such as licensing bodies) and supranational bodies (such as banks, insurers, food wholesalers, labelling bodies and Regional Fisheries Management Organisations) should also have access to these data to assess the reputation of a fishing business and drive out disreputable practice.

In reality all these mechanisms will need to be explored. The designation of MPAs without enforcement mechanisms is not in itself a bad thing as long as it is part of a longer term plan: to designate, regulate and enforce. There needs to be an understanding that enforcement will follow, either through prosecution or other social means. The conversation between law, engineering and fisheries management is something that needs to continue.

Finally, the researchers should reflect on the Ascension Island example. At the start of this paper remote VLMPA faced considerable criticism. That criticism is necessary to make sure that the cynical designation of ‘paper parks’ is not permitted to happen as an end in itself. However, it is clear that there are methods of making the Ascension Island VLMPA operate more effectively. The flexibility of the Ascension Island governance system make it a unique opportunity to test those systems. Not just for the waters around the island, but also the adjacent waters on the high seas and as a potential template for VLMPAs elsewhere.

## Acknowledgements

The authors would like to thank the Blue Marine Foundation for their invaluable assistance in this paper.

## Funding

The research is part funded by the Lloyd’s Register Foundation, a charitable foundation helping to protect life and property by supporting engineering-related education, public engagement and the application of research.

## References

- [1] A. Kalinauckas, Eyes on the seas, *Eng. Technol.* 10 (3) (2015) 68–69, <http://dx.doi.org/10.1049/et.2015.0353>.
- [2] S.C. Jameson, M.H. Tupper, J.M. Ridley, The three screen doors: can marine “protected” areas be effective? *Mar. Pollut. Bull.* 44 (11) (2002) 1177–1183, [http://dx.doi.org/10.1016/S0025-326X\(02\)00258-8](http://dx.doi.org/10.1016/S0025-326X(02)00258-8).
- [3] S. Advani, L. Rix, D. Aherne, M. Alwany, D. Bailey, Distance from a fishing community explains fish abundance in a no-take zone with weak compliance, *PLoS One* 10 (5) (2015) e0126098, <http://dx.doi.org/10.1371/journal.pone.0126098>.
- [4] A. Rife, B. Erismann, A. Sanchez, O. Aburto-Oropeza, When good intentions are not enough ... Insights on networks of “paper park” marine protected areas, *Conserv. Lett.* 6 (3) (2012) 200–212, <http://dx.doi.org/10.1111/j.1755-263X.2012.00303>.
- [5] P. Guidetti, M. Milazzo, S. Bussotti, A. Molinari, M. Murenu, L. Tunesi, Italian



- marine reserve effectiveness: does enforcement matter? *Biol. Conserv.* 141 (3) (2008) 699–709, <http://dx.doi.org/10.1016/j.biocon.2007.12.013>.
- [6] M. Pieraccini, S. Coppa, G.A. De Lucia, Beyond marine paper parks? Regulation theory to assess and address environmental non-compliance, *Aquat. Conserv. Mar. Freshw. Ecosyst.* 27 (1) (2016) 177–196, <http://dx.doi.org/10.1002/aqc.2632>.
- [7] R.L. Singleton, C.M. Roberts, The contribution of very large marine protected areas to marine conservation: giant leaps or smoke and mirrors? *Mar. Pollut. Bull.* 87 (1–2) (2014) 7–10, <http://dx.doi.org/10.1016/j.marpolbul.2014.07.067>.
- [8] P.J.S. Jones, E.M. De Santo, Viewpoint – Is the race for remote, very large marine protected areas (VLMPPAs) taking us down the wrong track? *Mar. Policy* 73 (2016) 231–234, <http://dx.doi.org/10.1016/j.marpol.2016.08.015>.
- [9] S. Jennings, The role of marine protected areas in environmental management, *ICES J. Mar. Sci.: J. du Cons.* 66 (1) (2008) 16–21, <http://dx.doi.org/10.1093/icesjms/fsn163>.
- [10] K. Newton, I. Côté, M. Pilling, S. Jennings, N. Dulvy, Current and future sustainability of island coral reef fisheries, *Curr. Biol.* 17 (7) (2007) 655–658, <http://dx.doi.org/10.1016/j.cub.2007.02.054>.
- [11] M.U. Bailey, R. Sumaila, M. Lindroos, Application of game theory to fisheries over three decades, *Fish. Res.* 102 (1) (2010) 1–8, <http://dx.doi.org/10.1016/j.fishres.2009.11.003>.
- [12] A. Di Franco, P. Thiriet, G. Di Carlo, C. Dimitriadis, P. Francour, N.L. Gutiérrez, P. Guidetti, Five key attributes can increase marine protected areas performance for small-scale fisheries management, *Sci. Rep.* 6 (1) (2016) 38135, <http://dx.doi.org/10.1038/srep38135>.
- [13] G. Edgar, R. Stuart-Smith, T. Willis, S. Kininmonth, S. Baker, S. Banks, N. Barrett, R. Thomson, Global conservation outcomes depend on marine protected areas with five key features, *Nature* 506 (7487) (2014) 216–220, <http://dx.doi.org/10.1038/nature13022>.
- [14] A.D. Couper, H.D. Smith, B. Ciceri, *Fishers and Plunderers: theft, Slavery and Violence at Sea*, Pluto Press, Chicago, 2015.
- [15] Oppian, *Haliectica*, Harvard University Press, Cambridge, 1928, <http://dx.doi.org/10.4159/dlcl.oppian-haliectica.fishing.1928>.
- [16] T. Appleby, M. Everard, R. Palmer, S. Simpson, Plenty More Fish in the Sea? A working paper on the legal issues related to fishing beyond maximum sustainable yield: A UK Case Study, University of the West of England, Bristol, 2013.
- [17] G. Oduntan, The evidentiary issues arising from the proposed use of the satellite based vehicle monitoring system and electronic logbooks in the FishCAM project within the European Union, *Int. J. Law Inf. Technol.* 12 (2004) 74–100.
- [18] Marine Management Organisation. Innovations and technology to protect our Overseas Territories. Retrieved from [www.marinedevelopments.blog.gov.uk/2017/10/19/innovations-and-technology-to-protect-our-overseas-territories/](http://www.marinedevelopments.blog.gov.uk/2017/10/19/innovations-and-technology-to-protect-our-overseas-territories/).
- [19] M. Everard, B. Pontin, T. Appleby, C. Staddon, E.T. Hayes, J. Barnes, J. Longhurst, Air as a common good, *Environ. Sci. Policy* 33 (2013) 354–368, <http://dx.doi.org/10.1016/j.envsci.2012.04.008>.
- [20] K. Newton, I. Côté, M. Pilling, S. Jennings, N. Dulvy, Current and future sustainability of island coral reef fisheries, *Curr. Biol.* 17 (7) (2007) 655–658, <http://dx.doi.org/10.1016/j.cub.2007.02.054>.
- [21] R. Purdy, Using earth observation technologies for better regulatory compliance and enforcement of environmental Laws, *J. Environ. Law Pract.* 22 (1) (2009) 59–87, <http://dx.doi.org/10.1093/jel/eqp027>.
- [22] RSPB. An 'ascension island ocean sanctuary': an initial review of options for surveillance and enforcement a report for the centre for environment, fisheries & aquaculture science, the ascension island government, & the UK foreign & commonwealth Office. Sandy: RSPB. 2014. Retrieved from [https://www.rspb.org.uk/Images/RSPB\\_ascension\\_island\\_report\\_2014\\_tcm9-382816.pdf](https://www.rspb.org.uk/Images/RSPB_ascension_island_report_2014_tcm9-382816.pdf).
- [23] B.J. Bergseth, G.R. Russ, J.E. Cinner, Measuring and monitoring compliance in no-take marine reserves, *Fish. Fish.* 16 (2) (2013) 240–258, <http://dx.doi.org/10.1111/faf.12051>.
- [24] M. O'Flainn, D. Ormerod, Social networking material as Criminal Evidence, *Crim. Law Rev.* 486 (2012) 499–501 (Retrieved from), <https://city.ri.talis.com/items/BA65A6C0-7352-119C-404C-4CBE84038F37.html>.
- [25] E.J. Molenaar, Port State Jurisdiction to combat IUU fishing: the Port State measures agreement, in: D.A. Russell, D.L. Van der Zwaag (Eds.), *Recasting Transboundary Fisheries Management Arrangements in Light of Sustainability Principles: Canadian and International Perspectives*, Brill Publishing, Leiden, 2010, pp. 369–386.
- [26] Penguin News, April 19). Poacher caught in South Georgia must pay £ 300,000. Retrieved from <http://en.mercopress.com/2005/04/19/poacher-caught-in-south-georgia-must-pay-300-000>.
- [27] Penguin News, 7 October). Update. Retrieved from <http://en.mercopress.com/2005/10/07/penguin-news-update>.
- [28] Watling, May 18). Fishing observers intimidated and bribed by EU crews. *The Guardian* Retrieved from <https://www.theguardian.com/environment/2012/may/18/fishing-inspectors-intimidated-bribed-crews>, 2012.
- [29] R. Purdy, *Satellite Monitoring of Environmental Laws: Lessons to be Learnt from Australia*, UCL Centre for Law and the Environment, London, 2010 (ISBN: 978-0-9560806-1-5).
- [30] P. Manoa, Judicial responses to illegal fishing prosecutions in Fiji, *J. South Pac. Law* 10 (1) (2006) 1–11.
- [31] D.M. Sodik, Analysis of IUU fishing in Indonesia and the Indonesian legal framework reform for monitoring, control and surveillance of fishing vessels, *Int. J. Mar. Coast. Law* 24 (2009) 67–100, <http://dx.doi.org/10.1163/157180808X353984>.
- [32] S.B. Colegrove. Project Jindalee: from bare bones to operational OTHR. Record of the in: Proceedings of the IEEE 2000 International Radar Conference [Cat. No. 00CH37037], Alexandria: VA, 2000, pp. 825–830.
- [33] Future Oceans, February 8). Satellite technologies at the forefront of the fight against illegal fishing. Retrieved from [www.futureoceans.org/satellite-technologies-at-the-forefront-of-the-fight-against-illegal-fishing/](http://www.futureoceans.org/satellite-technologies-at-the-forefront-of-the-fight-against-illegal-fishing/).
- [34] J. Serle, December 11). Army moves Watchkeeper drone training to tropics for winter after flying problems in UK weather. Retrieved from <https://www.thebureauinvestigates.com/stories/2015-12-11/army-moves-watchkeeper-drone-training-to-tropics-for-winter-after-flying-problems-in-uk-weather>, 2015.
- [35] G. Ogden, L. Zurk, M. Jones, M. Peterson, Extraction of small boat harmonic signatures from passive sonar, *J. Acoust. Soc. Am.* 129 (6) (2011) 3768–3776, <http://dx.doi.org/10.1121/1.3583500>.
- [36] H.J. Wang, R.J. Yang, J.H. Han, Signatures extraction of ship radiated noise based on passive sonar, *Appl. Mech. Mater.* 568–570 (2014) 233–237, <http://dx.doi.org/10.4028/www.scientific.net/AMM.568-570.233>.
- [37] N. Leal, E. Leal, G. Sanchez, Marine recognition vessel recognition by acoustic signature, *ARNP J. Eng. Appl. Sci.* 10 (20) (2015) 9633–9639 (ISSN 1819-6608).
- [38] M. O'Flainn, D. Ormerod, Social networking material as Criminal Evidence, *Crim. Law Rev.* 486 (2012) 499–501 (Retrieved from), <https://city.ri.talis.com/items/BA65A6C0-7352-119C-404C-4CBE84038F37.html>.
- [39] British Broadcasting Corporation, September 4). Police Struggling to Grasp Social Media. Retrieved from <https://www.bbc.co.uk/news/uk-wales-41127674>, 2017.
- [40] OceanMind, January). Ascension Island Case Study. Retrieved from <http://www.oceanmind.global/ascension-island-case-study/>.
- [41] Food and Agricultural Organisation of the United Nations. *Compliance Agreement*. Retrieved from <http://www.fao.org/docrep/006/y5357e/y5357e07.htm>.
- [42] Food and Agricultural Organisation of the United Nations. (1995). The United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (in force as from 11 December 2001). Retrieved from [http://www.un.org/depts/los/convention\\_agreements/convention\\_overview\\_fish\\_stocks.htm](http://www.un.org/depts/los/convention_agreements/convention_overview_fish_stocks.htm).
- [43] Food and Agricultural Organisation of the United Nations Port State Measures Agreement. Retrieved from <http://www.fao.org/port-state-measures/background/en/>.
- [44] E. Witbooi, Illegal, unreported and unregulated fishing on the High Seas: the Port State Measures Agreement in context, *Int. J. Mar. Coast. Law* 29 (2014) 290–320, <http://dx.doi.org/10.1163/15718085-12341314>.
- [45] European Commission, October 22) Regulation (EU) No 1052/2013 of the European Parliament and of the Council establishing the European Border Surveillance System (Eurosur). Retrieved from <https://eur-lex.europa.eu/legal-content/EN/TXT/?Uri=celex:32013R1052>, 2013.
- [46] T. Appleby, The Public right to fish: is it fit for purpose? *J. Water Law* 16 (6) (2005) 201–205 (ISSN 1478-5277).
- [47] T. Appleby, M. Everard, R. Palmer, S. Simpson, Plenty more fish in the sea? A Working Paper on the Legal Issues Related to Fishing Beyond Maximum Sustainable Yield: A UK Case Study, University of the West of England, Bristol, 2013.
- [48] E. Ostrom, *Governing the Commons: The Evolution of Institutions for Collective Action*, Cambridge University Press, Cambridge, 1990, pp. 335–336.
- [49] CBC News, November 7). Halifax trawler owner denies vessel damaged subsea cable. Retrieved from [www.cbc.ca/news/canada/nova-scotia/halifax-trawler-owner-denies-vessel-damaged-subsea-cable-1.2826531](http://www.cbc.ca/news/canada/nova-scotia/halifax-trawler-owner-denies-vessel-damaged-subsea-cable-1.2826531).
- [50] E. Witbooi, Illegal, unreported and unregulated fishing on the High Seas: the Port State measures agreement in context, *Int. J. Mar. Coast. Law* 29 (2014) 290–320, <http://dx.doi.org/10.1163/15718085-12341314>.
- [51] C. Stone, *Environmental Ethics: The Big Questions, Should Trees Have Standing? Toward Legal Rights for Natural Objects* 13 (1972).
- [52] A. Hutchison, The Whanganui River as a legal person, *Altern. Law J.* 39 (3) (2014) 179–182, <http://dx.doi.org/10.1177/1037969X1403900309>.
- [53] M.B. Rodriguez Ferrere, New Zealand - Whanganui River becomes a “person”, *Public Law* (2017) 524–525.
- [54] S.C. Jameson, M.H. Tupper, J.M. Ridley, The three screen doors: can marine “protected” areas be effective? *Mar. Pollut. Bull.* 44 (11) (2002) 1177–1183, [http://dx.doi.org/10.1016/S0025-326X\(02\)00258-8](http://dx.doi.org/10.1016/S0025-326X(02)00258-8).
- [55] E. Ostrom, *Governing the Commons: the Evolution of Institutions for Collective Action*, Cambridge University Press, Cambridge, 1990, pp. 335–336.
- [56] CBC News, March 13). Broken undersea telecom cable: Greenland seeks Canadian culprit. Retrieved from [www.cbc.ca/news/canada/nova-scotia/broken-undersea-telecom-cable-greenland-seeks-canadian-culprit-1.2570761](http://www.cbc.ca/news/canada/nova-scotia/broken-undersea-telecom-cable-greenland-seeks-canadian-culprit-1.2570761).
- [57] B. Pontin, Secret achievements of nineteenth century nuisance law, *Environ. Law Manag.* 19 (2007) 271.
- [58] Food and Agriculture Organization of the United Nations. GFCM illegal, unreported and unregulated (IUU) vessel list. Retrieved from <http://www.fao.org/gfcm/data/fleet-iuu-vessel-list/en/>.
- [59] Marine Management Organisation, February 24). Fine of £17,469.50 for fisheries offences in case brought by MMO. Retrieved from <https://www.gov.uk/government/news/fine-of-1746950-for-fisheries-offences-in-case-brought-by-mmo>, 2016.
- [60] Marine Stewardship Council. Tesco nabs top sustainable fish counter award. Retrieved from [www.msc.org/newsroom/news/tesco-nabs-top-sustainable-fish-counter-award?Fromsearch=1&isnewssearch=1&categories=shopping-and-eating](http://www.msc.org/newsroom/news/tesco-nabs-top-sustainable-fish-counter-award?Fromsearch=1&isnewssearch=1&categories=shopping-and-eating).
- [61] The Guardian, October 31). Consumers 'betrayed' over sustainability of world's biggest tuna fishery. Retrieved from <https://www.theguardian.com/environment/2017/aug/31/consumers-betrayed-over-sustainability-of-worlds-biggest-tuna-fishery>, 2017.
- [62] B. McCarron. Empty Nets: How overfishing risks leaving investors stranded. Fish Tracker Initiative. Retrieved from <http://fish-tracker.org/report/>.
- [63] L. Rocha, (, March 20). Bigger is not better for ocean conservation. *New York Times*. Retrieved from <https://www.nytimes.com/2018/03/20/opinion/environment-ocean-conservation.html>, 2018.