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Governance of High Seas Ecosystems & Big Data

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Glossary

ABNJ	Areas Beyond National Jurisdiction
AI	Artificial Intelligence
BE	Blue Economy
BEKS	Blue Economy Knowledge System
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources
EDA	Ecosystem Diagnostic Analysis
EEZ	Exclusive Economic Zone
EM	Electromagnetic
FFEM	French Global Environment Fund
GEF	Global Environment Facility
GFW	Global Fishing Watch
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICM	Integrated Coastal Management
IMO	International Maritime Organization
IUCN	International Union for Conservation of Nature
IUUF	Illegal, Unreported & Unregulated Fishing
MPA	Marine Protected Area
MSP	Marine Spatial Planning
OSPAR	Oslo Paris Commission
PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
RFMO	Regional Fisheries Management Organisations
SAR	Synthetic Aperture Radar
SDG	Sustainable Development Goal
SIDS	Small Island Developing States
SSC	Sargasso Sea Commission
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNGA	United Nations General Assembly
VIIRS	Visible Infrared Imaging Radiometer Suite
VMS	Vessel Monitoring Systems
WCPFC	Western and Central Pacific Fishing Convention

1 Background

The Sargasso Sea is a 2 million square mile open ocean high seas ecosystem. In 2022, the Sargasso Sea Commission (SSC) will be embarking on a major Ecosystem Diagnostic Analysis (EDA) financed by grants from the Global Environment Facility (GEF) and the French Global Environment Fund (FFEM) with the support of a wide number of partners including the ten Government Signatories to the 2014 Hamilton on Collaboration for the Conservation of the Sargasso Sea. In support of this project, the Swedish Government has mobilized funding through the International Union for Conservation of Nature (IUCN) for a study on the challenges and opportunities presented by the possible use of "Big Data" and Artificial Intelligence (AI) systems for the management and conservation of high seas ecosystems.

2 Report Purpose & Methodology

The report[1] aims to articulate the potential opportunities in the utilisation of big data and AI in providing future ocean governance at the global level, set in the context of a high-level user requirements assessment of the challenges to effective ocean/high seas governance. Our research and analysis focused particularly on the complexities associated with ungoverned sea spaces in Areas Beyond National Jurisdiction (ABNJ), a key characteristic and fundamental challenge faced in the Sargasso Sea. It reviews the current state-of-technology in earth- and space-based remote sensing and the use of AI technologies to access and analyse big data, creating information in a strategic and cost-effective way for the governance, management, and conservation of remote ocean areas.

What the report does not aim to provide are specific solutions to the considerable barriers that exist in data-sharing; this is outside the scope of this work, although it does set-out the key data-sharing challenges that do need to be solved.

To do this we drew on the advice of the SSC Expert and User Groups and others, to help us assess these technologies and to map potential future developments. We also leveraged the considerable capabilities of NLA International's in-house bespoke market intelligence curation and activation system, Blue Economy Knowledge System (BEKS), to rapidly search on-line communities to assist in quickly building a contemporary picture of what is being discussed, researched, and operationalised. The report identifies key technologies, datasets and stakeholders including data and technology providers, associated existing and potential end-users, and assesses the possibilities and limitations of existing big data and AI capabilities and initiatives. It outlines some of the risks, challenges, and opportunities they present for effective surveillance, monitoring, and potentially, enforcement of conservation and management measures in remote areas of the oceans beyond national jurisdiction.

It aims to suggest ways in which small organisations such as the SSC can use big data and AI solutions to strategically influence the long-term data gathering, monitoring, valuing, governance and management of remote ocean spaces and their ecosystems, and suggest a user decision-making protocol, covering factors such as time, cost, quality, availability, and compatibility.

[1] Caveat: this report has been somewhat restricted, both in timescale and resource available. As such, it does not seek to present itself in the style, or with the heft, of an authoritative peer-reviewed academic paper.

3 Executive Summary

An Executive Summary will be included in the final version of the Interim Report. This will allow us to incorporate as much of the feedback, insights and guidance gained during our engagements with the Expert & User Groups and others, such as during the online Workshop of 29th November 2021 and the written comments received in response to the circulation of this first draft.

3.1 (Interim) Conclusions

- The provision of contemporary good Ocean Governance and Technology underpinned by "Big Data/AI" are inextricably linked.
- The Technology exists today to generate suitably diverse, relevant, and sufficient ocean data. This "Big Data" can be analysed using Artificial Intelligence to:
  - Generate the necessary understanding of the relationships between human activities and their impact on the complex ocean biological and environmental ecosystems.
  - Provide compelling evidence to establish the need for good Ocean Governance by informing decision-makers responsibly for creating good Ocean Governance policies.
  - Generate convincing, near-real time, maritime domain awareness to enable enforcement of human-related activities and where appropriate underpin subsequent judicial action.
  - Provide suitable Measures of Effectiveness of in-place Ocean Governance policies to allow for subsequent review, revision, and release.
- A consistent barrier to justifying, evidencing, and implementing Ocean Governance is data sharing, availability, quality, and utility. Addressing these is a first order need and may be a pre-requisite to many AI methods. Specifically, data sharing and analytics platforms, combined with a drive for open data, is foundational to technologized governance.
- A key challenge in using big data and AI for Ocean Governance is one of trust; both trust in data and methods, and trust in key organisations and platforms to enable data sharing towards improved understanding. There are technical and human elements to this, and trust must be established alongside technology, with a focus on open data, algorithms, and methodologies.

3.2 Recommendations

To be included in the final version of this Interim Report.

4 The Needs of Ocean Governance and Technology

4.1 The need for governance

Ocean Governance is a strategy used to manage human activities in an ocean towards sustainable use and ecological regeneration. It is informed by, and includes, a whole range of economic, scientific, ecological, and financial activities and policies, covering all activities in the ocean space, at local, regional, national, and global levels. The process of establishing governance is granular, transparent, consultative, and ultimately evidence based. Ocean Governance necessarily involves action, response, and enforcement, requiring physical implementation at the lowest level, typically for remote sensing and responsive enforcement.

The industrial use of the oceans in general (and especially of the high seas) can be seen as a tragedy of the commons. Almost two thirds of the oceans are ungoverned and seeing a race to the bottom from industrial fishing, with fleets subsidised to fish greater and greater distances from shore. The consequence of this is diminishing resource availability and significant ecological damage. In the absence of governance there is no reason to expect that behaviour will change. Furthermore, other industrial uses of the ocean, such as seabed mining, whether in the high seas or Exclusive Economic Zones (EEZ) (particularly of developing and industrialising nations), will likely proceed in the same way if not subject to considered regulation.

In both economic and ecological senses, this practice is unsustainable. It can also be seen as self-reenforcing. In a tragedy of the commons, it is often the case that mitigating evident issues (such as resource depletion), and therefore enabling sustainability, is consistently seen as ‘someone else’s problem’. Therein, whilst sustainable solutions and practices enabling long-term economic benefit might exist, it can require external impetus (often in the form of governance) to change behaviour. This is not a theoretical issue, and we have seen collapses in fisheries already. In general, we need approaches to managing our natural ocean resources more effectively.

In areas with active Ocean Governance, efficacy can be limited due to limitations in monitoring and enforcement. This is particularly true for Small Island Developing States (SIDS), for whom enforcement can be a challenge beyond immediate coastal waters. Remote sensing and analytics tools are seen as a potential solution here and have seen success in reducing illegal fishing around Ascension Island.

It is also not always the case that where governance exists, it is sufficient. Loopholes in governance, especially pertaining to fishing, drive exploitative practices. An example of this can be seen in squid fishing, which does not fall under the competence of Regional Fisheries Management Organisations (RFMOs) and is seeing rapidly increasing fishing.

There is a natural competition between governance and entrenched interests. For example, a challenge with limiting fishing zones is managing the displacement of fishing activities. Once the fishing fleets begin to regularly use a particular ocean space, moving them on is challenging. Incumbent interests generally expect governing bodies to facilitate their continued activities post-displacement, which is challenging and slows policy implementation. Therein, there is a clear time imperative to implement Ocean Governance, particularly in areas where it is completely, or effectively, absent. This has particular pertinence to the high seas, and the Sargasso Sea.

4.2 Bringing governance to the high seas and the Sargasso Sea

The points above hold true for Ocean Governance in general, however there is an increasing focus on the high seas.

There is growing appetite for governance outside of EEZs. Problems that start outside EEZs can migrate inside gradually, both in terms of human activity, and its ecological consequences. There is also a growing sense of inequity between those fishing in and out of EEZs. Very few nations have the vessels necessary for distant fish capture; these activities favour a minority of developed nations, at the cost of global resource availability and local opportunity.

Thus, a key issue today is understanding how to collectively govern the high seas commons, and how to help smaller developing nations, especially SIDS, manage their EEZs. In both cases a balance needs to be struck between subsistence and local fishing fleets, and the global industry; a process that may need to be mirrored across ocean industries, including seafloor mining, and the harvest of genetic materials.

The general perception is that high seas governance could only be credibly delivered through action by the United Nations General Assembly (UNGA), the International Maritime Organization (IMO), and implementing bodies of the United Nations Convention on the Law of the Sea (UNCLOS). IMO regulations are sweeping, covering all vessels and oceans, but their remit has not yet been applied to the high seas proper. There is a need to catalyse action, and to enable governance and policy decisions.

One facet of enabling governance is building an evidence base of ecosystem issues and credible solutions. This is what is currently being established for the Sargasso Sea, a two million square mile open ocean high seas ecosystem, and a case study for high seas governance. Central to this will be gathering and collating the data necessary to inform and justify any specific action or policy. The overarching method for this is to undertake an ecosystem analysis, which could underpin a scientific approach to ocean management and governance, and lead to actions such as defining Marine Protected Areas (MPA), allowed vessel routes, and Marine Spatial Planning (MSP). It should be noted that whilst many advocate for a 'precautionary' model of governance, establishing policy early based on the risk of negative effect, in reality the burden of evidence appears high.

There are a range of management issues that the Sargasso Sea Commission have identified and prioritised. Establishing fishing governance in the Sargasso Sea is seen as one priority. Whilst blue fin tuna fishing is regulated by the International Commission for the Conservation of Atlantic Tunas (ICCAT), fishing of other species is not effectively addressed. Data from Global Fishing Watch (GFW) shows that fishing activity is increasing in the Sargasso Sea, but it is neither evident what is being fished (although it is likely to be squid), nor the impact of these activities on the ecosystem. The same is true for seafloor mining. The Seabed Authority have identified three prospective sites, but the consequences of potential activity on the surrounding ecosystem are not understood. Plumes from mining activities could easily sweep through the area, causing unpredictable but significant damage.

4.3 The relationship between policy, governance, and technology

The relationship between governance and technology is not simple. There is an interplay whereby innovative technology helps to formulate and justify policy, as much as to implement governance. Ocean ecosystems, including human activities, are evolving and complex. Our growing ability to interpret, predict, and monitor this may enable highly nuanced governance, that is aware of, and responsive to, the state of the ecosystem. For example, adjusting dynamically, based on the migration of fish stock, accommodating changing locations for spawning grounds, and optimising ecosystem regeneration. Ultimately this could lead to more targeted restrictions, based on a deeper scientific understanding, and substantially improved sensing and monitoring.

Therein, whilst governance decisions (captured in a legal and regulatory framework) are a pre-requisite for the use of innovative solutions, demonstration of the art of the possible may be necessary to catalyse decision making. A challenge here is the investment case; advanced solutions, such as those built on AI, may be costly to develop, and only economically viable in the context of long-term services. However, their development may be necessary in order to explore the forms technologized governance can take, and to establish the evidence necessary to generate action. It is clear from past cases that the introduction of governance can spur wider investment (e.g., water treatment technologies to reverse eutrophication in the Black Sea, and the new innovative industry in ballast water treatment solutions born of GloBallast) – but, until that point, there is a need to enable and de-risk technology realisation.

Central to these matters is the need for data, both as a form of evidence, and an underpinning of AI/analytics technologies. Whatever the use, there is a need to maximise free and open access to data in and of itself. Data access and sharing is a policy-level issue involving public, private, and scientific stakeholders; currently data availability and utility varies significantly, addressing this may be a pre-requisite to effective high-seas governance. The details of data utility will be discussed later, but there is a general lack of data standardisation within and across ocean industry and science domains, perhaps with the exception of satellite data. There is also a lack of consistent meta-data, tagging, and organisation; even if relevant data exists, discovery and retrieval can be challenging.

More fundamentally, there is a need to encourage data sharing and open science. It is not the view that data is strategically withheld (especially for public and scientific bodies), rather there is a time and fiscal cost to data sharing, and a technical challenge. Agreeing platforms for data sharing, and incentivising organisations to make their data available, is a priority. In the context of science, a minimum standard of data sharing – perhaps following sector agreed guidelines – could be built into future grants to ensure the effort is made to share collected data. The cost of doing this should not be ignored, scientific organisations operate at the limits of their budgets, and a model of financing long-term data availability may be needed.

In the context of analysing and collecting data on the human and industrial uses of the oceans, there is no sense that the barriers are predominantly technical. Current capabilities for tracking and monitoring vessels are already sufficient, and AI analytics can determine if their operations are appropriate or not. Emerging technologies can improve this, and help with scalability, but again the core barrier is sharing of vessel tracking data. Therein, the crux might be to encourage a culture of transparent operations, with fairness of ocean use guaranteed through mutual visibility, at least insomuch as each stakeholder has confidence others are not misusing the ecosystem. Any steps towards this are to the benefit of governance, and transparency weakens the influence of entrenched interests on policy decisions.

The challenge is not just data sharing; it is putting the right data and information in the right hands, enabling decision making and policy formulation. Understanding the form this needs to take, the enabling tools, and how to strengthen the translation of scientific advice to policy, is a priority challenge. Analytics and AI may play a key role in translating multivariate, layered, data into holistic metrics that are interpretable across decision-making and industry. The process of moving towards technologized, data-driven, governance needs to be road-mapped; exploiting the two-way relationship between technology and policy is an opportunity for transparency, objectivity, and better decision making.

4.4 The role of technology in Ocean Governance

Having considered the need for and nature of Ocean Governance in the high seas, it is necessary to explore the specific role of technology. What it is that we are looking to achieve through big data, AI, and remote sensing solutions, and therein the technical requirements that prospective solutions must meet.

The issues discussed in the previous theme on policy and technology are echoed here. There was a view that we will need to work backwards from management and governance frameworks to specify what technical approaches are necessary. And then to understand constituent data requirements, and innovative solutions, for each case. Necessitating the development of policy as a starting point. There was no consensus on this point, and irrespective of it several technology 'needs' were apparent.

Broadly the role of technology in ocean governance falls into four categories: establishing the evidence necessary to inform and justify policy decisions; enabling and implementing scientifically based management; implementing enforcement; and deepening understanding of ocean ecosystems – which is indirectly related to governance by improving the scientific foundation and developing models.

Some context is also provided by the Ocean Innovation Challenge, which is an accelerator for emerging solutions. It is funding innovation pertinent to the UN's fourteenth Sustainable Development Goal (SDG14), to conserve and sustainably use the oceans, seas, and marine resources for sustainable development. So far it has funded technology towards marine pollution reduction, and sustainable fisheries.

Considering the first category; establishing evidence relies on gathering and collating data (across ecological, economic, scientific, and industrial domains), deriving from it a snapshot of the ecosystem and its activities, identifying key risks and issues (especially ecosystem threats, such as loss of biodiversity due to vessel traffic), and predicting its evolution with and without proposed governance. This relies on a suite of technologies including: the full gamut of earth-observation, surface, and sub-surface remote sensing capabilities for data gathering; the big data and data sharing implementations that allow for this multi-modal information to be stored, retrieved, and utilised; and data processing, analytics, and insights tools that make sense of the information. These analytic tools could include AI methods (of various sorts, from mature rules-based approaches to more nascent techniques such as reinforcement learning and generative AI), but these will likely be adjunct to existing, successful, statistical methods and models.

The UNDP has a formalised methodology for implementing governance, which starts with a trans-boundary analysis covering much of the above. This process usually relies on historical data; whilst there have been some exceptions, such as a twelve-million-dollar oceanographic assessment in the Indian Ocean, typically the budget for formulating and justifying policy is not sufficient to enable new data gathering. Establishing governance directly depends on data first and foremost.

The general view is that a lot of data exists, covering many different and subtle aspects of ecosystems; the sum knowledge from decades of marine research is substantial. However, much of this data is not operational. There are several barriers to operationalisation: much of the data lacks standardisation (in multiple ways, including the temporal domain, depth regimes, ocean gridding, and data format) introducing challenges for interoperability; quality of data, in terms of resolution, coverage, and timespan, varies greatly; data certainty is not consistently expressed; and – perhaps most importantly – the right data sets can be difficult to find. For common ocean properties there can be unmanageably numerous data sets, each encumbered by choices specific to their data gathering process, and not necessarily suitable for all purposes. It is practically challenging for ocean managers, and non-data scientists, to understand what a good choice of data looks like for their purpose. This is doubly significant to developing nations, for whom there may be a substantial knowledge and expertise gap.

Addressing these problems is an acknowledged priority, with projects such as NASA's COVERAGE looking to do so currently. Given the enormous variety of data sources and types associated with ocean ecosystems, it is not clear if a single platform approach will be suited to the domain. There is a need to understand "what good looks like" for big data sharing and analysis services, seeking to maximise accessibility and broad usability, whilst providing an easy, low-cost way for data gatherers to open their data to public use.

When it comes to implementing governance, one key outcome is Marine Spatial Planning. MSP is about documenting existing sea uses and ecosystem properties, developing a rich picture of all activities in the region and their interactions. With the variety of physical, biological, and human activities in an ocean space, this problem is manifestly complex. A complex system can be characterised as being 'more than the sum of its parts'; practically this means that understanding each facet of an ecosystem in isolation is not sufficient to understand how it will evolve as a whole – with emergent properties developing due to the many unconstrained, interrelated, processes within it. Understanding and managing complexity is more than a big data problem; AI methods have proved their worth in interpreting and modelling complex systems in other domains (including climate physics, but also smart cities, transport networks, and more), translating these approaches for ocean governance and MSP could improve ecosystem understanding, help to analyse what the most important data is, and – by translating layers of data into a holistic, predictive, overview – provide operational knowledge to end users. Currently an MSP exercise for a small central American country, costs in the order of six-million-dollars; globally MSP would cost billions, and so the use of technologies to bring this cost barrier down is necessary. A deeper predictive understanding of ocean ecosystems may also enable more responsive and targeted decision making to the benefit of ecology and economics.

As much as the role and impact of big data and AI technologies may have on future Ocean Governance, the barrier to access must be considered carefully. Global problems require global solutions; candidate technologies must be scalable and have pathways towards ubiquitous use. In the context of data technologies neither of these barriers should be fundamental, but it is important that technology developers are as aware of these requirements, as of the technical challenge. From the perspective of catalysing better governance, developing new solutions is as important as reducing financial, capacity, and expertise barriers, and ideally all should be pursued in synergy.

So far, this analysis has centred around data sharing and data analysis in one form or another. There is also a need for more, and better, sensing. Our understanding of ocean physics is increasingly competent, and it is characterised by parameters that are reasonably easy to sense, including from space. However, ocean biology is much harder to sense, model, and understand. As is the influence of the physical environment on the biological, such as the effects of climate change on fish stock and migration. Ocean and climate physics are not entirely understood either. For example, understanding the fronts, gradients, and air-sea coupling that contribute to hurricane formation is not solved. Furthermore, human activities such as seabed mining occur in areas we know little about, with consequences (ecological and physical) that we do not fully understand. Improving our understanding will require more and better sensing, just as much as improved analytics.

Ultimately, a system-of-systems encompassing improving data gathering, communications, sharing, processing, and analysis, will be to the benefit of any of the aforementioned challenges, and most certainly improve, and lower the barrier of entry, to Ocean Governance. However, the path there will be subject to fiscal constraints, and necessitate prioritisation. The most pressing need is ubiquitous data-sharing and standardisation, providing utility to the ocean managers and non-expert end users, not just data scientists. Therein, big data solutions should be a sector priority.

4.5 Examples of good governance

Note to reader: This section will be expanded somewhat for the final report, particularly considering the priority placed on good examples and case-studies during the workshop.

In the interviews and questionnaire responses several examples of ‘good’ ocean governance were highlighted as case studies of what can be achieved.

A pertinent example a of technology driven solution for illegal fishing can be seen in the ocean space around Ascension Island. Satellite surveillance and analytics from Ocean Mind were used to help monitor fishing activities. On the enforcement side, very high fines were implemented for those who fished illegally. Knowledge of this system was pro-actively promoted; once the fishing community understood that a capable monitoring system was in place their behaviour changed and illegal fishing was substantially reduced. Furthermore, the implementation of better monitoring enabled the detection of a different problem; vessels transporting dangerous cargo. Rowlands et al, 2018 details this case.

In the former case extant technology was applied to test its impact; more often policy is set, and technology then develops to meet new demands. An example of this can be seen in the ‘The GloBallast Story’. A primary cause of the migration of invasive species to new waters has been attributed to the ballast water of long-distance vessels. These waters carry species across the oceans, at times resulting in transference to new waters where they destructively thrive. To combat this a global convention on ballast water was negotiated, adopted in 2007, and put into force in 2017. It provides technically specific stipulations on how clean ballast water must be to avoid transference of species. This clear technical guidance combined with enforcement methods has led to substantial growth in ballast water cleaning technologies, which are now widely operational. The drive for competitive compliance solutions has generated a $40bn industry. Whilst this is neither data nor AI, it is an example of successful technology-oriented governance, in this case driving innovation.

Similarly, policy driving innovative solutions can be seen in efforts made to reverse the eutrophication of the Black Sea. Policy on water treatment, combined with innovation funds, led to a new burgeoning industry. This provided substantial economic benefit to the region, whilst addressing the key issue of eutrophication.

Technology aside, several agreements are held up as examples of successful Ocean Governance and may inform governance in the high seas. In interviews, the OSPAR convention was most often cited as an example of successful governance, providing marine protection and ocean sustainability through regulatory agreement between ocean bordering states. The Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) is similarly seen to be effective in regulating fishing and has established key MPAs.

The Western and Central Pacific Fishing Convention (WCPFC) was the regulatory framework for the UN Straddling Fish Stocks Agreement. It has been highly successful, reducing overfishing in the zone to 6%, resulting in complete sustainability. Practically, this regulation was enhanced and enforced via technologies: VMS and on-board observations systems were mandated for all vessels fishing in the waters. With these monitoring capabilities available, the vessel day scheme was implemented, auctioning off daily fishing rights – economically enhancing the participating states, a boon particularly appreciated by the regional SIDS. Here governance was made achievable through technology.

Most examples of successful regulation have been achieved top-down. Partnerships in Environmental Management for the Seas of East Asia (PEMSEA) is a counter example, which was developed bottom-up, and involved agreement across east Asian states. Its signature result has been the introduction of Integrated Coastal Management (ICM) with cross-sectoral planning. By developing the methodologies and tools to do this, they have scaled up ICM in east Asia from close to none in the 1990s, to covering about 40% of the east Asian coast today. Governance and regulatory frameworks have been put in place to achieve this, generally seen at municipal and provincial levels. Implementation of this has involved Marine Spatial Planning, the cost of which has largely been taken by local governments; undoubtedly there is scope for future big data sharing platforms and intelligent analytics to improve capability and drive cost down.

5 Technology for Ocean Governance

There are several key roles for technology in creating and sustaining good Ocean Governance. This involves the collection and analysis of multi-source data, producing evidence to inform Ocean Governance policy makers of where and how to act. Data is also used to inform and direct enforcement activities and can subsequently be used to measure the effectiveness or otherwise of the governance measures put in place – this is a technology-enabled data-cycle.

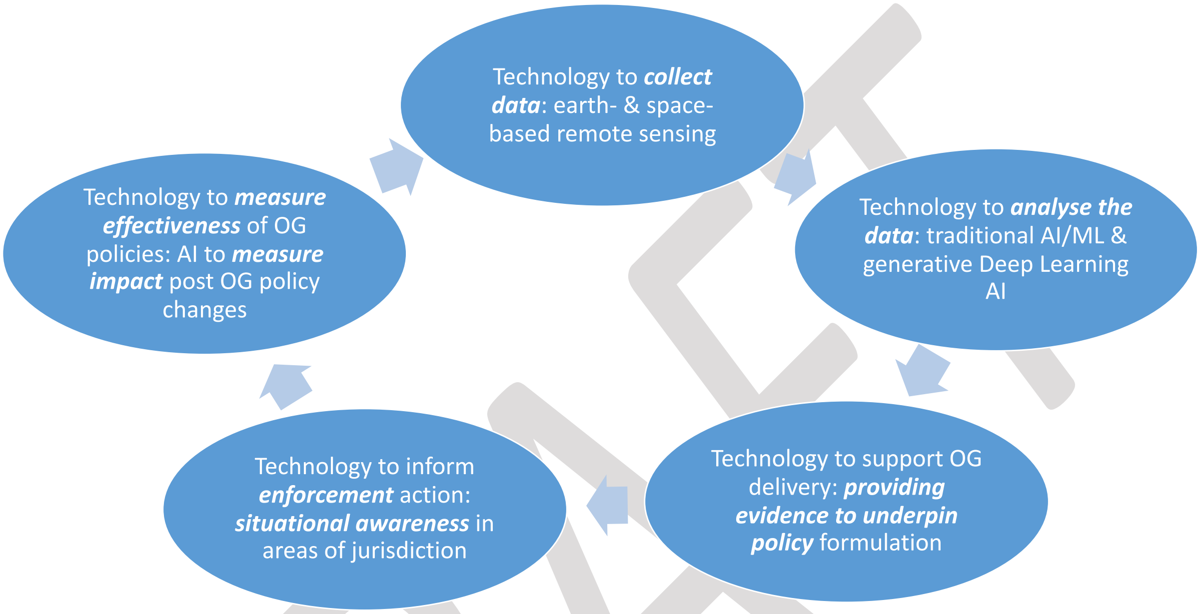

Figure 1: Technology-enabled data-cycle to create and sustain good Ocean Governance

5.1 Data Collection, Remote Sensing & Enforcement Technologies

5.1.1 The data journey so far

Data gathering in the world's seas and oceans has been ongoing for centuries. The first recorded scientific data collection in the Sargasso Sea is from the middle of the 19th Century and it has continued ever since. With the advent of steam ships and the industrial revolution, maritime routing and access to the Sargasso Sea has increased. Mariners are no longer limited by the vagaries of the complex maritime environment, particularly reliable wind, which was historically problematic in transiting the Sargasso Sea. The way in which data on environmental, biological, and human activity is collected has also changed considerably. Once only possible by the physical presence of an observer on a vessel, today technology-enabled remote sensing, both earth- (land and sea) and space-based, make it possible for a multitude of data relating to many differing characteristics and activities, environmental, biological, and human, to be collected 365-days-a-year, regardless of location, time of day or weather conditions.

The most recent large-scale scientific examination of the Sargasso Sea took place a decade ago which created an impressive amount of evidence relating to the existing ecosystem and the potential impact of human activity. The enhancements in data collection since then, specifically but not exclusively remote space-based sensors, alongside considerable advances in computing power and AI, (both rules-based Machine Learning, and the recently emerging Deep Learning, generative AI) mean the sheer scale of evidence available for policy makers to consider has increased manifold.

5.1.2 Technology to measure and address human-behaviour

Data collection relating to the environment and to biological activity does remain extremely challenging, but it does not have to deal with the purposeful obfuscation of certain types of activity, practically unique to the human species. Whilst fish and other sea creatures do seek to hide their whereabouts, they do this to evade likely predators, driven by a Darwinian instinct to avoid being eaten. This is contrary to the human predilection of doing so to gain unfair advantage and achieve some form of personal gain regardless of others, and with no thought for the morality and future sustainability of their actions. Without delving into an overly philosophical discussion at this point, it is worth highlighting the ever-increasing positive role technology can play in this seemingly unending battle against the human wish to operate in the shadows or darkness of the world's oceans, to amass ill-gotten gains.

5.1.3 The Electromagnetic Spectrum in remote sensing

The electromagnetic (EM) spectrum has played an increasingly important part in, quite literally, shining a light on human maritime activity. The advent of Radar in the 2nd World War and the considerable tactical, operational and safety benefits it provides, both in the air and maritime environments are well-documented. More recently, a different part of the EM spectrum has been used to further improve the safety of maritime shipping; radio-borne data from the Automatic Identification System (AIS) is now mandated to be fitted to ships over 300 tonnes displacement to allow suitable safe separation from each other. But this equipment (like the Vessel Monitoring Systems (VMS) mandated for industrial fishing fleets by some nations), suffers from 2 key weaknesses when in the hands of operators engaged in illicit activities; it can be modified to show incorrect information (so-called spoofing), or it can simply be turned off (creating so-called Dark-vessels"). Both these practices can in themselves be key indicators to law enforcement organisations of *potential* illegal activity, but it is just an indicator, it is not evidence.

5.1.4 Space-based sensors

AIS was designed as a short-range information sharing platform, but it is now also mounted on numerous communications satellites extending its reach globally. This adds to other rapidly improving space-based remote sensing capabilities which are making a real difference today. Space was once the unique domain of the security and defence organisations of developed, powerful and wealthy nations, but now highly detailed, time-sensitive data from a multitude of space-based sensors can be collected and sold, or simply bought, by commercial entities. As a result, when a vessel's operator decides to turn-off their AIS or VMS transmitter to hide their whereabouts and activity, there are now an array of other sensors already on hand to continue to illuminate the situation – "sea blindness" can be turned into "sea vision". Satellite-based Electro-optical (EO) cameras, the Visible Infrared Imaging Radiometer Suite (VIIRS) and Synthetic Aperture Radar (SAR) arrays now produce very high-definition imagery of ever smaller sized vessels. With ever-reducing revisit times measured in hours not days, enabled by more complex but more sustainable non-polar orbits that keep the satellite in permanent solar view, thus providing constant power to the onboard batteries, whilst also allowing satellite taskers to concentrate their sensor time on areas of the oceans with the most human activity, these capability improvements make even the furthest oceans a difficult place to navigate completely unseen.

But even SAR, EO and VIIRS are not omniscient. Whilst SAR is not affected as much as EO and VIIRS by poor weather conditions and time of day, it still does not provide the incontrovertible evidence often necessary to move to a court of law. EO can provide this in the best weather conditions and satellite orientation, but now a relatively old technology that is becoming more widely available is EM frequency transmitter fingerprinting (in military circles this is referred to as ELINT – electronic intelligence). Put simply, each transmitter on a vessel (e.g., radar for navigation, V/UHF radio for ship-to-ship communications, satellite telephone for speaking to vessel owners/accessing the internet) has a unique frequency fingerprint, meaning that whenever or wherever it is turned on, if it is "in view" of a suitably configured detector mounted on a satellite, its position can be determined. This sort of system can also be terrestrially, or aircraft/drone based, although this will clearly reduce the range of detection to vessels operating in coastal waters or perhaps to EEZ boundaries; it will not cover the more distant high seas and ABNJs. On its own this fingerprint detail might not be sufficient, but when fused with multi-source data from other earth- and space-based sensors, a complete and compelling evidential picture can be created and then presented to appropriate law-enforcement agencies for further action. Simply knowing this technology is available in certain geographical locations, has changed behaviour (as mentioned earlier in this report with reference to the case of Ascension Island fisherfolk engaged in illegal fishing).

5.1.5 Underwater remote sensing and human activity

Data gathering of the oceans is not only carried out by space-based sensors. To fully understand the oceans, data must be gathered from within; put simply, sensors must get their feet wet. Due to the physical characteristics of the water the capability to monitor using EM energy is limited to the space above, on, or just slightly below the sea surface. But this limitation can be overcome by exploiting the unique characteristics of sound travelling in water. Sound is particularly useful for tracking and understanding biological activity and other natural undersea phenomena, but it is also having an ever-increasing role in the tracking and recording of human activity – for example the use of hydrophones to listen for human-related insonification, either accidental or deliberate, which can have such a detrimental impact on cetaceans and other marine life. That said, where the near-ubiquitous nature of space-based platforms can be used, is in the receipt and retransmission of the wealth of underwater data being collected by these arrays. The use of communication satellites to relay data from remote oceans to remote laboratories, especially when near-real time transmission is needed is fundamental, thus allowing this wealth of data to contribute to providing the evidence necessary to support good Ocean Governance.

5.1.6 In-ocean remote sensing and data gathering of non-human activity

In-ocean remote sensing tools that measure physical factors are much more effective than those focused on measuring biological factors; to compound this challenge there are also orders of magnitude greater variability in biological sensing. Furthermore, biology and climate physics have additional but potentially very different sensing requirements to those for monitoring and managing human activities. Basically, understanding the biology and the underwater sensing picture, is more challenging than measuring and understanding human activities. More positively, from our research it appears that contemporary remote sensing capabilities are already highly capable, but they are constrained by the lack of commercial demand, and the practical challenges of monitoring vast ocean spaces. The problem of in-ocean remote sensing can be broken down into three distinct themes: understanding the physical and biological processes in the ocean – i.e., what is happening; monitoring natural activities; and monitoring human activities.

Alongside the need for sufficient monitoring to understand what human activities are taking place, and how they are affecting the ocean, there is also a need to monitor the essential ocean variables. Satellite-based sensors can detect and measure surface information such as: temperature; roughness; salinity; acidification; and human activity, but this is not sufficient to understand the complex physical, biological, and human processes taking place within the entire water column and on and under the seabed. Sub-surface observation systems can look at essential ocean physical and bio-geochemical variables such as chlorophyll and turbidity, and biological variables like, where life is and what lives where, as well as human activities. Sub-surface data is crucial, but not yet sufficiently available.

Passive ocean sensors are improving and moving towards reducing the ecological and environmental costs of their presence. Passive drifters, low energy gliders and sail drones, as well as high-altitude, very long endurance airborne drones are much less carbon-heavy assets that also do not require as much care and maintenance. Furthermore, so-called “platforms of opportunity”, e.g., fishing vessels, cargo vessels and ferries moving through the oceans as part of their normal business, could be used to gather a wealth of data, possibly regulated in some way to “pay-back” their carbon usage. It is highly likely that many maritime users would be willing to do this, but once again, the requirement to decide data standardisation and types well in advance needs addressing.

5.1.7 Affordability vs Cost Effectiveness

It must be noted, that much of this data does remain expensive and beyond the budgets of many small or developing nations, but it is becoming more affordable. Arguably, when you consider the long-term detrimental impact of much of the maritime human activity and the costs of recovery and regeneration, a case could easily be made for buying data to build a case for good Ocean Governance, rather than dealing with the downstream impacts is much more cost-effective. Affordability of data is perhaps a challenge that lends itself to regional, inter-governmental, international, or even philanthropic cooperative solutions to solve.

5.2 Big Data, AI and Analytics

5.2.1 The Needs for Big Data Solutions

As we have discussed, a consistent barrier to justifying, evidencing, and implementing ocean governance is the availability of evidential data and analytics. Establishing a big data picture is part of building the evidence necessary to justify policy; as shall be discussed, this is currently challenging and costly. There are a variety of needs for, and ancillary to, using big data in this domain, broadly they centre around data sharing, availability, quality, interoperability, and utility.

These needs are as technical as they are human; it is crucially important that ‘Big Data’ is not seen as the unique domain of the data analyst, computer scientist, or technical practitioner.

Whilst these may architect and implement solutions, the end-user is necessarily the Ocean Governance community, with varied specialisations, a focus on ocean management and policy, and ranging access to tertiary knowledge and expertise (from nations at the forefront of technologization, to SIDS and other developing nations). There is a need for technical development in this domain, to better assist establishing governance in the Sargasso Sea or elsewhere, but a sufficient solution must be ubiquitous, intuitive, and accessible. It is incumbent on those developing solutions to minimise barriers to use. Therein, it is also important that the Ocean Governance community is an active stakeholder in all ongoing development, ensuring that their needs are well understood and well addressed – this can already be seen to be the case in the relationship between the Sargasso Sea Committee and NASA/JPL with respect to their COVERAGE project.

Addressing these needs towards enabling Big Data for Ocean Governance is a first-order priority, and is a pre-requisite to many data-hungry AI methods and analytics. It is also a pre-requisite to us understanding the state-of-play – earlier we posited that it is a challenge for ocean managers to select the right data for their needs from the vast variety and quantity available. More abstractly, the challenge is understanding what 'good' looks like for data, for a specific purpose. Sister to this is knowing how much of this is what we already have, and are collecting, and where we need to improve to add to data collection.

These questions can only be addressed in knowledge of the whole; the data needs to be catalogued and shared. Furthermore, it must be comparable, invoking a need for standardisation across disciplines, sub-sectors, and collection methods covering at least: meta-data; formats; metrics of certainty; temporal information; depth regimes; and ocean spatialisation/gridding. It is only when the whole can be seen, and parts measured against one another, that we can understand – through human processes and analytic algorithms – the strengths and shortcomings of what is available.

Standardisation is also a pathway towards data interoperability and compatibility. Systems utilising big data for evidence, governance, and monitoring, must not be brittle to technical change. As ecosystems and human activities evolve, along with our understanding, such systems will need more and different varieties of data, they may need better data in specific cases (or, perhaps, be able to make cost savings and do with less in others), data from new and changing sensors, and data from different providers as projects and businesses change. Unless its purpose is highly specific a rigid, brittle, data system is unlikely to be long lived. Standardisation, with a focus on data interoperability, compatibility, shareability, traceability, and comparability, is a necessary enabler for the type of big data solutions that are needed.

Practically, using Big Data and meeting these needs, requires data sharing and analytics platforms. At the simplest level, such platforms serve two purposes. The first is to connect end-users with data, translating their needs from the context of their domain to one of data, and intelligently highlighting data that is fit for their purposes. The second – but of equal importance – is to facilitate data sharing. Standardising, normalising, formatting, and sharing data is time consuming and costly. Whilst we may advocate for open data, the reality is this task has costs and associated technical challenges, particularly if the shared data is to have sufficient visibility for use. A good data sharing platform would seek to handle as much of this as possible, also for its own benefit of guaranteeing consistency across data. Architecting an ideal data sharing platform is a task unto itself, and there are numerous organisations either doing this internally, or facilitating data sharing more broadly (e.g., Global Fishing Watch and

NASA). The idea of a singular data-sharing platform can be attractive, but considering data multi-use across domains ranging from ocean biology, to climate science, to economics, and to governance, a multitude of interoperable distributed platforms is likely ideal. To prevent new issues of fragmentation, it is important that such platforms could each access all the openly available data (and avoid per-platform data duplication, which incurs costs and causes issues), but be designed to best support their target sectors.

The elephant in the room is how one incentivises data sharing. Traceability plays a key part in this; relating use and benefit to those who provide data inherently increases recognition. For private organisations this allows them to demonstrate their contribution to addressing issues of global importance, such as ecology. For scientists and researchers, it is of even greater importance, as it allows them to demonstrate the benefit of their research – necessary to establish continued funding. One might also consider ways to mandate data sharing. For example, as a condition in grants of funds, or in high seas policy.

There is a significant human element to matters of data sharing, constituting a change in culture. A popular soundbite is that data is the most valuable resource in the world; this encourages the notion that data is a rivalry resource, and that sharing is to one's own competitive detriment. For all but the largest data collectors, this simplistic notion has been shown to be untrue. The effectiveness of data to provide insights in complex domains requires not only data quantity, but substantial variety. This can usually only be realised in the combination of data from numerous sources; data is generally non-rivalry, and sharing is to the mutual benefit of the sector. Establishing this shift in culture is a challenge, and is an issue of trust to share. It may be the case that this is best catalysed by independent and trusted organisations that can act as data masters, facilitating sharing whilst protecting the confidentiality of data partners – whether private organisations or nation states.

We may summarise these points into some top-level technical and non-technical requirements for Big Data for Ocean Governance, which may help solution engineering by the development community.

Technical requirements:

- Understanding ecosystems requires Big Data constituting earth observation, surface, and sub-surface data sources, with high volumes of data over long timespans, and of varied modalities. Therein, free and open data sharing is a priority need.
- This requires the standardisation and integration of data across communities, particularly datasets from the ocean physics, geo/biochemistry, ocean biology, and human activity monitoring communities. At a minimum, the need for standardisation includes: meta-data, formats, protocols, metrics of certainty, temporal information, depth regimes, and ocean spatialisation/gridding.
- Data sharing platforms are needed to facilitate both data access and data sharing; reducing barriers at both ends. Ideally data sharing platforms should help end-users understand what data is right for their needs, translating domain-expertise to data requirements. Similarly, they should handle as much of the data assimilation process as possible, reducing the cost and challenge of data sharing, and improving consistency across datasets.
- Due to the different needs across ocean sectors, and the multi-disciplinary use of data, a distributed but interoperable model of data platforms is likely needed. Data replication

should be minimised to avoid excess costs and errors from duplication, necessitating common access protocols and easy searchability.

- Data access and latency requirements differ based on intended use. Ocean ecosystem analysis is likely to require long-term data of many modalities. Conversely, response and enforcement may require (near) real-time data and analytics. This places requirements on data sharing architectures, as well as on data-collection.
- We need to better understand what 'good' looks like for ocean data, especially in terms of granularity/resolution. Both nuanced governance and ecological analysis may require data of a greater temporal and spatial resolution than conventionally captured; a baseline for analytics needs to be established through testing. Furthermore, significant quantities of data already exist, and are being actively collected; we must analyse where value can be added.

Human requirements:

- The foremost requirement for any Big Data solution is to be interpretable to the end-user community. It must reduce barriers and costs to technology access, enable ubiquity, and help the end user access the 'right' data for their needs. For Ocean Governance, this means that big data systems must provide actionable information and knowledge to ocean managers.
- Establishing free and open data sharing is as much as technical challenge as it is a human one. Data sharing must be encouraged and incentivised, there are several ways this could be achieved:
  - Specific positive recognition of those who share data. Particularly towards helping scientists, researchers, and NGOs demonstrate the benefit of their data gathering activities in order to secure future funding.
  - Establishing methods of trusted data sharing, involving respected, neutral, organisations as data masters, reducing the perception that data sharing may reduce individual competitive advantage, or cause risks to security.
  - Better communicating the need for diverse data, and the non-rivalry nature of data.
  - Mandating data sharing as an output of research grants, and introducing policy towards high seas data sharing.
- The cost of sharing data should not be ignored, and focus should be placed equally on facilitating data sharing and data access.

5.2.2 Artificial Intelligence for Ocean Governance

Note to reader: This section is subject to extension to include specific examples following workshop comments, however the broad contents here are representative of tone and view.

Computing power, quantity of available data, and data gathering have historically been barriers to analysis and an Artificial Intelligence based approached. It is only relatively recently, with modern computational capabilities and Big Data systems, that these approaches have become viable. They present a natural evolutionary step in data analysis, modelling, and prediction – and, as they have already in many domains, it is likely that they can generally assist in Ocean Governance.

Artificial Intelligence is a broad term, covering a wide range of methods, algorithms, and implementations, each with varying capability and maturity. At the simplest level, AI methods can be used to automate statistical data analysis processes, intelligently responding to context based on pre-defined rules. This can provide unique advantage in terms of speed and scalability, necessary for analysing oceans of data as opposed to test cases, but they do not provide unfamiliar capabilities.

Using AI in this way, typically for pattern recognition, pre-disposes that we know what patterns to look for, and in which data to find them. The weakness of rules-based approaches is that they demand *a priori* understanding. For human observation tasks this can be sufficient, especially in flagging the negative case – unexpected behaviour. This has use from detection of illegal activity to emergency response and rescue. Furthermore, the more policy specifies or constrains accepted behaviour, the easier it becomes to automatically identify deviations from what is expected (e.g., deviation from shipping lanes or entry into protected zones).

These matters are simple. It should also be noted that there are many established methods in ocean analysis, such as the statistical methods for fisheries stock assessment, that have proven themselves sufficient. The impulse to use new methods for their own sake (or, similarly, to generate data for its own sake) should be resisted; AI (and any other analytic method enabled by big data) is an addition to the existing set of tools, not an implicit replacement.

Similarly, mature AI methods focus on data enhancement and image enhancement, for example current AI tools can be used to improve ocean surface temperature data from satellites; improving data retrieval through cloud cover. There is potential to retrospectively enhance collected data using these tools, and to apply them to assessing quality of data on a large scale.

The use of AI becomes more interesting when used to analyse complex, highly correlated, systems. With the mixture of climatic, physical, biological, and human properties, oceans and sea-basins almost certainly exhibit complexity. This is more than a descriptive term, it specifically implies that an (eco)system must be described as a whole, exhibiting emergent properties that are not evident from considering each part and process in isolation. This makes analysis challenging for two reasons: firstly, causal relationships are not necessarily evident, with many small factors contributing to an outcome of scale, but no singular, dominant, cause; secondly, complex systems can be unstable, making predictive analysis, and scenario analysis, challenging.

In highly controlled, man-made, domains (such as semiconductor and aerospace design) we can capture and fully model complexity within a design process. For global and natural phenomena, we need alternative approaches capable of interpreting data of scale and variety, to identify patterns and relationships that are not pre-specified. This is serviced by AI, particularly by Deep Learning and Generative AI methods. These require large quantities of data, often of the greatest variety possible, and over large timespans. They have a weakness in that they are predicated on data completeness; no method can understand something that it does not see. Designing AI that can understand if it has the right quality and types of data is an area of active research, but it is challenging and often implementation specific. It is usually through use, test, and iterative system design that such issues are resolved.

In the ocean domain these approaches are already being used in a limited context, particularly for meteorological and climate analysis, and for vessel identification and route prediction. In a wider context they have been put to use analysing smart cities through to financial markets, to provide long-term predictions as well as low-latency situational awareness and alerts. Whilst the principles for these AI approaches are general, implementations are specific. Technology translation towards ecosystem analysis and enhanced governance should not be seen as trivial or necessarily straight forward. These tools straddle the boundary of research and application and will require both specific expertise and investment.

Industry investment in AI tools is substantial, including in the ocean sector. Increasingly automated operations of complex offshore installations necessitate AI capabilities, both for operations and monitoring. Much as with data sharing, it may be that through trusted co-operation cost-effective pathways to enhanced ocean governance can be established, facilitated by the knowledge industry has already developed, but not necessarily communicated.

Lastly, trust in AI solutions, and AI decision making, must be touched upon. Whilst we explore this more fully in the next section, trust in AI has a challenging technical and human dimension. There is a natural reluctance to place trust in non-human systems. Whilst to an extent this can be overcome through comprehensive demonstration and testing, it does raise deep technical questions. At the very least, deployment of AI systems will require fail-safes and fallbacks and will likely take the form of a series of staggered capabilities. AI systems can be prone to bias, particularly more traditional variants that rely on humans to sort the importance of data, and explicitly specify which data to use (a recent example is the issues face recognition systems have with recognising faces with dark skin-tone, due to having been predominantly trained using light skinned image data, and well-lit images). Means to verify and validate the performance of AI systems must be developed alongside them, at both a human and technical level.

Examples of AI use for ocean ecosystem and climate analysis: To be added in final draft.

5.2.3 Trust in Big Data and AI

One challenge in technology translation – of any sort – is trust in the new solution. This is particularly the case for data technology and AI, and it is an issue with both a technical and human dimension. The quality, or benefit, of a new solution is irrelevant if lack of trust prevents uptake. In purely operational domains trust can be generated through demonstration (for example, the use of AI in various forms of autonomy), governance is not purely operational though – it has human, economic, and political consequences. As we have already discussed, a barrier to establishing governance is building sufficient evidence; whether simply via data analysis, or through a complex, black-box, AI-driven system, the methodology must be trusted. Understanding and solving issues of trust are a priority, a perceived lack of trust can easily be used as a justification for inaction; building consensus on what trust means, and how it is achieved, should run before and alongside any technical development – not after it.

Building trust in data (or any information source) is an old issue, and also one that is well understood. Technically, trust is established through peer review and validation by neutral experts. It involves the scientific community testing and verifying the quality of sensors, sensor deployment regimes, data transfer and collation, and whatever models may sit atop this data layer. This process also involves establishing methods for baselining and communicating data quality, usually in the form of data standardisation and uncertainty metrics. As we move from disparate data sets to big data and data fusion, technical standards and data formats will need to be normalised across scientific domains. This is especially true of uncertainty metrics (e.g., range per pixel), as it is vital that data is mutually comparable.

National rivalries are an issue when it comes to data trust, this is best circumvented by data being owned and produced by independent entities. UN driven solution have an inherent advantage here, and technological solution acceptance needs to be demonstrated by independent bodies such as the UN. This also highlights the importance of collaborative action. People, organisations, and nations have trust in data that they have had a hand in producing and will be more confident in the outputs and analysis of that, whether through institutional or national collaborations, or distributed models of data collection such as platforms of opportunity.

Establishing trust in black-box methods, such as most AI analytics, invokes its own issues. Broadly there are two related problems at the core of this: it is not possible (or practically feasible) to view the workings of black-box systems in order to manually verify if they are well behaved, and doing what is expected; and, in some cases, the processes within the system are non-deterministic (such as the 'learning' in some, but not all, AI methods). Black-box verification and validation is a domain in its own right, with a multitude of approaches to technical testing and validation. The 'right' tests will depend entirely on what is implemented and how, however broadly include statistical methods observing both inputs and outputs, verification through use (or on historical data), providing false 'bad' data to verify that bad inputs result in bad outputs, and careful algorithmic design with view to creating reliable fail-states that unambiguously tell the end-user when the process should not be trusted. It would be an exaggeration to say that verification and validation of AI methods is a solved problem, it is however solvable on a per-implementation basis, and has been addressed in critical, complex, cases such as autonomy.

It is important that in developing AI systems these matters of trust and verification are transparently addressed, well documented, and that the wide range of user communities are informed as to why the systems are trustworthy. Whilst it is hard to establish in a competitive environment, open sourcing of tools for public scrutiny should be encouraged. Verification and validation should be continuous, especially for systems that learn, and users should have a way of interpreting the quality of outputs – presumably through a metric of uncertainty, combining data uncertainty with a meta-analysis of the processing. The quality of the data flowing into any system is also paramount; and addressing data issues can be seen as a pre-requisite to the wide use of AI methods. It may help to visually layer AI analytics on top of sensing data, providing end users with an intuitive means to validate what they see. Case studies are also a powerful tool towards building trust and showing success. As we move to AI driven governance, to feasibility tests to implementations, these case studies need to be built, providing a narrative that contextualises use.

Lastly, as with all novel technologies, fail-safes and fall-back methods must exist. New methods do not invalidate the old, and, at least whilst the technology is nascent, we should work towards a hybrid system-of-systems.

6 Blue Economy Knowledge System (BEKS) Analysis

6.1 Headline Findings

NLAI's Blue Economy Knowledge System (BEKS) is a bespoke market intelligence curation and activation system. BEKS utilises advanced Boolean search string techniques and targeted news alerts to ensure that all relevant market activity is captured and reviewed systematically. A comprehensive, searchable database of over 15,000 filtered Blue Economy (BE) news alerts is already in place, this builds day-by-day. Tailored BEKS campaigns can be aligned to users' needs and areas of interest, to track areas of research, individuals of interest, companies, competitors, territories, and general market conditions. All of these news alerts can be set up to drop into one project-dedicated inbox for daily, weekly or 'as-it-happens' review and analysis. Such intel can feed into market briefings, can help to identify emerging trends, or identify new contacts with whom to engage on our areas of interest.

For this project, BEKS was utilised to capture data relating to the advances of Big Data and Artificial Intelligence in global governance of ocean spaces. This data capture also had the aim of identifying key sub-sectors of ocean governance, i.e., marine monitoring surveillance, marine conservation, and mapping marine ecosystems. By using BEKS, we were able to capture over 140 relevant examples to inform this study. The data ranged geographically, spread across all oceans and sea spaces, including the Arctic. The spread of data on AI and Big Data was generous. However, the most common data source was concerned with **Marine Monitoring & Surveillance** and how Big Data and AI solutions could improve efforts for these technologies. The most popular, relevant solutions are ranked below:

Sector	Articles
Marine Monitoring & Surveillance	17
Ocean Navigation & Exploration	11
Technology: Satellite-based solutions, remote sensing, & Earth Observation	9
Ocean Conservation	8
Ocean Governance	6
Fisheries & Aquaculture	5
Marine Renewables & Sustainability	4
Marine Science	3
Marine Pollution	3
Marine Biodiversity	3
Ports & Shipping	2
Environment & Climate Change	1
Marine Mapping	1
Technology: Geospatial Data	1
Coasts & Environments	1
Maritime Security	1
Illegal, Unreported, & Unregulated fishing (IUUF)	1
Technology: Big Data	1

The use of AI in Marine Monitoring & Surveillance was more popular than Big Data; AI was the more popular term in the search results. This is likely due to the broader public understanding of AI compared to Big Data, which is a lesser-known concept. However, Big Data was a common subject when discussing satellite-based solutions such as remote sensing, earth observation and geospatial data.

Unfortunately, there was not a great deal collected that directly discussed the Sargasso Sea or the potential for technology solutions as a toolkit for ocean governance in this specific region. This may be because there is a lack of awareness or understanding about these solutions and the potential roles they play in ocean governance, or because there has been no practical consideration to expand the use of these tools in the Sargasso Sea. Thus, in this study we conclude that information specific to the Sargasso Sea was more accurately sourced by our Expert and User Group stakeholder engagement.

There are 2 BEKS data "cuts" included as attachments to this draft Interim Report. The bespoke BEKS inbox related to this project remains "open" and continues to gather useful and relevant information and data. This may be analysed if/as required if further research were commissioned that would continue to build understanding of the key relationships between Ocean Governance & Big Data/AI.

7 Appendices

7.1 Questionnaire responses

Raw data currently held in NLAI SharePoint – will be added to final Interim Report.

7.2 Interview responses[2]

A component to this project was targeted interviews with SSC expert and user group members, including representatives of the Sargasso Sea Commission, UNDP, Global Fishing Watch, NASA, and REV Ocean. The purpose of these interviews was to better understand the needs and challenges surrounding ocean governance, both in general, and specific to the Sargasso Sea. Further to this, the interviews explored the potential role of big data, artificial intelligence, and remote sensing technologies in enabling and supporting governance and enforcement.

We recorded the interviews in the form of recorded notes; these are not transcripts, and should not be taken as a literal record, free from the interpretive lens of the interviewer. As a general observation, we note that the views expressed by interviewees were in mutual agreement; each stakeholder group elaborated most on their own domain, however their perspectives on ocean governance, technology needs, and even examples of 'good' governance, were in agreement across the board. A caveat to this study is the lack of blue economy/industry stakeholders amongst interviewees, particularly those who would be at the receiving end of regulations, for example in the fishing industry. Whilst one should bear this in mind, we do not feel that it is a limitation of this work; our purpose in this study is to articulate why high seas ocean governance is needed, and what role the aforementioned technologies have to play. We do not seek to comment on the degree, or implementation, of governance that is acceptable, or to recommend policies.

From the interviews ten key themes were identified: The need for governance; Bringing governance to the high seas and the Sargasso Sea; The relationship between policy, governance, and technology; The role of technology in ocean governance; Big data, and data requirements; The use of artificial intelligence; Remote sensing technologies; Enforcement; Trust in data and AI; and Examples of good governance. These have all been drawn out and analysed in the report body.

7.3 BEKS evidence pack

The evidence in BEKS continues to build and is held in NLAI SharePoint. The 2 data "cuts" dated 9th & 24th November 2021, are both attached (pdf format) to this draft Interim Report.

[2] Notes from interviews are held in NLAI SharePoint.

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