Marine Pollution Bulletin xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

The role of citizen science in monitoring small-scale pollution events

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ARTICLE INFO

Keywords:
Small-scale pollution events
Citizen science
Monitoring

ABSTRACT

Small-scale pollution events involve the release of potentially harmful substances into the marine environment. These events can affect all levels of the ecosystem, with damage to both fauna and flora. Numerous reporting structures are currently available to document spills, however there is a lack of information on small-scale events due to their magnitude and patchy distribution. To this end, volunteers may provide a useful tool in filling this data gap, especially for coastal environments with a high usage by members of the public. The potential for citizen scientists to record small-scale pollution events is explored using the UK as an example, with a focus on highlighting methods and issues associated with using this data source. An integrated monitoring system is proposed which combines citizen science and traditional reporting approaches.

1. Introduction

Small-scale pollution events, such as the accidental or deliberate release of oil or chemicals into the environment, can arise from a number of natural and anthropogenic sources including industrial outfalls, discharges from storm water and untreated sewage. Whilst there are mechanisms in place for reporting of large-scale events, the extent and impact of small-scale pollution events is difficult to quantify. This is because these events are not consistently reported and are difficult to monitor using traditional scientific approaches due to their spatial scale and patchy distribution (Redondo and Platonov, 2009). One potential solution to improve monitoring and reporting of these events is the use of citizen science (Dickinson et al., 2012); a technique that has been used to great effect in monitoring marine environment (Hyder et al., 2015; Thiel et al., 2014) and is routinely used to monitor marine litter (Table 1), but has yet to be applied to pollution and spills.

In this viewpoint, the potential for citizen science to provide data on the extent and nature of small-scale pollution events is assessed. Here the focus is on oil, as many large and small spill events can be attributed to oil of various types and are better documented. The current mechanisms for reporting pollution events are summarised and existing citizen science projects that support reporting and monitoring are highlighted. Whilst the focus of this viewpoint is on oil spills around the UK, the findings are equally applicable to many pollution or spill events.

2. Pollution events

Polluting events can involve the release of chemicals, pesticides, oils, sewage, animal slurries, beverages, food products, detergents, and dairy products into the environment, all of which have the potential to cause damage. Marine-based sources include fishing, shipping (transport, tourism), offshore mining and extraction, accidents, or illegal dumping at sea (Kluser et al., 2006). Many studies have focussed on plastics in the marine environment (Derraik, 2002; Thompson, 2004) and plastics are well covered by citizen science (Table 1). However, many oil spills are observed each year (Carpenter, 2007) and small-scale spills are not well studied or reported especially as a result of human activities in coastal areas (Showstack, 2002). Around the UK a number of high-profile spills have been recorded, including oil pipeline leaks (Cheng et al., 2014) and oil tanker groundings (Kingston et al., 1995), with the English Channel identified as a high risk area due to the commercial transportation of oil along this major transport route (Vieites et al., 2004). Aerial surveys of the North Sea have shown that between 500 and 1,200 oil spill have been observed each year with 73–88% of oil spill being $< 1\ m^3$ in extent (Carpenter, 2007), so it is important to consider the extent and impact of small-scale spills on the marine environment.

2.1. Impacts of spills

Impacts of relatively large-scale spill events are well-documented, and can persist for decades causing effects at all levels of the ecosystem; including the indefinite persistence of hydrocarbons (found in crude

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http://dx.doi.org/10.1016/j.marpolbul.2017.04.038
Received 13 September 2016; Received in revised form 19 April 2017; Accepted 21 April 2017

Table 1
Examples of existing citizen science projects that aim to collect data on spills and pollution.

Name	Data collected	Coverage	Data available	Aims
Water Reporter	Pollution monitoring for waterways	Global (United States)	Yes	To keep track of local waterways and document pollution events. The site is designed and run from the United States, though reports have been received from the UK (North West London). http://www.waterreporter.org/
Marine LitterWatch	Marine litter	Europe	Yes	Set up by the European Environment Agency (EEA) to help fill data gaps in beach litter monitoring required by the EU Marine Strategy Framework Directive (MSFD). This project involves communities setting up events to record data, with an internet portal to manage events. http://discomap.eea.europa.eu/map/MarineLitterWatch/
OSPAR Beach Litter	Marine litter	Europe	Yes	Assess the trends in litter for Regional Sea Conventions, MSFD, and the United Nations Environmental Programme. http://www.mcsuk.org/ospar/
Marine Debris	Marine litter	Global (United States)	Yes	To report where marine debris or litter is found. http://www.marinedebris.engr.uga.edu/
Marine Defenders	Oil spills, marine debris, biological events	United States	No	To reduce the incidence of intentionally spilled oil. Oil spill reports uploaded are sent to the National Response Centre, providing data directly to the Government. www.marinedefenders.com
iWitness Pollution map	Oil spills, chemical spills	Global (United States)	Yes	Repository of eyewitness reports and photos of pollution from affected citizens, NGO's, government agencies (National Response Centre: NRC) and third parties responsible for the pollution. http://map.labucketbrigade.org/

oil) in the sedimentary record (Reddy et al., 2002) and the loss of marine and coastal flora and fauna (Frost et al., 1999; Halpern et al., 2008; Kappel, 2005; Kingston, 2002; Ranwell, 1968; Shahidul Islam and Tanaka, 2004; Votier et al., 2005). For example, the Exxon Valdez oil spill is estimated to have killed between 100,000 and 300,000 birds (Piatt et al., 1990) and between 500 and 5,000 sea otters (Garrott et al., 1993), with residual oil impacting on recovery (Bodkin et al., 2012; Garshelis and Johnson, 2013) and long term effects on the ecosystem (Peterson, 2003). In addition, other incidents such as the grounding of the cargo ship MSC Napoli in 2007, where significant amounts of hazardous materials were being carried, have the potential to spill not only oil, but mixtures of other chemicals, including those used for industrial, agricultural and personal care purposes (Kirby et al., 2008; Readman et al., 2007). Impacts from spills may result in the closure of public water supplies (surface and groundwater problems) and damage to wetlands, fisheries and river ecosystems. The scale of this impact can be linked to a number of factors including the quantity, the toxicity and concentration of the material, the time of year, weather conditions, environmental sensitivities, and the speed and effectiveness of incident response (Dicks et al., 1982; Fox et al., 2016; Fraser and Racine, 2016). For example, saltmarshes are classed as highly sensitive environments, due to the persistence of certain contaminants in the sediments (Baker et al., 1996; Michel and Rutherford, 2014). The variability in the sensitivity of different locations can be explored using Environmental Sensitivity Index (ESI) maps, which provide a means to highlight at-risk areas, and to reduce environmental consequences from spills, or improve the post-spill cleaning operation (Jensen et al., 1990).

2.2. Impacts of small-scale spills

Research has shown that the cumulative effects of small spill events may lead to chronic pollution and may have more severe consequences than larger individual spills (Blumer et al., 1971; Redondo and Platonov, 2009). For example, Showstack (2002) highlights the impacts of chronic oil release on the marine environment, with 85% of anthropogenic-sourced petroleum in the North American waters originating from land runoff, polluted rivers, and jettisoned fuel from aircraft, small boats and jet skis (Transportation Research Board and National Research Council, 2002). Although the volumes of oil can be small, it can lead to both short-term acute effects if the toxicity of the substance is high and long-term chronic effects (Camphuysen and Heubeck, 2001; Fox et al., 2016; Fraser and Racine, 2016; Wiese and Ryan, 2003). The impact on the organism is dependent on several factors including the exposure, effect, mechanism of toxicity, and the dose-response relationship (Sprague, 1971). There may also be sub-lethal effects of regular exposure to pollutants that could affect processes like growth or reproduction (e.g. endocrine disruptors (Porte et al., 2006)) and chronic effects have been shown to be important in recovery of ecosystem from large-scale spills (Peterson, 2003). In addition, much of these small-scale releases are in vulnerable coastal habitats that are subjected to many other pressures and may be an important part of the cumulative pressures (Crain et al., 2008), with increased level of contaminants linked to fewer species and diversity in marine and coastal habitats (Johnston and Roberts, 2009; Lotze et al., 2006).

2.3. Reporting mechanisms

In the UK, the Environment Agency (EA) reports on the quantity and type of pollution spilt out to 1 nautical mile both for court cases and for the Water Framework Directive monitoring of Good Ecological Status. The UK Inshore Fisheries and Conservation Authorities (IFCAs) also collect pollution event information where these events have the potential to affect fisheries. Additional pollution information is collected by academic bodies that are generally related to scientific hypotheses or short term monitoring of recovery after large spills (de la Huz et al., 2005; Glegg and Rowland, 1996; Kingston et al., 1995; Newey and Seed, 1995).

Numerous national and international organisations have been set up to record marine pollution events with several different reporting structures. In the UK, the government has a reporting site which redirects the spill notification to the affected local council. For example, the Advisory Committee on the Protection of the Sea (ACOPS) collates data from UK government agencies (Maritime and Coastguard Agency and The Department for Business, Energy and Industrial Strategy) and is the main repository of significant marine spill data from around the UK. In addition to pollution reporting by the government, several non-government organisations (NGOs) are also involved in the collection of this information, including the International Tanker Owners Pollution Federation (ITOPF).

The methods used to document spills ensure that appropriate measures are in place to minimise impacts on the environment and