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Citizen science and crowdsourcing in the field of marine scientific research — the MaDCrow project

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Abstract

Marine research is as important as very demanding since it requires expensive infrastructures and resources. Scientific institutions, on the contrary, have very limited funding so that the seas remain, still, mostly unexplored. Another serious concern is that society at large often resonates with fake news, while scientists sometimes tend to bias research with their backgrounds and paradigms. We think that all these issues can be addressed opening the process of knowledge building to the questions and needs of stakeholders and laypeople. The MaDCrow project proposed and tested several paths to attain these goals.

Keywords Citizen science; Environmental communication; Public engagement with science and technology

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Context

Marine studies, and in particular those focusing on coastal areas are one of the most important research fields in the endeavor to understand climate change and human pressure on the environment. This has been highlighted also by the United nations Sustainable Development Goals (SDG) 2030 agenda (https://sdgs.un.org/goals) through several specific indicators such as for example 14.1.1 (Index of coastal eutrophication), 14.3.1 (Average marine acidity: pH), 14.4.1(Proportion of fish stocks within biologically sustainable levels). At the same time, this field of research has intrinsic issues that span methodological, economical and even epistemological concerns that suggest the extension of traditional practices to newer and more open approaches.

Costs

Current practices in marine research impose several limitations, and in particular regarding spatial and temporal coverage of the observation of natural phenomena.

This is due mainly to the fact that they rely mostly on the use of large infrastructures, such as research vessels, buoys, satellites, gliders or drifters. These platforms have costs that are operational (on average a research vessel costs between 20–30 k$ per day), logistical, personnel related and due to the use of expensive sensors and equipment. Research institutions cannot systematically bear such costs so that acquisition of data is generally sparse and limited in time.

Research bias

An additional concern that emerges from analyzing the work of scientists and that originates, in part, from the difficulties in acquiring a sufficient mass of data, is the possibility to apply a bias to knowledge building but also to planning experiments and observations. These biases arise when reproducibility is at stake since the traditional view of the scientific method is founded on observations that should be reproducible at any time. Limitations in spatial and temporal coverage of course influence this, forcing reasoning to be made on cases that can vary too much, making them difficult to recognize analogies in the manifestations of the same phenomenon [Engelhardt and Zimmerman, 1982]. This moves the classical loop of scientific research, that revolves around the two gravity centers of induction and deduction, towards a more abductive mode [Peirce, 1931]. This is a type of reasoning that allows clues to be reconstructed in the light of an interpretation, but while it is a very effective method of reasoning to explore a context which is uncertain in order to come up with new ideas [Eco, 1981], it also has many limitations. We will not go into the details of this topic here (for further information on the importance of abduction in reasoning and in science see Diviacco [2014], Diviacco, De Cauwer et al. [2015] and Diviacco [2012]) but would like to pinpoint the main consequence of the introduction of the abductive mode in scientific reasoning, which is that multiple concurrent explanations of the same phenomenon can occur. These are not randomly distributed but tend to gather in what Kuhn [1962] called paradigms: a philosophical or theoretical framework, a tradition or school that conditions researchers' way of thinking. Different, concurrent, and incommensurable paradigms exist within any discipline. Lakatos [1970] introduced the concept of the 'protective belt' that identifies a set of auxiliary and peripheral hypotheses that preserve the inner main thesis form external attacks. Following Becher and Trowler [2001], researchers gather in communities that resemble tribes, that following Whitley [2000] tend to preserve their territories, way of thinking and practices, so that in the vision of Latour and Woolgar [1986] science becomes a social construct. This mirrors in many phases of scientific work. Theorization, in fact, is anticipated to intrude also the phases of experiment planning and observation. This vision is known as cognitive penetrability or theory ladenness and can be seen as a vicious loop that links planning, observations and theorization. The result of this mechanism is the difficulty to avoid prejudices, an effect called research bias.

Environmental awareness

Themes such as climate change, pollution or extreme meteorological events are very much at the center of the general public interest. However, a real understanding of what is at stake is not always easy to be grasped. The media such as newspapers or the television, often do not have the competences and authority to contrast 'fake news' that instead very easily and quickly circulate in the social media. Outreach of scientific initiatives and projects is often too expensive for research institutions and scientists consider it generally less important than research itself. The laypeople, therefore, are tempted to remain too far from those themes that, instead, matter for their lives and that require their participation to shape public consent. To overcome these obstacles, within MaDCrow we decided to follow Silvertown [2009] who maintains that the best way to introduce the large public to scientific research is to let them participate in the research activities: both in observation and data acquisition, but also in knowledge building.

Objectives

Crowdsourcing and citizen science in marine studies

To address the issues mentioned above, we think that it is necessary to leverage the area where cost optimization, participation by laypeople and open science overlap. This is the very base of crowdsourcing and citizen science, and we think that the introduction of this perspective in the field of marine environmental monitoring could be therefore a potential breakthrough that will overcome most of the current limitations. So far, a large amount of initiatives of crowdsourcing for science and citizen science took place in many scientific fields and domains [McKinley et al., 2017; Kosmala et al., 2016], while only few can be listed in the marine case and even less in the case of marine environmental monitoring [Lauro et al., 2014; Chang, Huang and Chang, 2019; Bärlocher, 2013; Kopf et al., 2015; Di Luccio et al., 2020]

On the contrary, several authors, such as for example Fraisl et al. [2020] and See et al. [2016] highlighted that this field is particularly suitable for a citizen science and crowdsourcing approach. Unfortunately, currently, this path seems to meet resistances that are due to institutional structures and responsibilities behind the management of such data. Our approach is a bottom up solution that could initially run side by side with the already existing initiatives and practices, and later, hopefully, gain momentum by reason of the amount of data acquired, the increase in spatial and temporal coverage and the impact it could have on public environmental awareness.

The MaDCrow project

The MaDCrow (Marine Data Crowdsourcing) project is a research and development project funded by the European Regional Development Fund — ERDF, aiming at developing all the technologies necessary to implement the perspective of crowdsourcing and citizen science in the field of marine environmental monitoring. It must be highlighted that the MaDCrow project was funded to develop technologies up to Technology Readiness Level (TRL) level 6 (EU coding). Notwithstanding the fact that the project is mainly technological oriented, it had the chance to explore also other non-technical themes that highlighted many relevant and interesting questions and issues. A deeper insight into the technical solutions of the project is described in more detail in a specific paper [Diviacco, Nadali et al., 2021; Iurcev, Pettenati and Diviacco, 2021] while here, beside a quick overview of the MaDCrow infrastructure we will try to cover the observations we made during the unfolding of the project, the methodological issues we identified and the solutions we proposed and developed to address them.

Methods

The MaDCrow infrastructure

The MaDCrow project's infrastructure is composed of several modules, and namely: the acquisition module, the processing module, the data access module and the contextualization and Decision Support System (DSS) module.

The acquisition module (Figure 1) consists of a removable device that can be attached to the hull of almost any leisure boat, small motorboat or the like, and that contains all the sensors and electronics to acquire and transmit marine data on land via any public mobile telephone network or in case of limited network coverage, using LORA-WAN technologies. The very important feature of the removable device, that entails some interesting consequences that will be described later, is that the acquisition device does not interfere with the activities performed inside the vessel, be them professional or recreational, and that within an initial phase of the project, the volunteers taking part in the acquisition of the data were not forced to follow any acquisition plan so that the owner of the platform was free to navigate where he prefers, when he prefers.

Figure 1. The acquisition device (the yellow box attached to the hull of the boat) can be easily deployed and does not interfere with the activities of the boat.

The acquisition device developed within the MaDCrow project hosts sensors for the most common physical and chemical marine environmental parameters. These are: temperature, pH, dissolved oxygen (DO), salinity and oxidation-reduction potential (ORP) which are the basic ones that can be of help in studying most of the natural phenomena occurring at sea. Biological sensors will also be introduced in the near future.

Considering that the crowdsourcing paradigm implies that multiple platforms acquire data at the same time, it is not possible to use high end and professional sensors. In fact, since their costs can easily exceed several tens of thousands of dollars per unit, multiplying them by the number of platforms will result in excessive budget requirements. On the contrary, within MaDCrow, low-cost sensors only have been employed. The costs of this class of sensors range around a hundred dollars, while further reduction of costs can be obtained considering that sensors can be purchased in large stocks. On the other hand, concerns about the precision and accuracy of low-cost probes can be raised. Several authors have highlighted this topic in several scientific fields and in marine monitoring as well [Okazaki et al., 2017; Yang et al., 2014; Marion et al., 2011] We, of course took the problem very seriously and have discussed in detail, in a specific technical paper [Diviacco, Nadali et al., 2021; Iurcev, Pettenati and Diviacco, 2021] that we have recently submitted, the limitations involved in this approach, but also the solutions we have developed and that seem to be very promising.

The acquisition device deployed on each boat, embeds a GPS positioning system that allows all the acquired data to be immediately time and geo-referenced. Once this is done, all the data are transmitted in real time to the MaDCrow data storage systems on land.

The processing module of the infrastructure then proceeds with a validation of the data. Anomalous data are filtered out when outside the parameter's standard ranges. Recordings are smoothed through a median moving average to remove spikes. Data are checked for errors in positioning and are then binned into 3D cells. In this, the area under study is overlaid by a geographic grid with side length of 200 meters. All data that have been acquired within that cell in a time frame of one hour are averaged to provide a single value for that specific datacube. All datacubes can be represented then in 2D geographic maps that evolve in time. These maps are made openly accessible to anyone through the MaDCrow data portal (https://madcrow.ogs.trieste.it/madcrow) (Figure 2) and using OGC compliant WMS and WFS web services that allow a direct connection between any geographic information system (GIS) and the MaDCrow database. This allows further processing of data at end user's workstations or even in other web based data exploitation or dissemination initiatives.

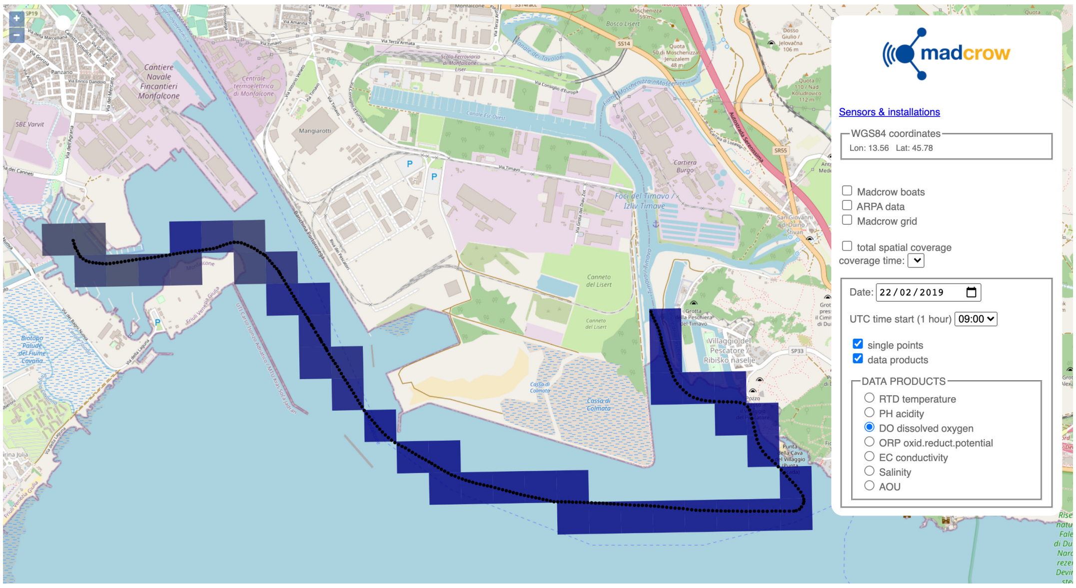

Figure 2. Crowdsourced data are mapped in real time on a dedicated web portal. In this image the distribution of dissolved oxygen is plotted. Measurements within the harbor (on the left) are low, while they increase towards the open sea.

These data are useful mainly for researchers and scientists, while they can be read by the laypeople only with difficulty. The third module of the infrastructure aims exactly at addressing this problem, simplifying knowledge that can be reconstructed from the data acquired within the project, and providing information that is easy to be understood by the non-scientists. Before describing how we addressed this topic we need to introduce few other considerations

Results

Participation and volunteer's motivation

The MaDCrow project is a combination of several layers where participation of the volunteers is differentiated and very likely will also change as the project will evolve.

In fact, since, as already mentioned, the MaDCrow project was devoted mainly to technological development, data acquisition campaigns that took place so far were aimed mainly at checking the operability of the infrastructure, while from now on a fully operative and stable initiative will be launched.

The 'geography' and trends of the terminology that can be used to label the possible forms of scientific research activities outsourced to volunteers, have been extensively explored in See et al. [2016]. These authors show that a very articulated vocabulary is available on this topic, that several terms have been used more in the past, that others gained more space recently and that some of them converged under the larger umbrella of the terms crowdsourcing and citizen science.

Within MaDCrow, during an initial test phase, data have been acquired mainly within a form of opportunistic crowdsensing paradigm, meaning that the acquisition system was hosted by volunteers on their boat without, as mentioned above, any interference of the device on the activities of the boat. Sailors were free to navigate how and where they preferred since no specific commitment on coverage was requested by the project. We realized that this can have advantages and disadvantages. The advantages identified were that since there was no prescription on volunteers, they perceived their participation in MaDCrow as an easy way to express their concerns for the environment, without the need to worry about losing time in maybe obscure research practices. This resulted generally in an easy to be negotiated early phase of enrolment and, to some point, also in a smooth later phase of support. The disadvantages were related to the fact that this way volunteers tend to cover inhomogeneously the area under study since, generally, they prefer more 'touristic' areas, as it is not pleasant for them to have an excursion, maybe during a vacation day, in a polluted zone. Problematic areas, therefore, tend to be undersampled, which of course is against the very fundamental aim of the project, that is to extend coverage, and contrary to researchers request to have information on possible critical situations. In addition, from our experience, the level of involvement into the initiative was not very deep and seemingly, although values, goals and desires were consistent between volunteers and the project we did not record high levels of identification with the initiative, which conditioned participation in the acquisitions surveys that, eventually, turned out to be, in many cases, sporadic. The importance of considering openly the goals of participants and stakeholders in these types of projects has been pinpointed by several authors such as for example Ellwood, Crimmins and Miller-Rushing [2017] or by Maund et al. [2020] with a specific focus on public awareness of environmental issues, where people contribute both because the environment has an intrinsic value but especially because they want to learn and gain knowledge. It is in fact this perspective we would like to follow to expand the dimension of the initiative and attract more volunteers. Maund et al. [2020] and Sutherland, Roy and Amano [2015], in fact, highlighted that engaging and retaining a critical mass of contributors is very important to achieve good results in these kinds of initiatives. In this we think that a virtuous circle needs to be established where from the availability of an initial quantity of data, gathered using the already described practices, the initiative needs to increase in dimension until it reaches an appropriate production rate. This, we think, will further motivate participation and co-design of the future evolution of the project.

Discussion

Knowledge sharing

To address the issues mentioned above we decided to introduce a new perspective based on the introduction of tangible and intangible rewarding mechanisms that rely on the availability not only of the raw data but of knowledge.

Scientific knowledge sharing is a very interesting and wide topic that cannot be fully addressed here. There is a vast literature on the difficulties of putting this in practice; issues such as, for example, the fact that scientific knowledge is embedded in practices and experiences [Taylor, 1992; Harper, 1987] or even in technologies and methods [Ribes and Bowker, 2009] so that, following Polanyi [1966], *"We know more than we can tell"*, meaning that, sometimes, it can be very difficult to even formalize scientific knowledge. This can be seen also in learning. From a situation in the past where science was associated with the truth and learning with its transmission, a new trend emerged where both become associated with situated and socially dependent knowledge building [Diviacco, 2016]. Within MaDCrow we start from the fact that knowledge needs to be built together with whom will use it. It is necessary to tailor how answers are shaped, in order to meet the questions and needs of the designated user, and, in this perspective, we considered the possibility of generating simplified data products that could reach specific classes of end users. We identified a first set of possible classes of end users taking into consideration the case of the Gulf of Trieste (Northern Adriatic Sea — Mediterranean Sea) both because it is a situation we know very well, since all the partners of the project are based in this area, and also because the implementation of the ERDF funding was done by the Italian region Friuli Venezia Giulia that faces the Gulf of Trieste, so that a focus on that area was required. In addition, it was mandatory to explore also the commercial aspects that initiatives such MaDCrow could introduce since, through a Brue Growth perspective, new competences, economic initiatives and jobs are expected to emerge. In this perspective we took into account the main economic activities that characterize the Gulf of Trieste. These are: tourism, maritime transportation and aquaculture. To satisfy the needs of these different communities, while bridging the cultural gaps between researchers and users, following Star and Griesemer [1989] we headed towards the possibility to create simplified artifacts, that will act as 'boundary objects' representing the knowledge available, reconstructed from MaDCrow data and other sources, in order to make it useful and understandable by the various communities of users that could insist in the designated area. This contextualization and simplification process is performed in the third module of the MaDCrow infrastructure, the Contextualization and Decision Support System (DSS) module.

Contextualization and DSS

In the MaDCrow project, it was decided to structure the data acquired with the crowdsourcing paradigm through the use of a DSS [Filip, 2020; Chiu, Liang and Turban, 2014]. A DSS is software that helps decision makers in solving real-world problems that can be strategic, tactical and operational.

A decision support system has as its fundamental elements the following: information sources, knowledge base and decision-making system.

The following steps were followed in the development of the DSS:

1. Definitions and general criteria for assessing the quality of water relating to the marine ecosystem;
2. Specification of significant scenarios (use cases);
3. Definition of decision-making criteria and indices of merit (KPI — Key Performance Indicator);
4. Collection and integration of data from multiple data sources (MaDCrow sensor, and other);
5. Management of the DSS through web service;
6. Visualization and verification of results via graphical interface (GUI — Graphical User Interface).

Sea water quality indicators and the science behind it

In developing the Contextualization and DSS module, we have delved into the relevant literature that reviews the methods and practices behind the measurement of environmental parameters, such as those acquired within the MaDCrow project, to understand how the crowdsourcing and citizen science paradigm could be integrated with traditional methods and therefore with the data already collected and available from several sources. We realized that this was not easy to do since MaDCrow acquisition device measures the seawater properties at the sea surface and while the vessel is sailing. This is pretty much unconventional since in the traditional paradigm research vessels stop at any given station and perform all the acquisition. Another aspect to consider is that MaDCrow was tested in coastal areas where land contributions influence more strongly the seawater properties, so that we realized that also the local geomorphological and hydrographic features, and the climatology need to be considered. To evaluate the state of health of the sea, we have analyzed in the literature which parameters are taken into account both from a scientific and regulatory point of view to evaluate the quality of the sea [Chapman et al., 1996; Gholizadeh, Melesse and Reddi, 2016, Bathing Water Directive 76/160/EEC see https://www.eea.europa.eu/].

In summary, the comprehensive list of contextual parameters that are used to evaluate the quality of seawater are:

A) Basic variables such as water temperature, pH, salinity, dissolved oxygen, and discharge;

B) Organic pollution indicators such as dissolved oxygen, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), ammonium;

C) Organic micropollutants such as pesticides and the numerous chemical substances used in industrial processes;

D) Specific major ions chloride, sulphate, sodium, potassium, calcium and magnesium. as essential factors in determining the suitability of water for most uses (eg. public water supply, livestock watering and crop irrigation);

E) Microbiological indicator organism such as total coliforms, fecal coliforms and fecal streptococci bacteria;

F) Biological indicators of the environmental state of the ecosystem such as phytoplankton, zooplankton, zoobenthos, fish, macrophytes and birds and animals related to surface waters;

G) Suspended particulate matter such as suspended solids, turbidity and organic matter (TOC, BOD and COD);

H) Metals cadmium, mercury, copper, zinc;

I) Indicators of eutrophication nutrients (eg. Nitrogen and phosphorus), and various biological effect variables (eg. chlorophyll a, Secchi disc transparency, phytoplankton, zoobenthos);

J) Indicators of acidification pH, alkalinity, conductivity, sulphate, nitrate, aluminum, phytoplankton;

K) Indicators of radioactivity such as total alpha and beta activity, 137Cs, 90Sr;

L) Visual pollution such as tarry residues, glass, plastic, rubber;

M) Perception based parameters such as color, turbidity, smell.

Within MaDCrow, sensors measure temperature, salinity, oxygen and pH. During the processing phase a further indicator is calculated which is the Apparent Oxygen Utilization (AOU) [Broecker and Peng, 1982; Ito, Follows and Boyle, 2004]. This parameter measures the biological activities that the sample of water has experienced since it was last in equilibrium with the atmosphere. AOU has low values when there is production of oxygen and larger values when there is consumption of it.

Crowdsourced data with the addition of the AOU parameter (e.g.: "MaDCrow package") are then used together with contextual data to implement the system for chlorophyll and the presence of harmful algal bloom (Ostreopsis ovata), fecal coliforms and total coliforms, and weather conditions.

End users quality indicators

In this project various stakeholders have been consulted in order to gather what are the main needs relating to the state of surface water quality. Fishermen, aquaculture operators, managers of marinas, managers of bathing establishments, but also swimmers, boaters, and ordinary citizens who are interested in the health of the sea were consulted.

Starting from this analysis of the needs, and taking into account which characteristics of the sea can be analyzed by the sensor, three use cases have been formulated that can clearly highlight the potential of the analysis of the collected data.

The three selected operational scenarios were the following: (I) "Let's go to the beach!" (II) "Vitality of the sea" and (III) "Be careful at sea!".

In order to define the KPIs for each scenario we have reviewed the relevant existing literature [Hines, Faganeli and Planinc, 1997; Kralj et al., 2019; Stachowitsch, 1984; Ingrosso, Giani, Cibic et al., 2016; Ingrosso, Giani, Comici et al., 2016; Ingrosso, Bensi et al., 2017; Cozzi and Giani, 2011; Giani et al., 2012; Mozetič et al., 2012; Brando et al., 2015; Cozzi, Falconi et al., 2012; Cossarini, Solidoro and Umani, 2012; Aubry et al., 2012].

KPIs are used in order to create a consensus matrix with all the data available in terms of temperature, salinity, oxygen, pH and AOU trends and gradients in the Gulf of Trieste.

For the scenario "Let's go to the beach!", we have used the "MaDCrow package" and also chlorophyll and Ostreopsis ovata (harmful microalga, that blooms in the summer months, coliforms (harmful bacteria that are discharged by the wastewater systems) abundances and local weather.

For the scenario "Vitality of the sea", we have used the "MaDCrow package" and also chlorophyll and Ostreopsis ovata abundances.

For the scenario "Be careful at sea!", we have used pH and AOU.

The KPIs have been tuned according to the measured data, the uncertainties and the database mining according to location and seasonality.

Possible business models

Although Maund et al. [2020] points at values and knowledge as the main factors that motivate citizen scientists in contributing to initiatives such as MaDCrow, they also maintain that predicting the levels of motivation is inherently more complex than is often speculated and that this can lead to a contraction in the participation of volunteers and ultimately in a reduction of data contributions. Having this in mind, and since ERDF funding mandates the introduction of a perspective based on Open Innovation and Blue Economy, we explored also the commercial possibilities that such initiatives can bring.

Following the Osterwalder and Pigneur [2010] classification, MaDCrow can be seen as a multi-side platform (MSP) business model pattern. This kind of business model has the following characteristics:

- brings together two or more distinct but interdependent customer groups;
- constitutes a value for a group of customers only if the other group of customers is also present;
- creates value by facilitating interactions between different groups;
- the value of a multi-sided platform grows as it attracts more users, a phenomenon known as the network effect.

Through the MaDCrow platform, very different subjects such as for example: citizens, policy makers, scientists, teachers, students, private companies, will be interconnected in real time, sharing data and creating contents. The platform can be simultaneously used to promote very different purposes (social, scientific, informative, institutional or commercial) and each end user must find his own personal interest in using it, co-creating "value" within the platform and generating the network effect that could make the business model effective, immediately scalable and even replicable in "glocal" terms worldwide.

One very important enabling factor in the MSP business models is that the value to customers on one side of a platform typically increases with the number of participating customers on another side [Hagiu and Wright, 2015]. This is easy to understand if we consider web-based hotel booking systems: these attract customers (one side) only if the hotel supply (the other side) is sufficient.

We built a matrix to study MaDCrow's business model, combining all the types of end users with the different value propositions that the platform could deliver.

The user segmentation activity was essential to understand the needs or the advantages of the end users: we made assumptions about their behavior and how they can use the platform.

The end user as "data detector" are the most important segment to make the model work on and it will be essential to build an incentive system to entice them to install MaDCrow equipment on their boat in addition to the already mentioned environment related concerns. The many other end users, who do not necessarily have a boat, will be equally important for the business model, in fact they will increase the value of the platform with their own contents and will be essential to create the network effect.

We have identified:

- Institutional users: public or private subjects with non-profit social purposes (regions, law enforcement agencies, universities, associations involved in environmental issues, all the Policy Makers, etc.)
- Business users: companies who instead pursue commercial purposes fish farmers, tour operators, boat renter, etc.) and would use the platform to provide an additional service to their customers and improve their business.
- The private user: a physical person who is moved by a personal interest in using the platform (bathers, tourist, citizen scientist, students, etc.) who

embraces the profound meaning of the MaDCrow project and feels part of a "Community"

In particular we believe that the diffusion of MaDCrow could be a great opportunity for all the Policy Makers, because the project represents an extremely innovative tool to promote and develop strategies aimed at the environmental sustainability making citizens an active part for the protection of their territory.

Conclusions

The MaDCrow project fully and successfully reached its main target, which was the development of all the technologies needed to enable crowdsourcing and citizen science initiatives in the field of marine environmental monitoring, with a particular focus on coastal areas. We tested extensively the infrastructure and the methods developed within the projects and were able to acquire a large quantity of data but also to make important experiences that led us to several conclusions in particular regarding volunteer's participation. In a first phase of the project we adopted an opportunistic crowdsensing approach to acquisition, where the acquisition device did not interfere with the activities of the boat and no prescriptive practices or rules were imposed on volunteers. We noted that this approach alone did not result in a particular motivation from the volunteers to acquire data nor in a convinced identification of the volunteers with the initiative, probably because they perceive themselves as mere carriers only. We therefore extended the original approach introducing rewarding mechanisms that at a first level could be based on the possibility to access a mediated and simplified representation of the knowledge collaboratively built, and further on, in specific cases, can result also in the possibility to exploit results in a more commercially oriented perspective. This is made possible by a specific module of the MaDCrow project that handles contextualization of information through a DSS. This produces artifacts that, as boundary objects, bridge the gaps between scientific research and specific communities of users. Starting from the case of the Gulf of Trieste we identified three initial scenarios, and namely "Let's go to the beach", "Vitality of the sea" and "Be careful at sea". These loosely correspond to the main economic activities existent in the area so that specific interests and therefore questions and needs are expected from designated communities such as, for example, tourists or fishermen. The DSS integrates data acquired within the MaDCrow initiative with other sources and contextualizes results in order to produce simplified products that should be easy to be understood by nonscientists.

Future work

As already mentioned, the MaDCrow project is entering a new phase where it will be fully operational. It is our intention to keep it as open as possible to the adjustments that will be suggested by a careful future analysis of the results of its current implementation. Besides some technical issues that will need a further round of improvements, such as, for example, a revised case for the sensors and electronics to deploy on the volunteers boats, or a further optimization of power consumption, particular care will be given to the results of the method we have developed to enhance participation that is based on bridging the gap between scientific research and specific communities of users.

In order to study this a consistent enlargement of the user base will be needed. This of course will be probably the most difficult challenge we will have to address. We are currently working on the means to reach the general public through newspapers, the media and several outreach and educational initiatives. These latter, unfortunately, have been severely affected by the Covid pandemics.

Once the strategies adopted will be hopefully positively confirmed we will proceed in developing additional services and extend the user base towards other communities of users.

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