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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 crowdsourcing 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