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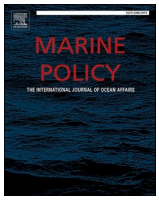

Exploring barriers to the implementation of geospatial technologies in marine spatial planning: Reports from practitioners

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ABSTRACT

This paper aims to contribute to the current discourse regarding the incorporation of geospatial technology in marine spatial planning (MSP) by drawing lessons from some existing initiatives. MSP is a continuously growing policy field under extensive research, and geospatial technologies (e.g., remote sensing, GPS, and GIS) are well-suited for acquiring and analyzing location-based data for marine planning needs. However, the role, extent, and nature of geospatial technology in the MSP process remain relatively underexplored. Here, we draw insights from interviews with seventeen global marine practitioners involved in developing or implementing eleven marine spatial plans worldwide to understand how extensively geospatial technology-derived data is utilized in existing practices. We briefly discuss the potential benefits of enhancing this type of data in MSP and then highlight some issues that need to be considered when shaping geospatial technology's input into the process. Based on the interviews, these considerations suggest that we need to develop a more critical and deeper understanding of how various interests frame the underutilization of geospatial technologies in some regions of the world. Additionally, we explore how the interviewed practitioners view their role in shaping the practices of geospatial technology use in the planning process. These findings highlight the importance of several key issues raised in the interviews as barriers to enhancing the use of geospatial technology. We conclude with suggestions for what priorities that could support the future enhancement of geospatial technology in MSP.

1. Introduction

Marine spatial planning (MSP) aims to achieve ecological, economic and social objectives [12], yet moving from ideation to practice is challenging. A major challenge is that a great deal of data is required for developing and implementing marine plans [44,59]. Data collected is used for: (1) assessing current and future conditions for the development of the marine plan, (2) effectively enforcing regulation on human activities to achieve compliance with the marine plan, and (3) adequately monitoring the plan's predetermined indicators of success [12].

Fortunately, various recent scientific and technological advances have the potential to address these data needs. Standing out among these advances are geospatial technologies (GTs) that connect data to a location. GTs enable collecting, mapping, and analyzing the oceans' physical, chemical, and biological components as well as tracking human marine space use. GTs are recognized in the peer-reviewed literature for their benefits to marine management and MSP in particular [13,1,40,47].

Common examples of GTs include remote sensing, global positioning system (GPS), and geographic information system (GIS). The type of data that can be extracted and analyzed using GTs (hereafter"GT-derived data") allows for remotely detecting and collecting near real-time data through aerial and satellite remote sensing, as well as through radar and sonar based-technologies, using active and passive in-water sensors. Remote sensing supports data gathering on biotic and abiotic elements of the environment, promoting habitat mapping, monitoring and estimation of anthropogenic effects (e.g., [16,17,51,2]). GPS and other equivalent satellite-based geolocation systems enable spatiotemporal tracking of uses of the marine environment by humans, such as for shipping and fishing (e.g., [10,29,30,36,55]) and of tagged mobile marine fauna (e.g., [22,48]). This type of GPS-based data supports zoning and identification of traffic lanes. GIS enables the display, synthesis and analysis of data within its spatial context as well as the production of maps and charts with collaborative data-sharing elements (e.g., [20,28,38]; Shaowen et al., 2019; [52]).

This paper builds upon Schwartz-Belkin & Portman [47], which reviews scientific developments in the field of GTs with the potential to support MSP-related challenges. Here, we want to explore how

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GT-derived data are used in actual marine plans, during their development and implementation stages (i.e., enforcement and monitoring). Generally, the exploration of the interaction between marine plans and the utilization of GT-derived data is at an early stage, necessitating additional research to fully exploit the potential of GTs in this field. We hypothesized that there is a disconnect between the available technology and its actual employment for decision-making in marine planning and plan implementation processes. To investigate this, we contacted worldwide practitioners involved in developing, enforcing, and monitoring marine initiatives. We interviewed seventeen practitioners about the use of GTs in their work, to identify factors that delay or support incorporation of GT-derived data in MSP processes. Through the interviews we identify various examples of barriers to optimal GT utilization, and gain more insight into the prospects for GT utilization in MSP.

2. Methodology

Specific information on how GT-derived data is utilized for marine plans is limited as planning authorities do not always publish their metadata. We conducted semi-structured, in-depth interviews with practitioners who took part in the development and implementation of marine plans to unveil existing use of GT-derived data and to identify key barriers to optimal utilization practices. We chose this method since semi-structured, in-depth interviews with open questions support exploratory research and enable the greatest possible openness of answers by the interviewees. They also allow the identification of new issues unexpected by the interviewer. Such methods also avoid suggestive effects [25,6].

2.1. Sampling

To focus our identification of preferred practitioner interviewees, we predefined categories to embody relevant professional roles in the planning process. Categories included: marine planners, scientists involved in policy advice, marine environment governmental authority's representatives, marine managers and marine regulators (enforcers). We anticipated that participants from these categories could testify to GT uses in marine plan development and implementation. We searched globally for contacts from various initiatives to get diverse perspectives. If specific individuals were not identified through marine planning initiative documents, we contacted the relevant organization asking for a contact person who could speak about GT use in initiatives they were involved in. We also used our own knowledge to contact organizations and individuals in relevant positions. We asked contacted practitioners to refer us to additional contacts who could participate in the research (i.e., "snowball sampling" [34]).

Seventeen of sixty-nine practitioners contacted (via phone or email) agreed to participate in the study. These practitioners participated in marine-related initiatives in Australia, Brazil, Germany, Israel, Reunion Island (France), Singapore, South Africa, Spain, Trinidad and Tobago, the United Kingdom and the United States (an East Coast state, unnamed) (Fig. 1). The decision to contact practitioners from all over the globe to ensure a broad range of insights on the use of GTs in marine planning proved useful, as seventeen of sixty-nine is within the lower, but normative response rate for this type of qualitative and targeted interview method [39]. In this case, the interview responses inform about the targeted topic, not to provide a fully representative set of opinion sources, as is common for exploratory research.

Those seventeen practitioners (nine male and eight female) embody the predefined professional categories (Table 1). The number of interviewees from each category was limited by respondents' availability and willingness to participate as well as our screening requirement of being able to speak about GT uses in the marine practices they took part in. The practitioners who agreed to participate were then emailed and signed an informed consent form, preapproved by our institution's ethics committee.

Table 1
Participants' role. Some participants had more than one relevant role.

Role	Participant no.
Governmental authority	(1)-(3)
Marine spatial planner	(3)-(10)
Scientist	(10)-(13)
GIS expert	(14), (15)
Regulator (enforcement authority)	(16), (17)
MPA manager	(17)

Fig. 1. Locations of marine initiatives, discussed during interviews with practitioners.

2.2. Interviewing

The interviews were conducted between August 2021- March 2022. We used Zoom software, "Zoom Video Communications, Inc."; researchers reap cost benefits from online interviewing. Respondents benefit from the opportunity to choose when and where the interview is to take place [21,37], and during the COVID-19 era, we assumed many people became comfortable with using online meeting platforms. The interview conversations typically lasted around one hour. The first author conducted all the interviews.

The interview process consisted of two parts, a preliminary introduction to the research and the interview itself. Before the audio recording started, participants were reminded they were being recorded and gave their consent for a second time (first being the informed consent form described in Section 2.1). Then, the interviewer defined GTs to the participants in a manner corresponding with the introduction in this paper, and the participants were asked to describe their affiliation, experience, and role.

Open-ended questions directed the participant to (1) identify the GTs used in marine practices they took part in, (2) describe challenges the participant faced during their work that they thought could have a GT-based solution, and (3) point out barriers to using GTs in their role. These topics were discussed with all participants to allow for comparison of interview responses. Other topics discussed varied based on the responses received, allowing for a flexible and individualized approach to data collection, depending on the respondent's answers and role; this flexibility is the advantage of conducting a semi-structured interview.

2.3. Analysis

Audio recordings of the interviews were transcribed using Otter.ai software, and Atlas.ti software was used for coding. Each interview was deductively coded to identify described concepts; passages with similar descriptive ideas were given similar codes and then grouped under the same category [4]. For example, the initial codes "lack of human resource", "lack of money for training personnel", and "lack of capacity" were all later grouped under "capacity".

Further analysis of the code categories enabled organization by themes, which identified the key challenges practitioners face. We used simple counting of how many interviewees mentioned a single topic to identify dominant or rare phenomena [32,4].

3. Results

The results present a description of the most common issues discussed by the interviewed practitioners (i.e., participants), as well as particularly interesting points identified in the analysis. The main interview questions we posed intended to clarify the state of GT derived-data use for marine plan development and implementation as well as barriers to the further utilization of GTs. The practitioners spoke of the initiatives in countries with different levels of experience with MSP. Some were very experienced and working already on subsequent iterations of existing plans and some were developing the first version or were working on its implementation.

The results point to the underutilization of existing GTs in some regions and describe the main barriers to enhanced GT use in MSP. By "underutilization" we mean that participants recognized there was more room to include GT in the process. The main barriers participants described were linked to four main themes: (1) knowledge gaps, (2) lack of capacity, (3) data sharing risks, and (4) politics. Knowledge gaps refer to lack of familiarity with technologies which, in some cases, led to mistrust in technology. Lack of capacity included lack of funding, lack of human resources and skill. Data sharing risks lead to cases of conflict of interest. Politics were a barrier because of conflicting interests between inter-governmental entities, or ignorance of politicians, who, as stakeholders, affected the marine plan's outcome.

Most practitioners agreed they lack data for plan development and implementation, and that GTs could be used in more stages of the process. Four practitioners from two of the eleven countries (Australia and the U.S.) directly expressed satisfaction with their current procedures for gathering data. Most practitioners from all countries were not concerned with the lack of data, but rather, their concern focused on how to manage existing data. Unsolicited, as this was not in our pre-interview set questions (Section 2.2), most practitioners discussed the lack of capacity to employ adequate database management systems.

The following review of the themes provides a more specific understanding of barriers to the widespread use of GTs in MSP processes. We begin with some practitioners' acknowledging their lack of data for creating marine plans and move on to barriers to enhancing the use of GT-derived data. We start with direct barriers and finish with broader limitations, which could be considered intrinsic to the MSP process itself, impacting not only the utilization of GTs, but also various other aspects in the process. The exact wording used by interviewees appears below in quotes to provide clear examples and understanding of the participants' experiences. Note that not all results in each section belong to the quoted participant alone.

3.1. Lack of data

Lack of data for planning may occur due to various reasons; data is not collected, data exists yet is not shared with the planning team due to conflicting interests and propriety issues, data resolution issues or because the quality did not match the needed scale. Another reason for problems was underestimation of what data exists due to unorganized or missing cataloging of the data in a governmental inventory, leading to its inaccessibility or perceived absence.

> Participant 12: I think that's true for everywhere…the data gaps are a huge thing. And we don't always acknowledge them in planning, because we're so happy to find something and to use something. We don't know most of the things about the environmental features and biodiversity, distribution of habitats, and also of economic activities, especially fishing.

One of the planners described how missing data interferes with transboundary planning. A neighboring country had a shipping route coming into their EEZ, where they did not have an existing shipping route. Another mismatch example is one country not sharing data on a bird migration corridor with a neighboring country, resulting in that neighboring country planning a windfarm in that path, which can be very harmful to migrating birds.

The inclusion of more dynamic spatiotemporal changes in plans and 3D planning was discussed with planners. Even to one planner from a developed European country, these more complex MSP practices seemed like a faraway idea. This planner also said that static MSP is complicated enough without incorporating spatiotemporal variations into the plan, and that data was lacking to even entertain ideas of dynamic closures to protect mobile species. For this country's marine space, planners created a broad-scale strategic plan, rather than a comprehensive plan with detailed implementation actions, partially because of the low quality of available data;.

> Participant 7: our maps … are two dimensional. I think that's a problem of having the right picture of the whole situation, the complexity…maybe when we could do three-dimensional planning. I don't think it's coming up in the next years.

3.2. Knowledge of technology

Lack of familiarity with technology manifested as uncertainty as to which technologies are available for marine management needs and how and when to best use available GT-derived data. The lack of familiarity, in some cases, led to a reluctance to develop further uses for

available GT.

An Australian scientist whose role is to introduce new technologies for monitoring ecosystems and then to give management advice to government, described a slow regulator and mistrust in technology. Slow regulation necessitates exhaustive testing for trust in any new technology while also significantly delaying the adoption of matured technology. The extended regulatory process requires considerable time for incorporating new technology applications. The mistrust in technology mentioned, manifested in two ways. First, government officials described having greater trust in the expertise of a human than they have in technology, e.g., wanting to know what the expert thinks about a situation rather than basing a decision on a model output and secondly, the reluctance of scientists to use new GTs. The latter was not because of a lack of belief in technology:

> Participant 11: In terms of new technology, there is a social side, which is about trust. There's also the social side about the fear… there will be resistance by people who are practitioners, to new technologies because they'll be afraid of being replaced.

The solution the Australian participant reported for this conflict with technological progression is that the entities responsible for monitoring marine environments are separated from those overseeing the assessment of technology readiness for marine applications. Another participant, working for a governmental authority from a different country than Participant 11, said that they depend on scientists to report to the government which GTs are mature enough for use. Yet there is no standardized reporting process in place to assure this happens.

One regulator revealed favoring the idea of using remote sensing technologies such as satellites, but was not sure how and where such data could be used. One planner firmly agreed that planners should know more about these types of technologies available for delivering marine data.

> Participant 12: It is something that maybe is really missing in the process. Maybe planners, [who] would be more oriented towards data collection methods could lead the way on data collection for their teams as well.

3.2.1. Technology limits

Technology limitations, meaning technology not being good enough, did not come up often in our interviews as a barrier; two participants who addressed optical satellite technology for marine uses mentioned technological limits. These were cloud coverage, set routine temporal resolutions, water penetrating depth limitation and the need to ground-truth the measurements from satellites.

3.3. Data sharing risks

Another barrier to the utilization of more GT-derived data in MSP originates in the perceived consequences of sharing data with the MSP team. Practitioners who participated in developing marine plans felt mistrust and misunderstanding of the process by stakeholders. Another barrier involved conflict of interest, which led to lack of use of existing knowledge specifically collected using GTs.

A planner working for intra-governmental authority described that data that was collected using GTs was not fully shared with their team by other governmental agencies. Another European planner was frustrated with how everyone talks about sharing data, yet no one wants to share any detailed data of their own. The planner described how one ministry made them sign a document stating they would not share the data received, which prevented it being standardized and used for trans-boundary planning, and another planner described datasets for a seasonal migrating animal (based on GT- biotelemetry), where data was not shared properly (too broad by purpose) and could not be used:

> Participant 6: The whole area was marked for this species, because they want to protect the species and don't want to give the people the real areas of distribution. because in some of these areas, hunting is allowed.

A GIS expert from the UK reported that fishery monitoring technology exists and was already installed on commercial fishing boats but its use for monitoring fishing effort is limited because then it could be used also for surveillance and enforcement of illegal fishing. The legal aspects of using the data for prosecution delay this monitoring technology's use for scientific needs.

Practitioners reported a shortage of fishery data. While vessel monitoring systems (VMS) collect data on commercial fisheries, there is little data from small-scale fisheries. Participants from nine of the eleven countries reported that fishers distrust MSP processes and that receiving data directly from fishers was hard. Fishers worry that reporting specific fishing sites as valuable will restrict them from entering other sites.

The fishery sector's approach to MSP is a two-way street, a scientist said. "We can't expect them to trust us with their data as we exclude them from the planning and decision-making process". A planner from Reunion Island described how by including the small-scale fishers in the consultation process they agreed to share their data.

> Participant 2: At some point, we also invested in collecting data straight from the fishing boats. So we bought… GPS tags, and then put them on small fishing boats. And then they wouldn't mind just sharing their data.

Depending on the size of the fishing sector in each country, as well as its political clout, some solutions were found for conflicts between the fisheries and other sectors. An American planner from the East Coast of the US told us how they kept the OWF (offshore wind farm) sites apart from each other in order to allow boats to pass between them, which saves fuel compared to sailing around. In Israel, where fishers do not have strong collective management, gas pipes running from offshore drilling platforms were not required to be buried. Fishers have to stay away from them or lift their gear from the bottom as they approach, which means losing the fish already inside the net. There is no knowledge on how this may affect the spatial distribution of fishing efforts since fishers do not share their location data, they turn off their AIS so they cannot be identified by competing fishers.

3.4. Capacity issues

Lack of capacity, both financial and human was a reoccurring theme in the interviews. Funds were lacking for pressing needs such as for bringing marine plans to completion and paying the team. This was not the case only in developing countries, but a demonstration of a lack of understanding about funding needs for the MSP process in countries creating their first-time plan. Thus, funding data-gathering techniques and data management was deprioritized. Lack of human resource capacity included not having enough people as well as skilled individuals able to utilize GTs-derived data.

3.4.1. Funding for professional personnel

Participants described the link between funding and lack of professional capacity as a situation in which the government does not pay competitively enough to the private sector for the services of professionals. We mention this because participants talked about the lack of personnel who know how to work with GT-derived data.

> Practitioner 5: What the lack of political will does is it means they're not finding a proper data management process. They don't have money for that, or they don't think it's important to fund. So if you don't fund it, you don't get the right people. And if you don't have the right people, you can't do the job. So it [all] starts with a lack of political will not funding something like this. … so they pick a bunch of people who need mentoring, and can't get that mentoring because

you can't pay a double salary for one post. Um, so then, so then you don't have the capacity [to manage the data].

3.4.2. Data management

Capacity for data management was mentioned by many practitioners. The management included funds allocated for skilled personnel to create and manage a database holding all marine plan's raw and processed data. Many planners were concerned with how to handle the data that exists, rather than with lacking or missing data. Practitioners believed this database should be government funded, yet governments were described as not having the capacity to manage it.

> Participant 4: Storage lags, let's say by a central body like a ministry… I think there is underestimation of the data that we have… probably the reason we are not efficiently using the data that we have because probably it exists and a lot of data is not cataloged.

One practitioner described that while governments funds marine plans that include data management sections, they often do not hold planning teams accountable to such sections in plans. A GIS expert expressed worry that vessel tracking through GTs generate massive realms of data and yet government does not have the resources "to do what it needs to, and what it could do, what it should do with all of these data." He hopes that AI (artificial intelligence) will unlock some of the potential in this type of data.

A planner reported that the project did not keep track of the data or of its origin:

> Participant 12: I left the project, [and] because I'm a responsible person, I gave all the data in a very organized way to the people that may remain in the project. But I was not obliged to do that. I could just leave with my computer, with my hard drive. And they will never have this data. And if somebody wants to use the data…they needed to start all over again.

3.4.3. Implementing marine plans

We explored the idea of targeted patrols, based on GT-derived data, with our participants. We wanted to know which technology options are used to enhance the enforcement of marine plan's regulation (e.g., as in [9,42]). A participant from Australia in charge of enforcement was happy with their use of GTs-derived data for supporting targeted patrols, yet participants from Tobago and Trinidad, South Africa, and Brazil were all missing funding to implement their plans through pre-targeted, GT-based patrols. The lack of funding included funding for equipment, and trained personnel to enforce plan regulations. Two participants from different countries brought up the idea of local work culture affecting attitudes toward enforcement.

> Participant 8: It's like, okay, we have plans now. Now what? …we have a good history of making plans, but not of implementing plans… A lot has to do with capacity. Again, you don't have enough bodies… you don't have the equipment. And maybe it's just the culture a bit of, of a perpetual lack of enforcement.

A manager from a remote MPA was aware that in all their places of work in South America, which were always far from the coast, a lot of money was spent on enforcement efforts yet lacked GTs' use to target patrols. Another participant from a different country was asked why existing technology, AIS (automatic identification system) already installed on vessels for safety, is not also used to target enforcement efforts:

> Participant 2: they don't use it. Its either ignorance or they don't want to know…[either] shortage of manpower [or] they don't want to deal with it because it complicates their lives.

3.5. Barriers based on politics

3.5.1. Political will

Many interviewees discussed lack of political will. They talked about political will both in terms of ignorance about MSP process requirements, and of conflicting political interests, both of which impacted the MSP process operation. We asked a practitioner from a governmental environment authority why they do not have a database of the national monitoring data. The response was that marine environment health issues do not have a strong political lobby in their country, so no politician will push for it as a part of their political campaign.

Specifically in terms of GTs, a planner described that the planning authority within government lacks marine-related knowledge, which means government does not even know which skills and professionals they need to hire for their MSP team to develop a plan. For example, the MSP development stages lack funding for GIS and data management experts to deal with data that can be gathered from existing technologies.

A conservation scientist expressed frustration with how the government holds on to power and data:

> Participant 5: Nine times out of ten, the government scientists don't have time, or capacity or capability to analyze the information.and we [academy] can't do that because now the government sits with this inefficient, useless system holding on to the data which they don't manage properly, and nobody can use it… they spent all their money on collecting it. And then, you know, nothing happens.

Three planners from three non-European countries claimed that the planning authority lacks professional capacity, which harms the MSP process. One planner claimed that another problem with the decision makers within the government is that they sit at the capital, far from the sea, and they are not part of the marine community; they do not understand ocean dynamics and how it affects planning for the sea, the need for flexibility and data updates. This harms the formal GT integration within planning processes because GTs support such flexibility.

One other planner, a European, discussed how politicians that saw the complete plan decided, not based on data, but rather on political gain, to ask for more green energy to be placed on the map in "empty" areas, so the plan would seem to promote renewable energy development, as those politicians promised the public. They described how political needs came first:

> Participant 6: And this was really, like, in most cases, independent from any data analysis data we had. Nobody is listening to it. and it's like, useless.

3.5.2. Governance structure, authorities and jurisdictions

A planner described overlapping authorities between fisheries enforcement and environmental authority, causing potential gaps because each authority denies responsibility. The European planners said that marine planners' role in the EU is more of a coordinator role. They continued explaining that the level of government in the country-national, regional, provinces and municipalities affects the type of formulated marine spatial plan: In European countries with regions and municipalities, these lower levels of government overlap with the federal level, requiring a strategic and broader approach to the planning. This approach allows for regional entities to enforce their own regulations and mandates, even when the marine spatial plan is developed at the national level. This structure also creates confusion during implementation, but from a GT perspective, when such general qualitative plans are made, the level of detailed data required is different than when very detailed plans are made, such as in the non-EU countries.

3.6. Keeping updated with potential uses for GTs

Utilizing technologies effectively includes the science team testing which monitoring technologies could fit best for collecting data for baseline gathering when developing the plan, and for monitoring environmental success indicators during implementation stages. One planner even described testing five different ways to monitor seagrass and compare between them. This planner was involved in one of the more data-oriented marine plans that intends to include more spatio-temporal variations in future plans that will include varying spatial restrictions over the seasons:

> Participant 9: So, there are two things [for which] we are generating the data, the change by season as you are. One thing will have these, changing [seasonal] maps, the other thing is that for whales, and for a lot of species of fish, …knowing when they are with their life cycles, how they go, etc., look like time of [the] year restrictions. [And] we think we can refine them further and make it easier for developers. And so, impact for… many species, if we have these, like moving, less static, maps.

Implementation of marine plan regulations requires effective usage of resources. One regulator from Australia protecting remote MPAs reported repeated trials with various GTs for targeting and improving their patrols. They reported being happy with their enforcement procedures based on satellite-based VMS, in which every commercial fishing vessel approaching a MPA is alerted beforehand (i.e., "geo-fencing").

Altogether, experiences from this study bring up the need to evaluate how GTs are perceived and utilized within the MSP context. We identify four main groups of barriers from examples presented by the practitioners, who hold diverse roles within the MSP process, each contributing unique perspectives and experiences. The barriers were: familiarity with technologies, data sharing conflicts, capacity of the MSP process, and political considerations. The findings indicate that challenges to enhanced utilization could be met at different levels. At the top level within the relevant authorities initiating the MSP processes, and also throughout the entire process, where challenges to implementing GT-based tools and data persist.

4. Discussion

Marine spatial initiatives' success in managing human activities requires the best spatial data available [12,46,50]. Our findings, drawn from interviews with 17 worldwide marine practitioners referring to 11 different marine initiatives suggest that utilizing GT-derived data for marine plan development and implementation is limited in some regions. Numerous initiatives and networks have been established for data collection, validation, and sharing across Europe (e.g., ICES; EMODnet; HELCOM; OSPAR; [35]), yet by adopting a broader global perspective on the utilization of GT-derived data within MSP processes, we identified four types of barriers hindering greater GT's use. These barriers are particularly interesting to the authors, as they may have broad implications and applicability to many countries engaged in marine planning. These barriers may have special significance particularly for those countries lacking practices to enhance GT-derived data uses.

Studies examining the lack of specific GT use in MSP reached related conclusions to the underutilization of technology in MSP. For example, Dupont et al. [10] look into how many maritime surveillance systems (maritime traffic systems) were acknowledged in the literature specifically for MSP practices. Out of 2030 papers, only 63 mentioned MSP. These authors contend that this delay in incorporating technology in policy, meaning here in MSP, is primarily associated with matters of accessibility, acceptance by economic sectors' stakeholders, and adoption by decision makers. As do other researchers (e.g., Dupont et al. [10]), we consider this evidence of the science-policy gap.

Furthermore, Al-Quhali et al. [1] suggest improved communication and knowledge exchange between vessel traffic services experts and marine planners could enhance marine transport integration into marine plans. We mention this since one of our participants stated that planners could better lead their teams if they became more oriented toward data-collecting methods. Another participant claimed that conservative regulators slow the process of incorporating new technologies, mistrusting their abilities. This leads us to suggest that planners should hold more workshops and communications with scientists working with GTs-derived data for mutual education and two-way learning opportunities. Inviting relevant regulators to such workshops might be viable as well.

In our interviews, planners favored the idea of using satellite technologies, but often were unsure of the abilities of satellite-based technologies. They mostly mentioned optical earth observation technologies and were often unfamiliar with other earth observation means, such as VIIRS or SAR. These other satellite technologies allow the collection of both environmental and human-related data [14,19,24,26,8]. While these technologies may fit some marine management applications and not others, the lack of familiarity with them is the concern we raise here. Janßen et al. [27] also address the lack of use due to unfamiliarity. They explored why decision support tools were not being used in MSP and found that the reason is simply a lack of awareness of them.

We describe some barriers as rooted in unfamiliarity and distrust in the MSP process as a whole. Mistrust led to a lack of data sharing. GT-derived data exist but could not be used for the plan development because of conflicts of interest. European planners described encountering challenges in obtaining accurate data about the locations of endangered species from environmental organization concerned about the risks of exposing the animals' locations. While the reasonable desire to protect endangered species hinders data sharing, similar conflicts have occurred before, and there are potential solutions and compromises. For example, Tulloch et al. [57] created a decision tree for assessing risks and benefits of publishing spatial data and suggested methods of publishing information on where near species occur without directly releasing locational data.

Another conflict we noted relates to the lack of fishing effort data in marine plans. Participants from Spain, Israel and South Africa reported on this. Fishers avoided sharing their data. In countries where VMS functions, this could be partially overcome; however, wherever small-scale fisheries are employed, VMS cannot provide data and other solutions are needed [15]. Small-scale fishers in Poland believe that authorities undervalue and underutilize their experience and knowledge, making them hesitant to share their fishing effort data [54]. Yet, the Reunion Island participant told us that small-scale fishers were happy to participate since they knew of their direct contribution to the process. This highlights the importance of stakeholder participation, which while beyond our current scope, is widely covered in the MSP related literature (e.g., [44,45,59]).

Issues with vessel tracking data arise with AIS as well. Dupont et al. [11] describe fishers in France as lacking acceptability of the use of a system designed for safety at sea, for tracking and spying on their location. Le Tixerant et al. [29] discuss the legal challenges of exploiting AIS data in Europe. In one of our interviews a participant mentioned their frustration with how similar legal issues kept fishery scientists from analyzing fishing efforts from existing satellite-based fisheries tracking data. The conflict between fishery enforcement and privacy issues hindered the data released strictly for fishery data analysis. As Le Tixerant et al., [29] point out, this is another barrier to overcome within a country's legal system if the promising perspectives offered by AIS data are to be fully integrated into MSP.

The final conflict-related factor we identified is lack of cross-border cooperation. This was noted by a European participant who described poor planning that resulted from neighboring countries not sharing GT-derived data on traffic lanes, OWF and migration routes in the initial planning stages. Ansong et al. [3] describe how institutional barriers to transboundary MSP result in undermined achievements of sustainability goals in shared marine ecosystems. Similar to what this European

participant told us, Ritchie et al. [43] argue that cross-border MSP is not initiated early enough in MSP processes when meaningful engagement is most relevant and that greater integration is required to deliver sustainable outcomes. Janßen et al. [27] interviewed marine planners, from the Baltic Sea region on the topic of cross-border cooperation. They suggest that planners should initially utilize existing data and data management systems. Then, gradually, they should work towards harmonizing these aspects to create a more consistent and unified approach to data and information exchange in MSP processes. Joint projects and cooperation could potentially improve planning. Gacutan et al. [18] suggest working with standardized information as a baseline for collaboration across borders.

Toonen & Mol [56] discussed the importance of information for marine governance. Some of their claims resonate well with our findings, particularly the emphasis on challenges to ensuring high quality and reliable information. They also mention, as we do, the danger of information overflow, i.e., challenges of too much data. Regarding the first issue, we observed a difference between European and non-European countries concerning data quality and suitability. Our participants discussed the integration of GT-derived data during the development stages of marine plans. MSP can take many forms, from high-level strategic plans to comprehensive plans with detailed implementation actions [58]. There are progressive analytical and decision support tools explicitly aimed to advance MSP (e.g., Symphony from Sweden (https://www.havochvatten.se/en/eu-and-international/marine-spatial-planning/swedish-marine-spatial-planning/the-marine-spatial-planning-process/development-of-plan-proposals/symphony—a-tool-for-ecosystem-based-marine-spatial-planning.html) and ECOMAR from Denmark, [2]). These rely on validated quality data feeding into models, including much GT-derived data. Further, if other countries wish to employ such tools, aiding in developing ecosystem-based MSP, such quality data is needed.

As mentioned by the European planners, not all data collected for various purposes is of good quality for MSP needs. If a country is developing iterative plans, such as Germany, that only uses pre-collected data tailored to the targeted projects, then some data might be missing to successfully utilize the tools mentioned above. Even in Denmark's ECOMAR framework, with its state-of-the-art datasets (European MSP Platform) some models are renounced as "weak," due to poor or missing data (ECOMAR's supplementary materials). By contrast, a non-European planner explained how they compared five different methods for collecting environmental data, to determine the most effective and informative method for their planning requirements. Future research endeavors could be directed toward developing more comprehensive methodologies to integrate GT-derived data into MSP processes. However, considering the influence of a country's federal system, size, and regulatory intricacies, the approach may need to be adapted. Consequently, the roles of GT, data, and tools must be addressed by responsible agencies through their management policies.

The second pertinent topic addressed by Toonen & Mol [56] that we highlight, focuses on the issue of too much information. Too much information may reduce its usefulness and steering capacity. This was echoed in our interviews. One of our respondents, a regulator from Australia protecting remote areas, told us how they tried various GTs and chose the one that produced targeted results, yet with the amount of data limited to what they could handle. A GIS expert from the UK expressed how much human-use related data was constantly collected and stored, yet remained unmanaged and ultimately failed to be analyzed due to capacity issues. As this is a recognized global problem it becomes more likely over time as AI and data science evolve [41,5], that technology improve to treat all data gathered in ways that will lead to improved marine management.

In the meantime, the more GT-derived data gathered, the harder it is to manage without proper funding for a structured database. Many of the practitioners interviewed were more concerned with managing the data they possess than with the overall lack of data. Gacutan et al. [18] suggest promoting an ocean governance framework, a structured and standardized 'data foundation' for MSP that provides a structure to integrate the information describing ocean ecosystems and their changing relationships with society and the economy. A cautionary comment came from a participant who described a case where government gave funding for managing a database without any mechanism for ensuring its delivery.

Looking at GTs in the MSP context has forced us to consider the limitations of the MSP process itself. As noted by Gacutan et al. [18] and Zhang et al. [59], oceans have been impacted by a history of imperfect governance, resulting in a substantial lack of capacity to manage marine socio-ecological systems. Practitioners from Israel, South Africa, and Reunion Island, expressed disappointment with their governments' approach to the MSP process. Lack of capacity in government, and more specifically in the planning authority, manifested as misunderstanding and unfamiliarity with MSP process needs and failures of governance challenged the MSP teams. Participants discussed the government's lack of capacity, resulting in underfunding of certain aspects of the process, including data collection, data management, legislation, and enforcement. Lack of investment in recruiting a skilled planning team also led to inability to efficiently collect and analyze GT-derived data.

In their 2021 MSP planning guide, UNESCO-IOC warned that additional costs associated with greater than estimated workloads and/or time overruns could be avoided by investing in good project planning at the outset and throughout the planning process (p.55). One of the practitioners interviewed described time and financial constraints leading to proxies replacing real satellite-based fishery effort data. This practitioner described how the first barrier to using GT-derived data occurred at the funding stage, primarily due to a lack of government understanding of MSP needs. This, in turn negated GT data analysis because the planning project had no more time or money.

With regard to financial issues, there are strategies dedicated to the funding of planning and implementing marine plans [53,58,7]. For example, one practitioner reported in their interview a sustainable financing strategy for monitoring its MPAs that involved raising funds for research by taxing the oil companies exploring the nearby areas. Booth & Brooks [7] examine a successful debt-for-nature swap in the Seychelles yet warn against the grave consequences this mechanism may cause by corrupted governments.

The concept of government's power and political intrests continues our discussion on its effect on the MSP process. In our interviews, a European planner noted that politicians in the current plan requested more OWFs without considering the existing data that led to the suggested optimal physical OWF location. This emphasizes how political interests can supersede evidence-based approaches. As we discuss barriers to GTs implementation, we offer our notion that basing OWF allocation on data such as seabed type, local biota and human activities [49] may align better with any evolving objectives and be more effective in the long run.

Using GTs to address more complex aspects of MSP processes, such as spatiotemporal variation within plans and three-dimensional planning, was discussed with participants. Only participants from Australia and the U.S. mentioned such actions. Factors like dynamics and the third dimension (depth) are often simply not addressed in efforts such as marine conservation planning. This is unfortunate, considering the global need for improving human-wildlife interactions in a manner beneficial for both human activities and nature conservation goals [22,23,31]. These authors indicate how GTs-derived data supports strategies for balancing tradeoffs. Therefore, it is important to learn lessons from those engaging in complex spatiotemporal planning, considering seasonal variation or different depth characteristics, thus adding more dynamic elements into planning and management (e.g., *2021 Massachusetts Ocean Management Plan* [33]).

Lastly, we asked the interviewed practitioners for possible solutions to the barriers identified. Suggestions included increasing instruction on GTs and the type of data they provide through workshops and

communications between scientists and planners; starting with a core planning team that will educate other, peripheral and partner planning authorities on all MSP process-related resource needs. This should include educating about the need to allocate funds for managing MSP-related data in a centralized database and stipulating adequate enforcement expenses, including GT-derived data uses. This type of government preparation could prevent going into an underfunded project, ending in overrun (time and money) or unimplemented plans.

One may note that the participant can only share personal experiences and not a complete set of opinions. The snowball sampling of practitioners we used resulted in information that is not generalizable to all. This methodological shortcoming, posed by a limited number of willing participants, could be partially overcome if more countries were to document and publish their operations. While we employed interviews to attain information on the integration of GTs in MSP processes, a greater body of literature reporting similar or variations on our findings would facilitate broader dissemination of best practices and effective methods for others to learn from.

5. Conclusion

Geospatial technology-derived data is essential for planning in the marine environment. The barriers we identified through this research to enhance GTs use in MSP processes include unfamiliarity with existing technologies, data-sharing conflicts, a lack of capacity in MSP processes, and the precedence of political considerations. Unfamiliarity with technology could be addressed through training and workshops involving scientists working with GTs, planners and other relevant marine managers. Unfamiliarity and lack of trust in the MSP process led to the last three barriers we recognized as hurdles to further utilizing GT-derived data in MSP. We conclude that acknowledging the key role of authorities responsible for initiating MSP could potentially overcome certain barriers related to improving GT-derived data use within the context of MSP. Authorities providing the MSP team with essential conditions for success, including funding for data gathering, database maintenance, and the hiring of skilled teams capable of analyzing and managing data, would undoubtedly improve the use of GTs and enhance MSP practices.

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Declaration of Competing Interest

None.

Data Availability

The data that has been used is confidential.

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