Cecilia et all. | ACM, 2021. This is a author version of the work published in ACM GoodIT, https://dl.acm.org/doi/10.1145/3462203.3475925

SMARTLAGOON: Innovative modelling approaches for predicting socio-environmental evolution in highly anthropized coastal lagoons

José M. Cecilia*
Pietro Manzoni
Universitat Politècnica de València
Valencia, Spain
{jmcecilia,pmanzoni}@disca.upv.es

Dennis Trolle
Anders Nielsen
WaterITech
Aarhus, Denmark
{dt,an}@wateritech.com

Pablo Blanco
Vielca Ingenieros, S.A.
Valencia, Spain
pablo.b@vielca.com

Catia Prandi
University of Bologna
Bologna, Italy
catia.prandi2@unibo.it

Salvador Peña-Haro
Photrack, A.G.
Zurich, Switzerland
pena@photrack.ch

Line Barkved
Norwegian Institute for Water Research (NIVA)
Oslo, Norway
line.barkved@niva.no

Don Pierson
Uppsala University
Uppsala, Swedeen
don.pierson@ebc.uu.se

Javier Senent*
Universidad Católica de Murcia (UCAM)
Murcia, Spain
jsenent@ucam.edu

ABSTRACT

Coastal lagoons are ecosystems with significant environmental and socio-economic value. However, these natural systems are especially vulnerable to climatic and anthropogenic pressures, such as intensive agriculture and extensive urbanization as a consequence of the tourist development. Despite the vulnerability and complexity of these ecosystems, there has been limited development of novel techniques which can provide real-time monitoring, analysis and management of these critical resources. Beyond being useful for policy-making procedures at multiple levels of granularity, such tools can increase local and citizen awareness of environmental impacts. This paper introduces the key concept behind the SMARTLAGOON project, which intends to develop a digital twin to build a systemic understanding of the socio-environmental inter-relationships affecting coastal lagoons and their ecosystem. Particularly, we focus on the main research activities carried out since the beginning of the project (January 1st, 2021), which are mainly based on initial mapping and reporting of the main stakeholders' needs and wishes in relation to the technological products to be developed in SMARTLAGOON. This will onset the initial development pathway, while additional stakeholder inputs during the project lifetime will help to further explore and prioritize the key developments, thus maximizing the relevance and impact of the Mar Menor's digital twin.

CCS CONCEPTS

• **Computer systems organization** → **Embedded systems**; *Redundancy*; Robotics; • **Networks** → Network reliability.

KEYWORDS

SMARTLAGOON, Digital Twin, Environmental Intelligence, Citizen Science

ACM Reference Format:
José M. Cecilia, Pietro Manzoni, Dennis Trolle, Anders Nielsen, Pablo Blanco, Catia Prandi, Salvador Peña-Haro, Line Barkved, Don Pierson, and Javier Senent. 2022. SMARTLAGOON: Innovative modelling approaches for predicting socio-environmental evolution in highly anthropized coastal lagoons. In *Proceedings of ACM Conference (Conference'17).* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/nnnnnnn.nnnnnnn

1 INTRODUCTION

Coastal lagoons occupy 13% of the world's coastline, representing 5.3% of Europe [8]. They are among the most productive ecosystems on the planet, being valuable ecosystems for fishing and aquaculture, a location for saltworks, supporting a variety of human recreational activities, and providing other ecosystem services such as the retention and purification of pollutants, that are critical to the ecology of the coastal zone [7]. However, these natural systems are especially vulnerable to climatic and anthropogenic pressures [2]. Moreover, the high degree of heterogeneity and complexity of hydrological, hydrodynamic, ecological and socioeconomic processes classifies coastal lagoons as highly complex systems [6].

Conference'17, July 2017, Washington, DC, USA

ACM ISBN 978-x-xxxx-xxxx-x/YY/MM…$15.00
https://doi.org/10.1145/nnnnnnn.nnnnnnn

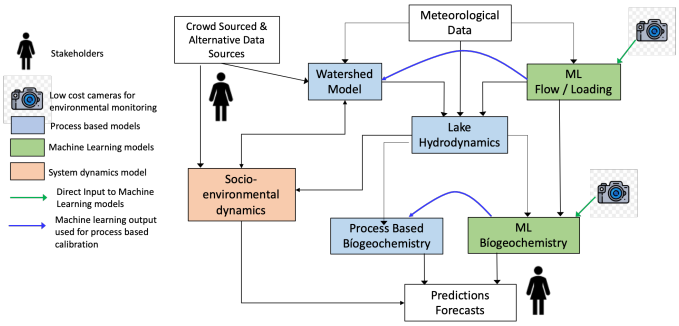

Figure 1: SMARTLAGOON concept in a nutshell

SMARTLAGOON is a H2020 funded project under the call "Environmental Intelligence". It main concept consists of designing intelligent systems based on digital twins to: i) build a systemic understanding of the socio-environmental processes affecting coastal lagoons systems, and ii) enable assessment of the outcomes of future management options. A digital twin is a virtual replica of a product, service or process that simulates the behavior of its physical counterpart, in order to analyze its reaction to certain situations and improve its performance and efficiency [3]. Application of Digital twins started as part of optimization of processes in Industry 4.0. Thanks to advances in Artificial Intelligence (AI), high performance computing (HPC) and the Internet of Things (IoT), digital twins have spread to other sectors such as smart cities [5] and natural disaster management [4].

The SMARTLAGOON digital twin will combine different modeling approaches that will be distributed in different modules, which will feed into a forecast and prediction portal (see Figure 1). Particularly, SMARTLAGOON will be application-driven based on the Mar Menor (Murcia, Spain); the largest hypersaline coastal lagoon in Europe and catalogued as a RAMSAR site[1]. It was chosen as an example for rolling out the SMARTLAGOON's approach as it has intensified pressures (agriculture, tourism, fishery, urbanization, eutrophication, contamination, flash flooding, climate change) that have led to environmental deterioration, which through negative feedback impacts some of the socioeconomic drivers [1]. In addition, the Mar Menor area is a challenging scenario from a technological point of view because of its large geographical spread (135 km^2), which limits Internet connectivity in many regions. Therefore, new approaches for monitoring, modelling and forecasting socio-environmental dynamics are needed, to restore, preserve and manage them adequately in the future. Stakeholders will play a fundamental role in SMARTLAGOON as they will provide qualitative information based on their local knowledge, main concerns, opinions and subjective perspectives of their reality. They will be involved at several stages and for different purposes, including participatory model and scenarios development, data collection, interpretation of results, etc. This paper presents the first findings of the interactions with stakeholders in the Mar Menor area to define the first requirements and expectations of SMARTLAGOON's digital twin. Situated within a Responsible Research and Innovation (RRI) approach and being an application-driven project, the development will be guided by a continuous interaction with stakeholders that will be periodically evaluated to redirect possible refinements.

The rest of the article is structured as follows. First, section 2 describes the methodology carried out with stakeholders, which has been conditioned by the constraints of the COVID-19 pandemic. It then shows the results obtained after this set of interviews in Section 3 before determining the main conclusions and directions for future work.

2 METHODS

To identify stakeholder expectations, wishes and needs connected to the hydrological and water quality forecast portal to be developed in SMARTLAGOON, this paper presents the main results achieved by carrying out a set of interactions (interviews and questionnaires) with relevant stakeholders of the Mar Menor area (Spain). This would identify an initial pathway for relevant developments of the forecasting portal and establish the roadmap for software co-development with stakeholders. The original intention was to host a small stakeholder workshop in the Mar Menor (Spain), where current state-of-the-art could be demonstrated (based on WaterITech's ASAP portal [2], Photrack's DischargeApp [3] and UPV's sensingtools [4]). This on-site workshop participants would get the opportunity to test preliminary developments and provide feedback, with focus on their specific needs. However, this had to be changed to an online format, due to COVID19. In what follows, we describe the online stakeholder interactions that have been carried out in SMARTLAGOON for initial requirements acquisition.

2.1 Stakeholders interactions

Rather than hosting one physical workshop alongside the kickoff meeting, arrangements were made for several stakeholder interactions. These interactions were facilitated by Vielca Ingenieros, S.A. [5], who also conducted an initial stakeholder mapping. The interactions can generally be divided into interactions with main stakeholders, represented by those that provided letters of support for the project proposal, and interactions with additional stakeholders, who were identified in the stakeholder mapping as someone with potential interest in the SMARTLAGOON project. Figure 2 shows the classification of stakeholders developed by SMARTLAGOON in the first semester of the project execution. The first round of meetings focused on identifying the main stakeholders. We address at least one representative stakeholder from each group by only video meetings or, in some cases, by face-to-face meeting, ensuring all security measures established by the health authorities. For example, we met with the CHS[6], the Directorate General of the Mar Menor, and the town councils of San Javier and Cartagena as public administrations. From the private companies sector, we met with the Regional Confederation of Business Organisations of Murcia (CROEM), which represents private companies from different sectors, including tourism, agriculture, etc. In the NGOs category, we met with "Pacto por el Mar Menor", and finally, with

[1] https://rsis.ramsar.org/ris/706

[2] https://waterwebtools.com/
[3] http://www.photrack.ch/products.html
[4] https://sensingtools.com/aplicaciones
[5] http://www.vielca.com/web/
[6] https://chsegura.es/en

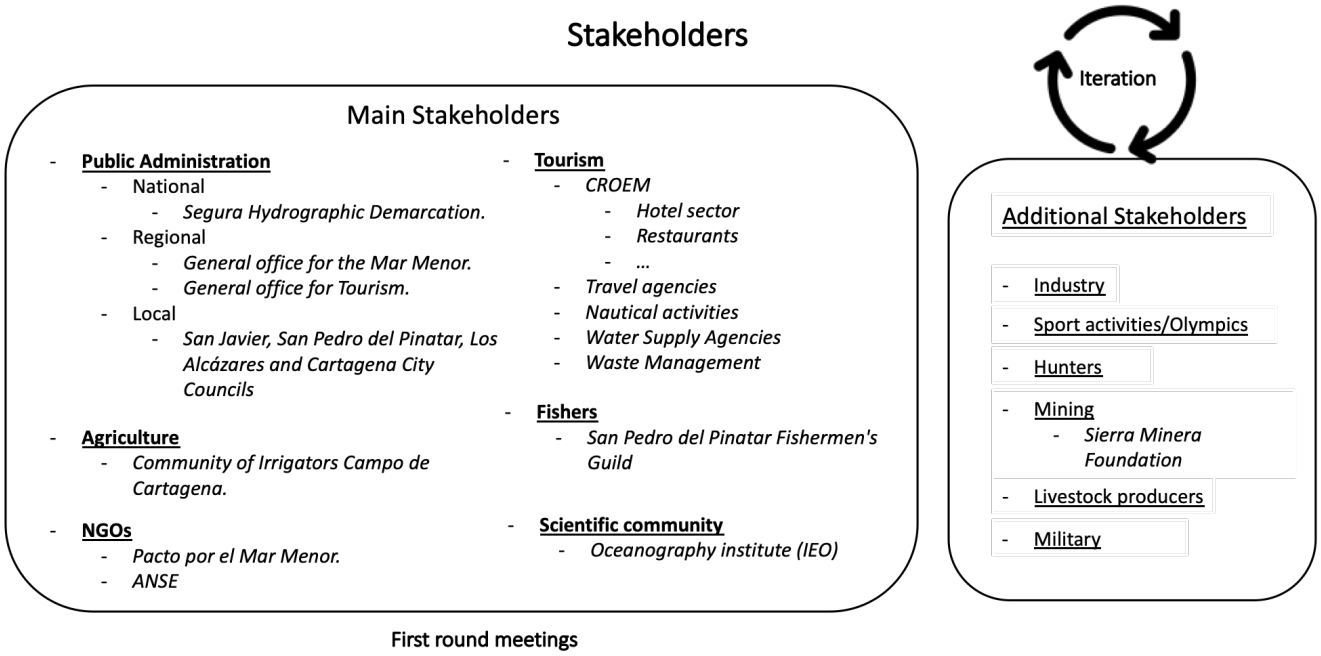

Figure 2: Main stakeholders classification developed by SMARTLAGOON of the Mar Menor area (Murcia, Spain).

the scientific community we met with the oceanographic institute, whose headquarters are at the shore of Mar Menor. In addition, more than 100 institutions were contacted via telephone in the different categories identified.

The interactions generally followed this procedure:

- Brief introduction to the project and the scope of the interaction by Vielca, UPV and UCAM
- Display of (or sending link to) introduction video produced by WaterITech, which sets the scene and showcase the value of water from different perspectives, key challenges relating to water, and a teaser for how a forecasting portal could potentially be useful to get insights and make decisions to overcome or mitigate these challenges
- As a follow-up, stakeholders where sent a link to an anonymous online questionnaire, which they were also encouraged to share with colleagues and affiliates.

As stakeholder inputs are required for several work packages of SMARTLAGOON, the questionnaire was developed together by all project partners, whereby the inputs from stakeholders could provide a first general picture of environmental and socio-economic issues in the area. Particularly, SMARTLAGOON aims at identifying the following aspects: what are the main population segments in the study area, their channels of information and expression of opinions and concerns/complaints related to environmental and socio-economic issues and what are their expectations of the technological products developed by SMARTLAGOON, including environmental monitoring and forecasting tools, crowdsensing, etc. We have also taken into account any disadvantages for stakeholders, by minimizing the total time required for them to spend on interactions in SMARTLAGOON. The questionnaire was produced and completed using Google Forms, in both an English and Spanish version (link to English version [7]). Finally, the questionnaire was published on social networks such as Twitter, Facebook and Linkedin, as part of reaching the main local entities in the study area, as well as their citizens. It is important to note that the questionnaire was designed following the main principles of General Data Protection Regulation (GDPR), i.e. no personal data was requested at any point.

3 EVALUATION

At the time of writing, a total of 105 individual stakeholders had been contacted, and a total of 77 individual answer reports for the questionnaire had been received. The key outcomes in relation to wishes and needs for the forecasting portal and the social sensing tool are reported in this paper. Moreover, we also provide discussions and outcomes for other aspects of the questionnaire such as gender and age dimension of the targeted people and the use of social media tools. Several sectors were represented in the stakeholder group, where particularly Science, Tourism, and local citizens amounted to a high proportion of the respondents at this stage of the research. (see Figure 3).

In addition, this survey also considered the age dimension. 75.3% of the sample surveyed reported being between 35-65 years old.Hence only a small remaining % were over 65. This data represents the population of the region of Murcia, where 53% of the Murcian population is in the 35-65 age bracket according to the 2021 census. 28% are in the 18-35 age group and only 19% are over 65. Although

[7] https://docs.google.com/forms/d/1DsUzOaM-hrvt2Psyt1RsB3WxX2jBUluqMLaZRZzxi65o/

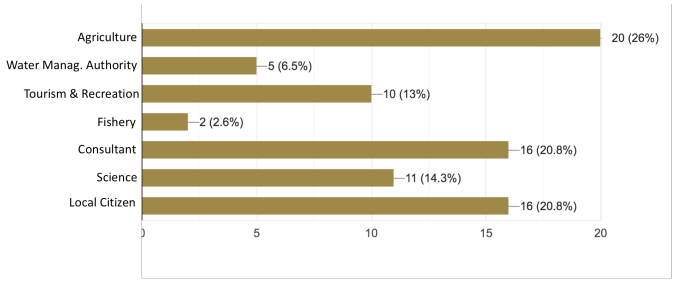

Figure 3: The proportion of different sectors represented by the stakeholders.

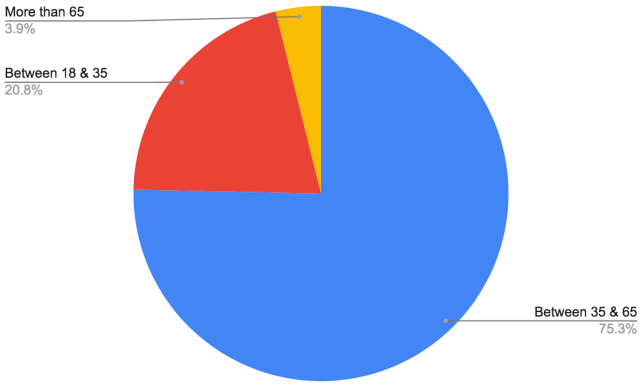

Figure 4: Age dimension of targeted stakeholders.

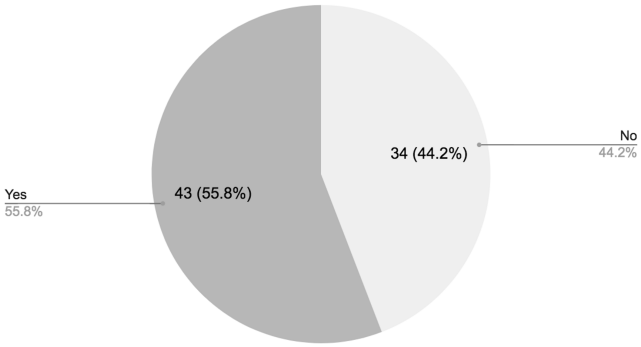

Figure 5: Percentage of social media users (e.g. Twitter, Facebook) to express their opinions about socio-economic or environmental issues

it is true that this last age group is under-represented in our sample, mainly due to the digital divide, as the surveys were carried out online. Face-to-face meetings could potentially have reached this age group more easily.

As part of a comprehensive overview of the perspectives and management of the coastal lagoon, a relevant aspect of our research

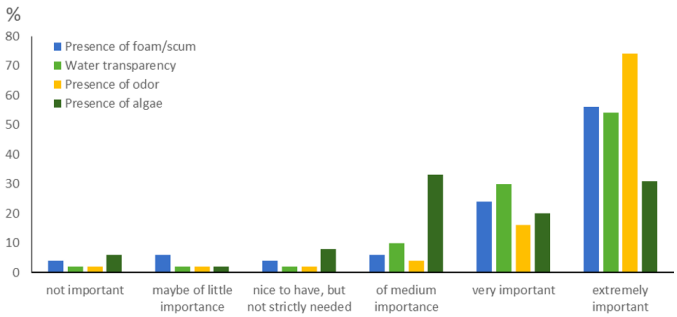

Figure 6: The importance of different water related aspects for stakeholders

is if stakeholders use social media to express their socio-economic and/or environmental concerns. Figure 5 shows that more than half of the surveyed sample uses this type of channels to express their opinions. It is important to note that the most active group of users on social networks, i.e. under 35 years old, only represents 20.8% of the total. Therefore, these results confirm the wide use of social networks in the selected area. In particular, the most used social network is Twitter with 51.9% of the surveyed users, followed by Facebook with 50.6 and Instagram (16.9%). The traditional press is also a prominent source of information with 51.9% of respondents. It is noteworthy that this information is more passive, i.e. users receive information, but rarely express their opinions. Therefore, it is understood as a one-way communication channel to communicate certain relevant aspects of the research carried out by SMARTLAGOON.

When focusing on elements of key importance to the stakeholders, in relation to the Mar Menor, stakeholders were asked about both traditional water quality elements, which can be modelled (e.g. algal levels and water transparency), but also aspects which are not usually quantified by predictive ecosystem models, such as the presence of odor or foam. Interestingly, aspects, which are not usually targeted for modelling, were generally equally or even more important. Hence, odor and the presence of foam/scum were ranked more important than the levels of algae (see Figure 6). All these elements were, however, generally ranked either as "very important" or "extremely important" for the stakeholders.

In order to target the developments of the forecast portal, and better understand which specific information – predictable by a model – that stakeholders would value the most, stakeholders were asked to rank a series of outputs, known to be predicted by a hydrological or ecological model (see Figure 8). Generally, the majority of the traditional model outputs were ranked as very important or extremely important. The single most important model output was oxygen levels in the Mar Menor, which fifty percent of the respondents reported as "extremely important".

Another key aspect, when developing the forecast portal, is knowledge about the time horizons that are most relevant to the stakeholders (see Figure 9). The stakeholders were therefore asked to rank different time horizons, ranging from present (real-time) and up to two weeks into the future, in terms of how useful such information could be for them. Generally, real-time data and 24

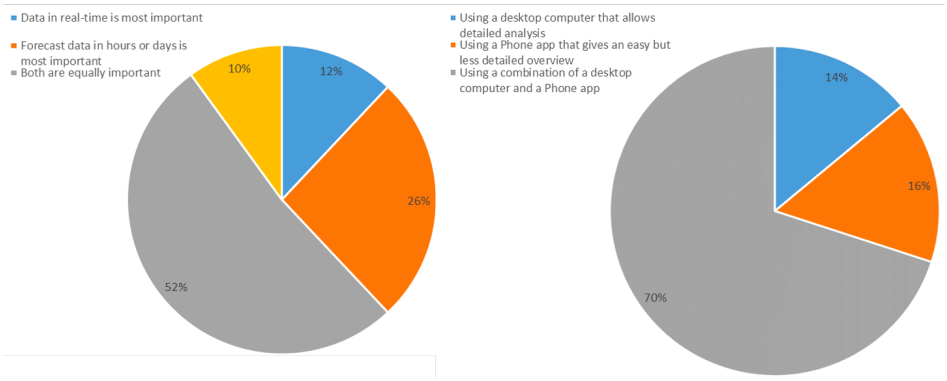

Figure 7: The importance of real-time data vs. forecast data for stakeholders (left), and how stake-holders would prefer to work with the data (right).

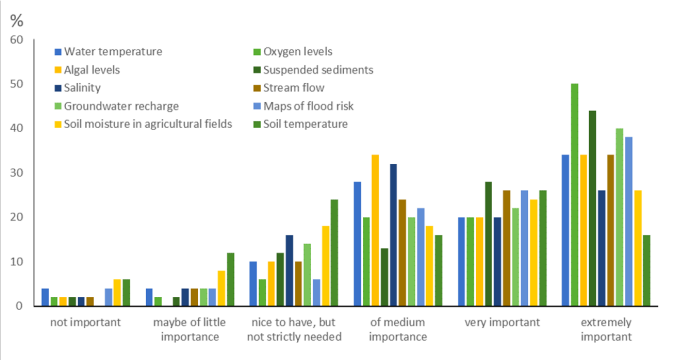

Figure 8: Ranking of the importance of known model outputs types.

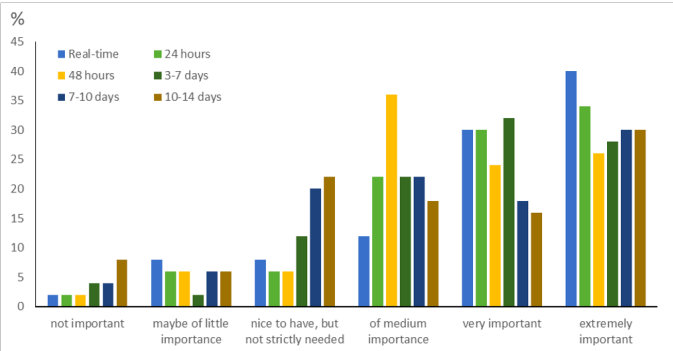

Figure 9: Ranking of the relevance of different forecast time horizons.

hours into the future were the most important time horizons for the stakeholders. While most stakeholders found forecast data and real-time data equally important (52%), there was a somewhat higher proportion of stakeholders that found forecast data more important (26%) compared to real-time data (12%) (see Figure 9).

It is possible to work with real-time and forecast data on different devices. Desktop applications, such as the ASAP portal by WaterITech, generally allow detailed analysis of the forecast impacts, whereas phone apps can provide a quick, but much less detailed overview. However, the stakeholders revealed that they would much rather work with a combination of a desktop solution and a phone app, rather than being restricted to only one of these solutions (see Figure 7).

A final aspect analyzed in relation to the forecast portal was the stakeholders "willingness to pay". Only a small proportion (14%) were willing to pay for access to a forecasting service (see Figure 10), while, in contrast, a large majority of the respondents (76%) felt that a hydrological and ecological forecast service should be paid for by public authorities, and then be made available for the private and public sectors.

4 CONCLUSIONS

SMARTLAGOON is a H2020 European project which intends to develop a digital twin to build a systemic understanding of the socio-environmental inter-relationships affecting coastal lagoons and their ecosystem. A particular case study is targeted; the Europe's largest salt water coastal lagoon, i.e. Mar Menor (Murcia, Spain), which has suffered serious environmental degradation due to several socio/environmental reasons. This particularisation of the study area makes it possible to delimit the area of influence and the groups involved in the ecosystem. Therefore, SMARTLAGOON, follows a software co-design approach with stakeholders to make the transition from science-to-technology through developing advanced TRL products. This is an iterative procedure throughout the project implementation in which stakeholders play an important role in decision making. This article presents the first round of stakeholders interviews, conditioned by the COVID-19 pandemic, where several aspects are analyzed to start developing our monitoring and forecasting tools.

Through the inputs collected from key stakeholders of SMARTLAGOON, we have learned about their key interest and priorities for a hydrological and water quality forecast portal for the Mar Menor and its surrounding area. Stakeholders have identified social media

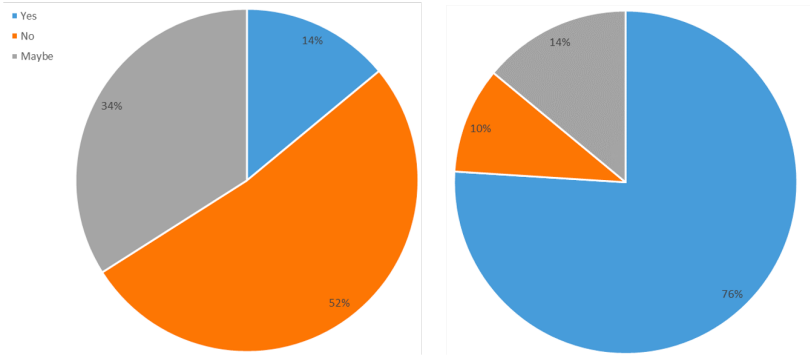

Figure 10: The willingness to pay. Would you be prepared to pay for a forecast service (left), and do you think that public authorities should pay and provide a forecast service to you (right).

as a relevant channel to be informed about environmental/socio-economic issues and where they can express their concerns about these issues. Specifically, Twitter is the most widespread social network for this type of manifestations in this area. The stakeholders generally ranked key water related information, which can be predicted by state-of-the-art hydrological and ecological models as either "very important" or "extremely important". Oxygen levels and water transparency, which are well-known outputs from models, were amongst the most important outputs. Aspects, which are not traditionally predicted by models, such as odor and foam or scum, were also identified as important. Overall, the responses of the stakeholder suggest that the digital twin to be development in SMARTLAGOON address an important unmet need, and that there is great potential for this to be very well received. According to a large majority of the respondents, subscriptions to such information service should be paid for by public authorities, and then be made available for the private and public sectors.

The most important time horizon in terms of forecasting was 24 hours into the future, followed by predictions up to 7 days, and the stakeholders indicated that a combination of a desktop computer application and a phone app would likely be ideal when working with the forecast data. These initial stakeholder inputs represent a highly valuable resource, and revealed key priorities of the stakeholders, which the project partners will now try to accommodate as much as possible in the developments throughout SMARTLAGOON.

Based on the analysis of these results, SMARTLAGOON continues the execution of its tasks by designing the environmental and social monitoring systems established through the deployment of various IoT infrastructures that measure the variables of interest to the community and designing a social sensing strategy that allows people to be used as sensors, identifying potential environmental problems. Once this data is collected, several socio-economic and environmental models will be designed.

ACKNOWLEDGMENTS

This work has been supported by the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017861.

REFERENCES

[1] Javier Bayo, Dolores Rojo, and Sonia Olmos. 2019. Abundance, morphology and chemical composition of microplastics in sand and sediments from a protected coastal area: The Mar Menor lagoon (SE Spain). *Environmental Pollution* 252 (2019), 1357–1366.

[2] Ana C Brito, Alice Newton, Paul Tett, and Teresa F Fernandes. 2012. How will shallow coastal lagoons respond to climate change? A modelling investigation. *Estuarine, Coastal and Shelf Science* 112 (2012), 98–104.

[3] Abdulmotaleb El Saddik. 2018. Digital twins: The convergence of multimedia technologies. *IEEE multimedia* 25, 2 (2018), 87–92.

[4] Chao Fan, Cheng Zhang, Alex Yahja, and Ali Mostafavi. 2021. Disaster City Digital Twin: A vision for integrating artificial and human intelligence for disaster management. *International Journal of Information Management* 56 (2021), 102049.

[5] David N Ford and Charles M Wolf. 2020. Smart cities with digital twin systems for disaster management. *Journal of Management in Engineering* 36, 4 (2020), 04020027.

[6] S García-Ayllón. 2017. Integrated management in coastal lagoons of highly complexity environments: Resilience comparative analysis for three case-studies. *Ocean & Coastal Management* 143 (2017), 16–25.

[7] A Newton, JD Icely, HC Tseng, S Cristina, AC Brito, I Clara, V Derolez, S Angus, G Schernewski, M Inácio, et al. 2018. Assessing, quantifying and valuing the ecosystem services of coastal lagoons. *Journal for Nature Conservation* 44 (2018), 50–65.

[8] A Razinkovas, Z Gasiūnaitė, P Viaroli, and JM Zaldívar. 2008. Preface: European lagoons—need for further comparison across spatial and temporal scales. *Hydrobiologia* 611, 1 (2008), 1–4.