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ORIGINAL RESEARCH ARTICLE

The importance of citizen science in coastal monitoring. Learnings from experience in Villa Gesell (Argentina)

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ABSTRACT

Climate change has affected the coasts of the world due to numerous factors, including the change in the intensity and frequencies of the storms and the increase in the mean sea level, among others. Argentina has extensive coastal areas, and research and monitoring tasks are expensive and require a significant number of personnel to cover large geographical areas. Given this, citizen science has become a tool to increase scientific research's spatial and temporal extension. Therefore, the paper aims to analyze the methodology and development of the citizen science project in Villa Gesell and its lessons for applying them in future coastal environmental monitoring projects. The methodology was based on an experience of the project co-created between activists and researchers. This project included four phases for social and physical aspects: training for the citizens, theoretic and practical aspects of coastal dynamics, and how to measure its geomorphological and oceanographic variations; data collection: the activists who received the training performed the measurements to monitor the beach; data analysis by scientists; and dissemination of results; the report data were disseminated by citizens in their community. The analysis of case studies in citizen science projects generates a fundamental learning arena to apply in future projects. Among the positive aspects were the phases established for their development and the methodology used to collect beach monitoring data.

Keywords: citizen science; co-created project; participative action; coastal monitoring; learning arena

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1. Introduction

In recent years, climate change has affected coastlines around the world. Severe storms have caused erosion in urbanized coastal areas, resulting in the loss of human lives and economic losses[1,2]. For this reason, continuous monitoring of sea level rise and the impact of meteorological, oceanographic, and anthropic events on coastal zones is necessary[2–5]. Monitoring tasks are generally costly, require a significant workforce to carry out these activities, and cover large geographic areas[6]. Therefore, a growing number of scientists are choosing to train citizens to learn about and monitor their environment by acquiring their data, an activity known as "citizen science"[7]. Citizen science is a type of science where nonprofessionals are involved in diverse aspects of scientific research[8]. Citizen science is a two-way process. On the one hand, scientists educate and provide people with a structured way to record their observations; on the other hand, citizens can become an integral part of the exchange of results and findings within the community at large[9]. Participation in citizen science projects allows the public to contribute observations and amateur expertise during the acquisition of new knowledge[10]. Several studies highlight the benefits of this activity, including enhanced monitoring capacity, citizen empowerment, and increased environmental awareness[9,10] among others. When questioning the quality of the data obtained, several studies have concluded that, with the appropriate validations, records will be reliable and accurate; for example, by checking each record or quantifying the accuracy so that the error can be considered in the analyses[11–15] among others.

In recent years, there has been an increase in citizen science projects[16], especially those aimed at coastal monitoring with varying degrees of involvement and different objects of study, such as reefs, whales, and marine debris, among others[17]. Some projects have a high degree of citizen participation; for example, the Southern Maine Volunteer Beach Profile Monitoring Program at the University of Maine (USA) has over 100 volunteers[9]. Others involve either intermediate participation, such as the Coast Watch project in Portugal (https://coastwatch.pt), or only occasional citizen involvement, such as the Coast Snap project (www.coastsnap.com), which has spread along the coasts of several countries. The classification of a citizen science project can vary depending on the degree and type of participation by both citizens and scientists. For example, Wiggins and Crowston[18] classify the types of projects according to scientific researchers and citizens' roles in them (action projects, education projects, virtual projects, etc.). Another classification, provided by Shirk et al.[19], divides the types of projects according to the participation of citizens and scientists into contractual, contributory, collaborative, co-created, and collegial, in which citizens participate from only a request to full participation in the project, whereas scientists do so with inverse participation (**Table 1**).

Table 1. Types of projects according to the participation of those involved. PPSR: Public Participation in Scientific Research.

Public action in each PPSR model	Members of the public…
Contract	ask scientists to conduct a scientific investigation and report on results
Contribute	are asked by scientists to collect and contribute data and/or samples
Collaborate	assist scientists in developing a study and collecting and analyzing data for shared research goals
Co-create	develop a study and work with input from scientists to address a question of interest or an issue of concern
Colleagues	independently conduct research that advances knowledge in a scientific discipline

Source: Wiggins and Crowston.[19].

In Argentina, Buenos Aires province has approximately 1200 km of coastline that, in recent decades, has been affected by climate variability, anthropic activities, and elements that have modified the natural dynamics of this environment, generating areas of erosion and sedimentation[20]. Due to the spatial and temporal extension, it is challenging for the scientific community to manage coastal monitoring requests over time. Current monitoring initiatives face limitations related to budget, human resources, instrument availability, and geographical constraints. In this country, citizen science projects are few and have not been developed to their full potential. There are some initiatives, mainly collaborative-type projects focusing on reptile and bird sighting (e.g., https://savethefrogs.com/es/), primarily conducted through mobile applications due to the growth of the Internet and real-time access to information[21]. However, with co-created projects, greater results can be obtained. This type of project is designed by scientists and citizens to help refine their design, analyze data, and disseminate findings, in addition to acquiring knowledge and awareness of the topic to be investigated[19,22]. Scientists and citizens work together, and citizens are actively involved in most or all aspects of the research process with input from scientists to address a question of interest or issue of concern[19,23–28].

Between 2012 and 2016, there was a co-created participatory science project for coastal monitoring in the seaside town of Villa Gesell (**Figure 1**) that involved scientists from the Instituto Argentino de Oceanografía (IADO) and members of an NGO from Villa Gesell called "Asamblea Ciudadana en Defensa del Médano Costero" (ACVG). This citizen science project offers an excellent opportunity to learn from a well-established and successful citizen science initiative. Understanding the achievements and lessons learned from the inclusion of citizens in participatory science projects will enhance the study of coastal areas and their management. Therefore, the present paper aims to analyze the methodology and development of the citizen science project in Villa Gesell and the lessons learned to apply them in future coastal environmental monitoring projects.

Figure 1. Location of the town of Villa Gesell. Source: Modified from Google Earth.

2. Materials and methods

This work was based on the experience of the project co-created between IADO researchers and ACVG. This project included four phases: 1) Training: it was provided by researchers to citizens; 2) Data collection: citizens monitored their beach; 3) Analysis: scientists analyzed the data and prepared the report; 4) Results: they were used by citizens to disseminate among their population, providing environmental education with greater impact on the rest of the community (**Figure 2**).

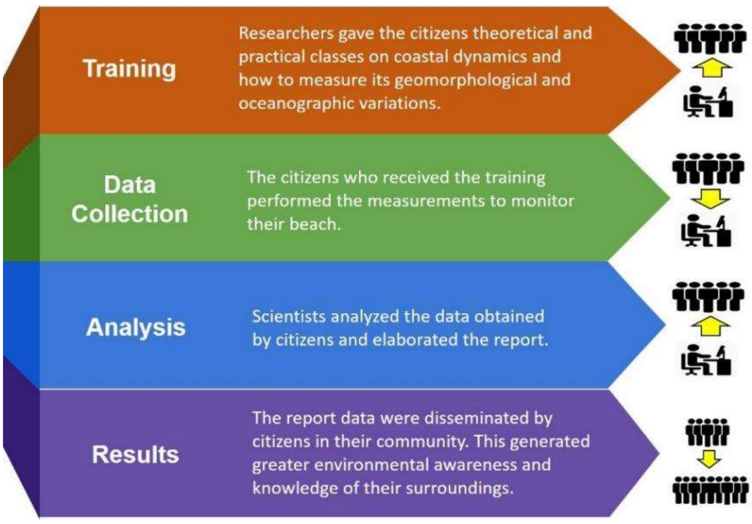

Figure 2. Phases of the citizen science project co-created with ACVG.

These phases (**Figure 2**) were based on two lines of research: a social line, which included the selection of the group of citizens and the way to carry out the project in order to make it sustainable over time, and a coastal monitoring line, which included data collection and analysis to obtain the results sought by the citizens involved. These results can be found in the study of the Bustos[29].

2.1. Social methodology

In co-created projects, it is imperative to carefully curate a group of key citizens to enhance and facilitate effective communication between the community and scientists, fostering a mutual exchange of ideas and insights. For this reason, and in order to keep the project active and, consequently, the monitoring, key actors were selected within ACVG as indicated in **Figure 3**[27]. Before training, researchers selected two members as contacts to organize training activities and coordinate with the media to inform the rest of the community of the activities being developed in the town. After training, two other people were designated to follow up and organize the data collection activities over the three years of measurement and monitoring (**Figure 3**). They remained in permanent contact with researchers and played a key role in ensuring the permanence and continuity of the monitoring activities over time.

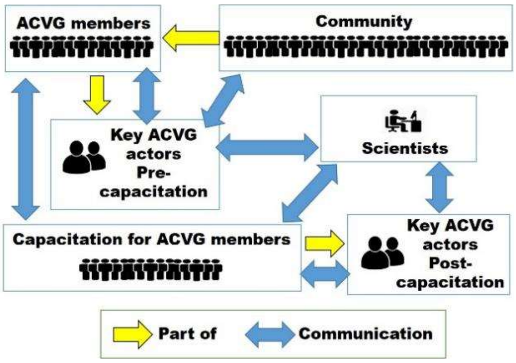

Figure 3. Methodology for key actors' selection and communication relationships.

2.2. Methodology for coastal monitoring

After the training sessions, researchers and citizens jointly selected the sites where the measurements would be taken continuously (**Figure 4**). The measurement sites were distributed and named as follows:

- 47th Street and beach: Area without buildings and high vehicular traffic (**Figure 5a**). During the high season, up to 3,000 vehicles were counted per day (Data from ACVG, 2015).
- 35th Street and beach: Area with little construction and, according to the perception of ACVG members, the least eroded segment of the beach (**Figure 5b**).
- 31st Street and beach: The most densely built-up zone within the study area (**Figure 5c**).
- Lindabay: Selected and named after the construction of the Lindabay complex behind the profile benchmark. ACVG wanted to know if the 130 m building influenced the beach (**Figure 5d**).

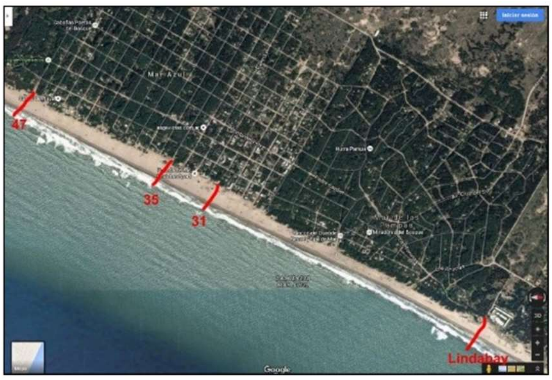

Figure 4. Monitoring sites using beach profiles. Image designed by ACVG members.

Figure 5. Photographs of the measurement areas. **A)** 47 St. and beach; **B)** 35 St. and beach; **C)** 31 St. and beach; **D)** Lindabay. Photographs from ACVG (2012).

In order to carry out the profiles, citizens were trained in data collection by adapting the stake method proposed by Emery[28] and developed by Bustos et al.[29] (**Figure 6**). This method allowed perceiving the beach behavior as a function of time and at a meager cost, which made it possible to have several pairs of rulers and to move them without the need for vehicles by people living near the measurement sites.

Figure 6. Measurement of beach profiles with the method developed by Bustos[29].

For each measurement, a spreadsheet was kept in which the data measured with the rulers, horizontal distance, and slope were recorded, as well as other information of interest for the survey. These data included the presence or absence of berms, channels, bars, outcrops, storm undertow, clasts, etc., as well as the time of low tide and the start and end times of each profile. As a complement, during the monthly measurement, breaker type, angle of incidence of the waves on the beach, wave height and period, and coastal drift velocity were measured using the methods taught in the training course based on the methodology developed by Bustos et al.[29].

Once the measurement stage was completed, the data were sent by ACVG members to IADO researchers for analysis. In the office, spreadsheets were created with information on the distance, slope, and height of the benchmark; following the methodology by Bustos et al.[30], beach profiles were plotted, and for each profile, the sediment volume, the sediment Annual Variation Rate (TVA for its acronym in Spanish), and the slope were calculated and classified according to MOPUT values[31], which are the most suitable for flat reliefs.

3. Results and discussion

Socio-temporal sustainability of the project

In Argentina, one of the biggest challenges in coastal monitoring is maintaining measurements during the school vacation months, which coincide with the high tourism season in coastal towns. Most citizen science projects, except for virtual ones, are based on working with students of different educational levels since they provide an improvement in literacy, scientific skills, and positive attitudes towards the surrounding environment[32,33]. Although studies such as Kelemen-Finan et al.[32] demonstrated that citizen science activities in primary and secondary level students could achieve high individual learning on the addressed topic, in coastal monitoring with co-created projects, this does not represent an advantage. With students, the most significant months (January and February) in terms of anthropic beach impact would be neither evaluated nor monitored. Therefore, in this project, alternatives were sought, and ACVG was involved. The choice was due to the commitment of the members of the ACVG to the environment. They were 30 people of legal age, men and women, from varied socioeconomic classes, different professions, and different education levels, but with the same aim, which was to know and take care of their living environment, in this case, the beach in the area of Villa Gesell. This generated the members' interest in this project and kept their commitment to work until the end of it. In addition, the ACVG members covered the cost of the travel and stay of researchers in the locality. This action helps to confirm studies such as Earp and Li Conti[6], which stated that if citizens contribute monetarily to the activity, they see it as an investment, and it helps to guarantee their collaboration over time. The results of this project showed that this action could be significant in the success of citizen participation.

Once the group of volunteers, who were part of the ACVG members, was defined, the training phase was initiated (**Figure 3**). At this stage, it was essential to take the necessary measures to help increase the credibility of the data obtained[34]. As stated by Freitag et al.[35], it is essential to take actions to ensure data quality, but these should not always be the same for everyone; they should consider the aim of the project, the number of volunteers, time commitment, etc. In addition, as the authors mention, training is essential and should contain technical and social aspects in a dynamic feedback process. To this end, we worked in three stages: training prior to data collection, training in the field, and data validation in the office[35].

Pre- and in-field training were theoretical and practical. They were divided into two groups according to the time availability of the interested parties so that as many of them as possible could participate (**Figure 7**). Monitoring of the coastline was carried out by ACVG members who had received training and who lived near the areas selected for the measurements. As mentioned earlier, measurements were not interrupted during the vacation months (July and December to February) because the individuals conducting the measurements were not students.

Figure 7. Data collection training for ACVG citizens in 2012.

Finally, the data were validated in the office. Researchers analyzed 38 monthly measurement campaigns that were carried out by participating citizens between 2012 and 2015. They obtained 145 oceanographic measurements and an equal number of beach profiles, with more than 5300 altimetric data points. These data were analyzed and plotted using Excel® software and compared with photographs taken by citizens during the measurements to verify the presence or absence of relief on the beach (bars, berms, channels, etc.). Scientists and citizens jointly made the initial profiles that were used as references and to validate the following ones. Although there are several alternatives for the measurement of beach profiles that allow increasing precision in temporal and spatial resolution, only Emery's method has demonstrated that it can be sustainable over time due to its low cost and easy understanding of the technique. This is confirmed by Heinze Hill et al.[36] and Eberhardt et al.[37], who have used this method of beach measurement in a successful citizen science project that has been conducted since 1999 off the coast of Maine (USA). There are other methodologies that are more accurate than the visual perception by which Emery's method is governed and that also require the horizon line to be visible. For example, in the citizen science project conducted by Ferreira et al.[38], they implemented for beach profile measurements a method based on the principle of vessel communication developed by Andrade and Ferreira[39]. They demonstrated that this method is effective, fast, and easy for anyone to understand. However, on our beaches, it is inefficient to mark steps or slope changes that are formed due to sediment accumulation or erosion dynamics since it does not allow changing the distance between the rulers, and these changes cannot be recorded in detail. Other authors, such as Splinter et al.[40], compare various methods of measuring beach morphology and demonstrate the sustainability and validity of Emery's method data when they state that through measurements based on this methodology, science has managed to know the evolution of beach morphodynamics and the importance of sediment transport along the coast. Among the aspects to be corrected is the inclusion of meteorological stations to monitor weather and climate variability. The ACVG project did not include meteorological measurements. These are necessary to correlate them to the results of sediment losses and gains. In this way, more accurate conclusions could be obtained, for example, about the recovery times of the beach under study.

After data analysis, a technical report was prepared and delivered in 2016 to ACVG members. They gave several interviews explaining the results obtained in different local and regional media (television, radio, and newspapers). In citizen science projects, such as the one analyzed by Heinze Hill et al.[36], it is shown that this dissemination of results translates into possible approaches between the volunteers who participated in the monitoring and the community in general as well as decision-makers. As stated in McAteer et al.[41], for these volunteers who characterize themselves as "activists," it is very important not only to collect data in the field but also to disseminate results and how these can become a means of approaching the community and exerting pressure on decision-makers. In addition, encouraging volunteers to actively participate in a co-created project will enhance communication among scientists, participants, and the community[24]. As a direct consequence of this communication, the fluid transmission of knowledge from scientists to citizens is achieved. On the other hand, by being part of the project and seeing its results and progress, citizens generate lines of awareness towards the rest of the local community, which will respond with greater openness and support to the scientists and citizens involved in the project (**Figure 8**)[25,26].

Since the delivery of the report, contact between researchers and ACVG members has been reduced over time until it became almost nonexistent in 2021. This continuity in the dialogue would have generated a possible prolongation in the monitoring of the same zone or other zones of interest. In addition, contact has resumed in 2022 to start a new coastal monitoring project. In this new project, a positive predisposition to participation was obtained from 20% of the previous participants.

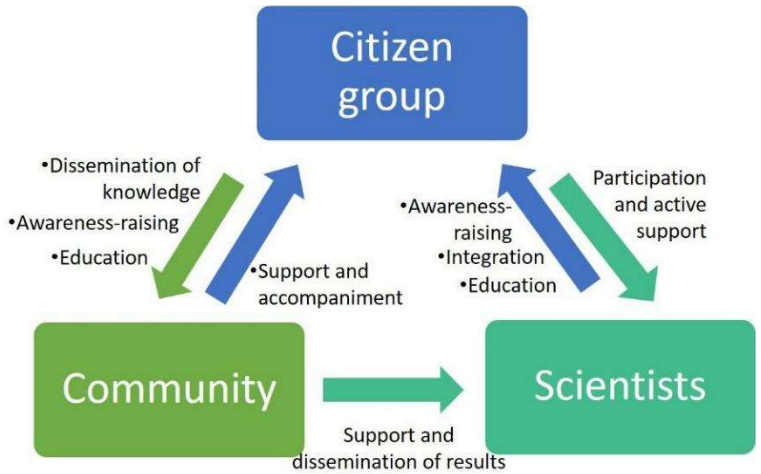

Figure 8. Relationships are generated by the participation of citizen groups in co-created citizen science projects.

4. Conclusions

Lessons learned and future actions

Among the lessons learned from this co-created citizen science project, the phases established for its development stand out as positive (**Figure 2**). These phases allowed for synchronizing the activities and generating the concrete results stipulated at the beginning of the project. Another aspect to highlight was the methodology used to collect beach monitoring data. It was easy for citizens to adapt, understand, and apply, and they could see results quickly. The fact that the analysis of all the data collected by citizens could be summarized in a report was also one of the most outstanding achievements of the project. This was a fundamental tool for participants to disseminate their activities and generate, in them and the rest of their community, a greater environmental awareness of the knowledge acquired.

Among the aspects to be corrected is the continuity in contacting and exchanging information with citizens. Although there was a fluid exchange between the researchers and citizens involved in the project, it was not maintained over time after the last phase of the project was completed. Another particularity to be improved is the inclusion of a meteorological station to monitor sediment dynamics and storm movement, for example.

In addition, as a future action, another similar project is being developed based on this one, which seeks to monitor the entire coast of Buenos Aires province. This may establish new lines of research that incorporate the citizens who have already participated as key social actors in disseminating this type of project and its benefits for the community and the coastal environment.

The development and implementation of citizen science projects has the potential to bring about a fundamental shift in study, management, participation, and access to information within the community. Engaging citizens in the study of the coastal areas can strengthen the connections among them, scientists, decision-makers, and the places they inhabit.

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Conflict of interest

The author declares no conflict of interest.

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