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Citizen science and the power of public participation in marine spatial planning

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ABSTRACT

Marine spatial planning (MSP) is becoming increasingly used in the sustainable management of marine and coastal ecosystems. However, limitations on time and resources often restrict the data available for MSP and limit public engagement and participation in the MSP process. While citizen science is being increasingly used to provide fine-scale environmental data across large terrestrial planning areas, there has been little uptake in MSP to date. This paper demonstrates how consistent citizen observations can be used to identify hotspots of *good* and *poor* environmental health across a MSP region, and where environmental health has *improved* or *degraded* in the past five years; information that is difficult to obtain by other means. The study demonstrates how citizen science provides valuable insight into environmental health across a MSP region, while fostering a supportive space for the public to contribute their own observations and participate in the planning process.

1. Introduction

Marine spatial planning (MSP) is increasingly used to identify objectives for the sustainable management of marine and coastal ecosystems [24]. MSP incorporates ecological, economic and social data to mitigate human impact on the marine environment and to inform decision-making [10,23]. Marine users are an important source of information on local environmental conditions, and stakeholder engagement is thus considered crucial for the effective design and implementation of MSP [24]. However, while it is common for MSP processes to advocate stakeholder engagement, many resort to a top-down, or deficit model, of consultation. Few MSP processes encourage participation through a two-way exchange of information, and new methods are needed to account for different types of local knowledge [27]. As a result, there has been a recent call to rethink MSP processes to encourage public participation and incorporate local environmental knowledge in MSP [5,21,23,24,27].

Citizen science is becoming increasingly prevalent in terrestrial monitoring programs, with voluntary observations from the public used to inform academic and environmental research [26]. Citizen science engages millions of people around the world, contributing valuable information that can be used by researchers, practitioners, planners and the public [2]. However, despite its successes, citizen science is not widely accepted as a valid scientific method due to concerns about data quality [2,21]. Much of this scepticism relates to potential biases in survey effort, errors in records, issues of scale, and inconsistencies over time [26]. To counter these issues, new technologies are being developed to improve data collection, management and quality control [18]. For example, a new statistical technique has been developed to identify signals of change in noisy ecological data collected by citizen scientists [17]. Studies have demonstrated that data collected by citizen scientists can be of equal quality to data collected by experienced researchers, provided that citizen scientists are given proper training and appropriate protocols are used [25,6]. Environmental agencies are increasingly using citizen science to overcome limitations of time and resources for data collection [9]. By crowdsourcing data collection, citizen science can provide fine-resolution environmental information over large geographic regions that would be difficult to achieve otherwise [26].

Citizen science also provides additional benefits beyond the collection of ecological data. Citizen science broadens engagement and inclusion in ecological research while building a cooperative space for planners, practitioners, researchers and participants to work together [18]. Incorporating diverse local knowledge provides a means to address community-driven questions [2], and bridges management planning with local efforts and interests [18]. Citizen science has been described as a public good itself, as it increases the scientific knowledge held by the public while also promoting environmental stewardship [8]. A recent review regarding the full potential of citizen science identified eight benefits for nature conservation, including advantages for management, awareness, education, recreation, social and economic research, increasing ecological knowledge, improving methods

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of monitoring and evaluation, and discovering unexpected information or events [26]. As a result, citizen science provides key outcomes for science, for the individuals taking part, and for broader society [21]. There may still be some issues of data quality in citizen science, but no dataset is perfect [25], and arguably the positives outweigh the negatives [26]. Many conservation agencies are increasingly turning to citizen science as a cost-effective method of collecting large environmental data sets while fulfilling multiple ecological and social objectives [26].

The case study in this paper demonstrates how citizen science can also be used to provide fine-resolution environmental health data across large marine regions to inform MSP. The environmental health of the Hauraki Gulf Marine Park, New Zealand, has been reported to have been in decline for a number of years [14,15]. Key environmental indicators considered by the reports included fish and shellfish stocks, toxic chemicals, nutrient inputs, microbiological contamination, sediment quality, introduced marine species, harmful algae and pathogens, litter, maintenance and recovery of biodiversity, and coastal development. The key threats identified were a lack of protected areas, inadequate fisheries management, coastal development, and inputs of nutrients, sediments and contaminants from land-use. However, while there has been research into various environmental parameters, limitations to time and resources have restricted the number of sites studied. As a consequence, these reports often describe declining environmental health across the entire region [14,15]. While many of the threats are likely to vary across the Marine Park, much of the data in the reports has been collected at selected sites and extrapolated to a regional scale.

The Hauraki Gulf Marine Park covers 1.2 million hectares with a resident population of over 1 million people, mostly concentrated in Auckland City at the south west corner of the Marine Park [15]. The Marine Park was established under the Hauraki Gulf Marine Park Act (2000) [16] to monitor the environment and enhance management practices. However, while it is a legal requirement to consider different parts of the Act (2000) in decision-making affecting the region, it is not a legal requirement to give effect to the Act [15]. Further, proposed changes to the Resource Management Act (1991) [20] suggest easing environmental regulations related to active land management in the Marine Park while encouraging urban and infrastructure development. The Marine Protected Areas Policy and Implementation Plan (2005) was developed ten years ago [7], but no new fully protected areas were created in the Marine Park. As a result, six no-take marine reserves currently protect approximately 0.3% of the Marine Park [15]. The Sea Change–Tai Timu Tai Pari spatial planning process is currently underway to develop the first spatial plan for the Marine Park, improve land management, and identify new areas for marine protection [15,22]. The plan will be released in September 2015.

This study demonstrates how citizen science can be used to determine public perceptions of current environmental health, and recent change in environmental health, across the Hauraki Gulf Marine Park region. Hotspot analyses were used to identify areas that were consistently rated as being in *good* or *poor*, and *improving* or *degrading*, environmental health. By identifying areas that have been consistently rated with similar values by different respondents, hotspot mapping accounts for data quality and spatial variation. Data gathered in this study, from the local community, will be used to inform the Hauraki Gulf Marine Park spatial planning process.

2. Materials and methods

An online survey was open to the public for seven weeks between 3 March and 21 April 2014, encouraging participants to enter data directly in to the collaborative mapping tool *SeaSketch* (www.seasketch.org). Participants were recruited through crowd-sourcing via newsletters and mailing lists of environmental and spatial planning agencies, online and print news media, social media, promotional events across the region, and a television interview on a national news station. Participants would drop point markers on an online map of the Hauraki Gulf Marine Park, identifying areas that were important to them. At each point participants were asked to rate the health of the environment at that location (very good, good, ok/average, poor, very poor), and to identify how the health of the environment at that location had changed over the past five years (improved, stayed the same, degraded). Participants could also respond to indicate that they did not know how to rate the environmental health, or could not determine how the health had changed, at each location. The term 'environmental health' was used in this study as the term is commonly used by environmental and council agencies in New Zealand in their public communication and engagement strategies, and so was considered a familiar term to the general public [14,15].

Point data were mapped to provide fine-resolution data of current environmental health, and change in environmental health, across the Hauraki Gulf Marine Park. Environmental health data was coded as 1 = very good and good, 2 = ok/average, 3 = poor and very poor, and change in environmental health was coded as 1 = improved, 2 = stayed the same, and 3 = degraded. Points that were rated as 'I don't know' or 'could not determine' were excluded from the hotspot analyses. Hotspot analyses [11] were used to identify point data that were significantly correlated ($p < 0.05$) around low and high values for each question. Heatmaps of correlated point data were produced using kernel density analyses [13] to visualise hotspots of consistently rated *good* or *poor*, and *improving* or *degrading*, environmental health. The heatmaps of *good* and *poor*, and *improved* and *degraded* hotspots were then converted to polygons. Intersect analyses were used to identify areas where polygons of *good* and *poor* health corresponded with polygons of *improved* and *degraded* health [12]. Intersecting areas were reclassified as areas of *good* and *improved*, *good* but *degraded*, *poor* but *improved*, and *poor* and *degraded* environmental health.

Point data added to the maps by the public have been shown to accumulate between 3 and 6 km [19], so a circular search radius and fixed distance band of 5 km were used for the analyses in this paper (as per [1,3]). Kernel densities are influenced by the number of points added, so density analyses were standardised by subtracting the mean grid density and dividing by the grid standard deviation (as per [3,4]). Kernel densities were plotted in 3 equal interval bands (top third, middle third and bottom third value density) for the hotspot heatmaps, where standardised kernel density was greater than zero. Point density grids were determined with a 20-m grid cell size, and all analyses were performed in ArcGIS 10.2.2 (ESRI, Redlands CA, USA).

3. Results

Of the 4495 total points dropped on the spatial map by participants, environmental health was rated at 4281 points (95% response rate), and change in health over the past five years was rated at 3383 points (75% response rate). Environmental health was rated *very good* at 1248 points (28% of total responses), *good* at 1734 points (39%), *ok/average* at 1012 points (23%), *poor* at 235 points (5%) and *very poor* at 52 points (1%). Point data show that environmental health was rated *good* or *very good* across most of the region, while most points rated *poor* or *very poor* were located around the south west coast (Fig. 1a). Hotspots confirm health was consistently rated as *poor* in the south west and several other

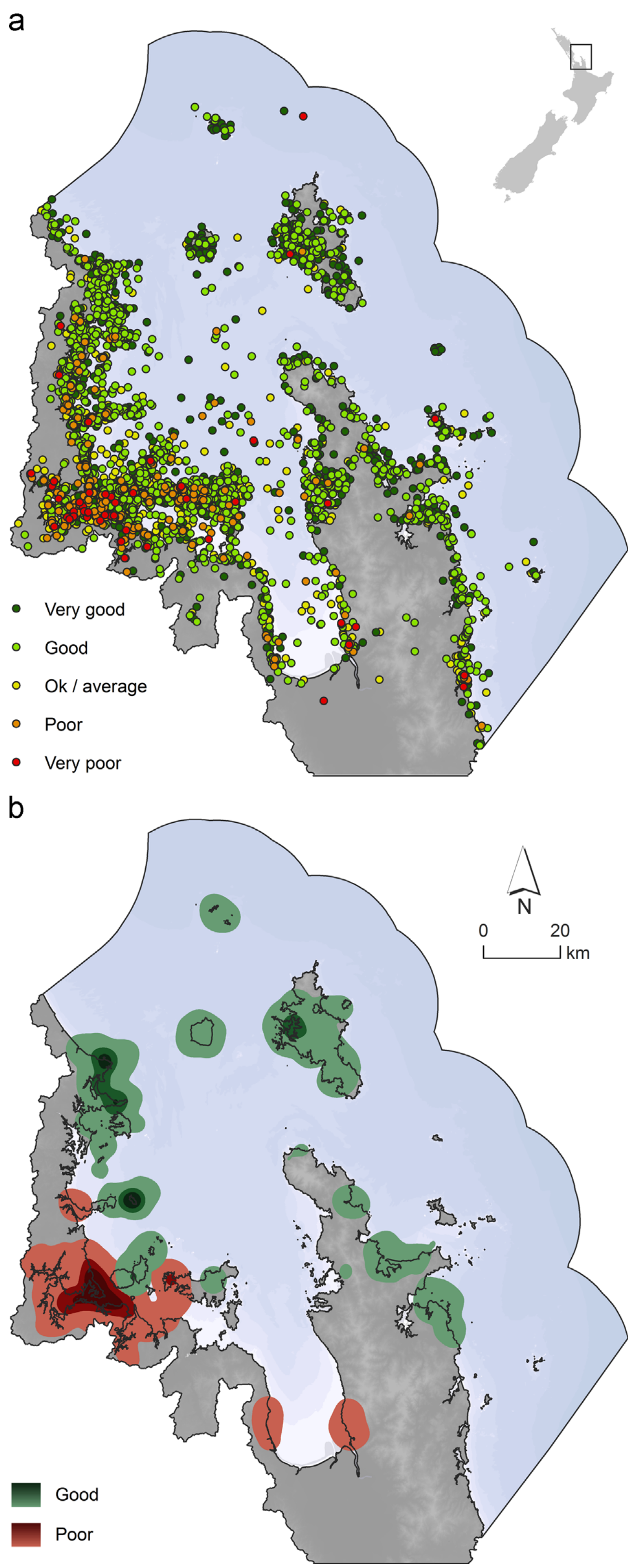

Fig. 1. (a) Point data for environmental health (very good, good, ok/average, poor, very poor), (b) hotspots of good and poor environmental health.

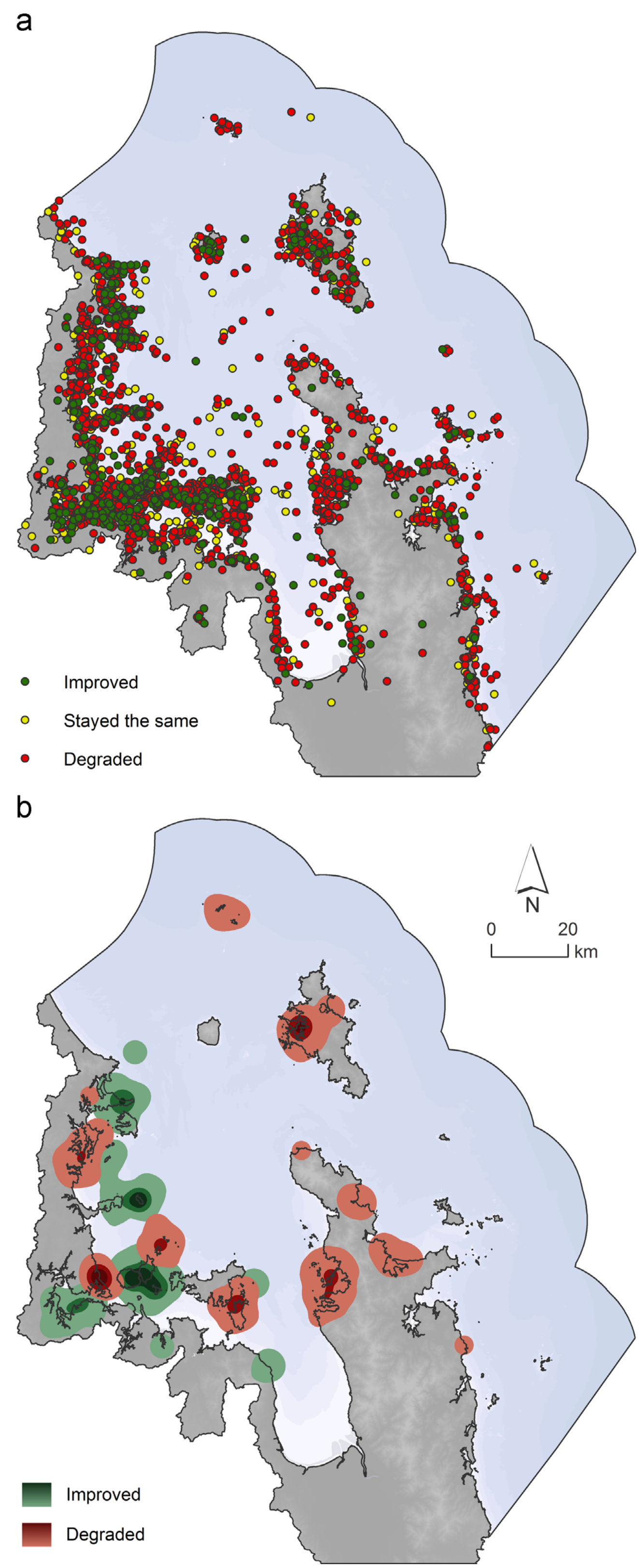

Fig. 2. (a) Point data for change in environmental health over the past five years (improved, stayed the same, degraded), (b) hotspots of improved and degraded environmental health.

areas around the south coast of the MSP, also demonstrating many coastal areas and offshore islands that were consistently rated as having *good* environmental health (Fig. 1b).

Change in environmental health in the past five years was rated as *improved* at 553 points (12% of total responses), *stayed the same* at 720 points (16%), and *degraded* at 2110 points (47%) (Fig. 2a). Hotspots confirmed environmental health was consistently rated as having *degraded* over the past five years at several areas around the coast and offshore islands, while other sections of coast and islands were consistently rated as having *improved* environmental health over the past five years (Fig. 2b).

Overlaying *good* and *poor* hotspots (Fig. 1b) with *improved* and *degraded* hotspots (Fig. 2b) identified where these hotspots corresponded. Intersect analyses identified areas around the west coast and several offshore islands that were in *good* environmental health and had *improved* over the past five years, and areas on the east and west coast and offshore islands that were in *good* environmental health but had *degraded* over the past five years (Fig. 3). The analyses also identified areas that were in *poor* environmental health and had *degraded* in the past five years on the south west coast of the MSP, surrounded by areas in *poor* environmental health that had *improved*. Combining the spatial analyses in this way identified trends in the data spatially consistent across citizen science observations.

4. Discussion

In this paper we demonstrate how citizen science can be used to provide thousands of fine-scale environmental observations on current and recent trends in environmental health across an MSP region. The study also demonstrates how hotspot analyses can be used to determine areas rated similarly across citizen science observations to identify hotspots of *good* or *poor*, and *improved* or *degraded*, environmental health. By comparing hotspots of current and changing environmental health across consistent citizen science data, areas can be identified as being in *good* and *improved*, *good* but *degraded*, *poor* but *improving*, and *poor* and *degrading*, environmental health. First identifying statistically significant point data rated similarly by different respondents overcame potential limitations regarding variations in accuracy and data quality. Differences in survey effort were controlled for by standardising hotspot data so that the number of responses would not affect the hotspots identified by density analyses.

In particular, the survey demonstrated that the majority of the ratings of *poor* and *very poor* environmental health were located in the south west of the Marine Park, around Auckland City. As the most heavily used and most populated area in the Marine Park, these results may be unsurprising, but they do provide insight into areas the public feel need increased attention by planners. Combining current health data with change over the past five years suggested that some of the areas in and around Auckland have been *improving*. Understanding where areas have been *improving* is valuable for planners so that they can better understand what actions have been successful in the past. However, the results also indicate that increased efforts should be dedicated to these areas to improve environmental health around Auckland City, which, whether *improving* or *degrading*, was consistently rated to be an area of *poor* or *very poor* environmental health by the public. While reports have extrapolated environmental data in previous surveys to suggest environmental health is declining across the entire region, public observations suggest there are a number of areas also in *good* condition. Some of these locations are also *improving* and it may be useful for planners to communicate these areas as success stories in the Marine Park, and investigate what actions may have led to successful management and *good* health to inform and improve future planning actions. It is also important to note that a number of sites were rated *good* but *degrading*, and these sites will require more focused attention in the future to identify key threats and to mitigate against decline.

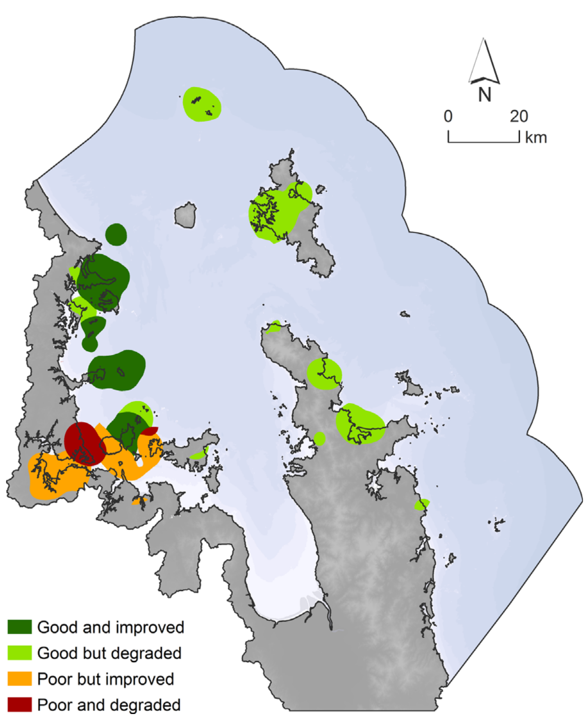

Fig. 3. Areas of good and improved, good but degraded, poor but improved, and poor and degraded environmental health.

However, several issues still need to be considered when using citizen science observations. As the point data covered most of the coast and offshore islands, any area not identified as a hotspot in Figs. 1 and 2b was either given a consistently neutral rating (*ok/average* or *stayed the same*, respectively), or there was too much variability in the data to determine a consistent trend. This highlights a potential issue as the analyses do not allow us to distinguish between neutral ratings and data with high variability in these areas. It is also important to note that while hotspots identify areas of consistent ratings across citizen science observations, it is still unclear as to whether this reflects the health of the environment itself or public perceptions of the environment at these locations. For example, areas consistently rated as being in *good* or *improved* health by the public may be a reflection of the health of the environment or a result of positive public perceptions of local conservation efforts. Similarly, areas consistently rated as being in *poor* or *degraded* health may reflect the environment or may be negative public perceptions related to recent development proposals, or a damaging newspaper article or opinion piece. Another limitation of citizen science is the potential bias of the participant sample, and it would be useful to compare the results of the study to a representative sample of the public. Underrepresented groups could then be targeted in future efforts to ensure public participation and local environmental knowledge is representative of the population. The authors recommend triangulating data from a range of sources including workshops and focus groups, qualitative fieldwork, media analysis, and a review of local events that may have affected public opinion, to provide a greater understanding of the results of the study. It is also recommended that future research efforts sample across the region to compare observations of experienced researchers to the citizen science observations contributed by the public. While additional steps in the citizen science process, understanding whether consistent citizen observations represent local environmental health, or reflect a public response to social influences, local media, or communication strategies, will be of value to both planners and the public.

Despite the limitations identified in this study, the authors believe citizen science provided valuable insight on how the public view environmental health across the planning region. Citizen science provided fine-scale environmental observations across the area that would be difficult to achieve by other methods, or the time and resource limitations faced by environmental agencies and planning organisations. Identifying hotspots of *good* and *poor*, and *improved* and *degraded*, environmental health across consistent citizen science observations provides valuable information for planners, researchers, practitioners and the public. Further, recognising where these hotspots overlap provides insight into trends beyond hotspot analysis, characterising areas rated as *good* and *improved*, *good* but *degraded*, *poor* but *improved*, and *poor* and *degraded* environmental health. Although citizen science data may receive scepticism over issues regarding data quality [2,26], identifying hotspots across thousands of observations demonstrates consistent data in these areas. Coupling hotspots of current health with hotspots of how health has changed in the past five years demonstrates a method for determining trends across the MSP region as defined by citizen science. Although analyses from thousands of observations are likely to be representative of environmental trends, further work is required to disentangle whether consistent public ratings are influenced by other social factors. If consistency is reflective of trends in environmental health, planners can use these data to target areas undergoing different trends to identify new threats to environmental health and monitor the effectiveness of different management actions. If consistency is also influenced by other social factors affecting how the public rates the environment in these areas, planners can use this information to determine the positive and negative influence of communication strategies, management actions, and public media. Where environmental assessments may diverge from public assessments they still remain valuable in providing insight into unexpected information or events [26], and indirect influences of other environmental and social factors. Focusing future management efforts in areas where citizen observations match and diverge from environmental health will build trust, respect and a collaborative working environment between managers and the public to better understand the Marine Park. This study provides valuable data which can be used to develop a framework for more intensive research to better understand how environmental and social influences affect assessments of environmental health.

5. Conclusions

While increasingly used in terrestrial monitoring programs, there has been a lack of uptake of citizen science in MSP to date. By crowdsourcing data collection, citizen science provides fine-scale environmental data across a marine planning region, overcoming the limitations of time and resources usually faced by decision makers and environmental agencies. Citizen science can also be used to enhance public participation in MSP by broadening engagement and inclusion in environmental research and monitoring. Hotspots identified across thousands of citizen science observations identified trends in environmental health that would be difficult to achieve by other methods. Understanding where environmental assessments converge or diverge from citizen science observations is of value to planners in the region, and to future research and management efforts. Further, incorporating diverse local environmental knowledge through public participation fulfils multiple ecological and social objectives of MSP management. The study also contributed to developing a supportive and cooperative space for the public to become involved in research that contributes knowledge useful to the MSP being developed in the region. By incorporating local knowledge in to the spatial plan, citizen science can make an important contribution to increasing awareness, inclusion and management of the Hauraki Gulf Marine Park.

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