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Research article

An analysis of environmental incidents for a national Antarctic program

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ABSTRACT

Research stations in Antarctica are concentrated on scarce ice-free habitats. Operating these stations in the harsh Antarctic climate provides many challenges, including the need to handle bulk fuel and cargo increasing the risk of environmental incidents. We examined 195 reports of environmental incidents from the Australian Antarctic Program, spanning six years, to investigate the impacts and pathways of contemporary environmental incidents. Fuel and chemical spills were most common, followed by biosecurity incursions. The majority of reports were assessed as having insignificant actual impacts. Either the incidents were small, or active, rapid response and mitigation procedures minimised impact. During the period only one spill report (4000 l) was assessed as a 'high' impact. This is despite over 13 million litres of diesel utilised. The majority of incidents occurred within the existing station footprints. The pathways leading to the incidents varied, with technical causes predominately leading to spills, and procedural failures leading to biosecurity incursions. The large number of reports with inconsequential impacts suggest an effective environmental management system with a good culture of reporting environmental incidents. Our findings suggest that the key to continual improvement in an ongoing environmental management system is to learn from incidences and take action to prevent them occurring again, with an end-goal of minimising the residual risk as much as possible.

1. Introduction

Extreme cold, wind, altitude and isolation make Antarctica one of the most challenging operational environments on Earth. Antarctic Treaty nations demonstrate their commitment to protect the Antarctic environment through adherence to the Protocol on Environmental Protection (the Environmental Protocol – Article 3.1). Despite such commitments, human activities and incidences in Antarctica are known to affect biota, degrade the environment and habitat, contaminate substrates, and impact wilderness and aesthetic values (Hull and Bergstrom, 2006; Tin et al., 2009). The potential significance of many environmental incidents increases because Antarctic program activities are focussed in terrestrial areas, which constitute just 0.34% (or less) of the continent (Burton-Johnson et al., 2016; Terauds and Lee, 2016), and most stations are located in the ~0.05% of terrestrial Antarctica within 2 km of the coast (Hull and Bergstrom, 2006). The impacts of contamination and disturbance are compounded further by slow natural recovery rates in the cold environment (Ferguson et al., 2004; Bargagli, 2008; Polmear et al., 2015).

The main forum for reporting environmental incidents associated with national Antarctic program operations is through the Council of Managers of National Antarctic Programs (COMNAP). In 1999, COMNAP released an assessment of environmental emergencies from a voluntary survey of 17 National Antarctic Programs (COMNAP, 1999). During a ten-year period (1988–1998), 133 incidents which had 'potential' to result in adverse environmental impacts or required an emergency response had been reported (COMNAP, 2000). The majority of incidents were hydrocarbon spills (93), predominately of diesel fuel (69) with 30 in excess of 1000 litres (l) (COMNAP, 2000). There were also 10 transport-related incidents where the vehicles/aircraft were irretrievable. COMNAP (2002) updated this assessment with a further 58 environmental incidents reported between 1999 and 2002.

Environmental incidents have continued to occur since 2002. At least 14 vessels have sunk or run aground, including the sinking of the tourist vessel MV *Explorer* in the Bransfield Strait in 2008

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(Darby, 2010; ASOC, 2012; Baxendale, 2016). The ship was carrying ~210 000 l of hydrocarbons, with an undetermined amount polluting surrounding marine environments. Onshore spills have also continued to occur; some with quantities up to 25 000 l (NZAS, 2003). Hydrocarbon contamination around stations suggest that smaller spills are also common and widespread (Bargagli, 2008; Klein et al., 2012; Raymond et al., 2016). Such contamination is known to impact Antarctic biota and habitat function (Raymond et al., 2016).

Heavy metal contamination is readily detected in substrates around active and abandoned stations (Santos et al., 2005; Bargagli, 2008; Guerra et al., 2013). While more evidence is needed on the direct effects of heavy metal on Antarctic ecosystems (Claridge et al., 1995; Santos et al., 2005; Bargagli, 2008; Guerra et al., 2013), they may have synergistic impacts when combined with hydrocarbon contamination (Stark et al., 2003).

The treatment of waste has improved since the adoption of the environmental protocol by most Antarctic nations. Despite reports of waste dispersal issues now being rare, they are inevitably associated with operational accidents. Within the past 10 years these have included two catastrophic station fires, with known contamination occurring (Russia, 2009; BBC, 2012; Guerra et al., 2013). Remote area aircraft accidents have also occurred, with certain levels of waste deposition (ABC, 2010; AAD, 2013; ATSB, 2015). Near-shore resupply incidents including barges overturning and ships running aground also occur (e.g. Brazil, 2012; AAD, 2016), with a potential for release of waste and pollution (e.g. abrasion and release of anti-fouling treatments into the local environment). There is also ongoing legacy waste associated with the presence of old tip sites and waste management practices from prior to the environmental protocol.

Introductions of non-native species into Antarctic environments have also been reported (Hughes et al., 2009, 2011; Houghton et al., 2014). Research has demonstrated that national program and tourist operations are vectors for non-native species and propagules (Whinam et al., 2005; Hughes et al., 2009; Chown et al., 2012; IAATO, 2012; Houghton et al., 2014). Incursions of non-native flora and fauna are occurring, with increasing ranges into natural habitats (Hughes and Worland, 2010; Olech and Chwedorzewska, 2011; Chwedorzewska et al., 2014). Although most species arriving are outside their climatic range, the diversity of species arriving (Whinam et al., 2005; Hughes et al., 2011; Houghton et al., 2014), and warming temperatures in Antarctic regions (Mulvaney et al., 2012), increases the possibility of establishment (Frenot et al., 2005; Chown et al., 2012; Hughes et al., 2012; Molina-Montenegro et al., 2014; Pertierra et al., 2016; Lee et al., 2017).

Negative impacts on Antarctic vertebrate wildlife have been demonstrated from disturbance associated with general Antarctic program operations (Coetzee and Chown, 2016). Although there has been no evidence of introduced disease (Grimaldi et al., 2010), individual animal deaths (IAATO, 2011a; IAATO, 2011b; IAATO, 2012), the ease of possible transfer (Curry et al., 2002), and discovery of antibodies for common avian disease in wildlife near stations (Miller et al., 2008) have raised concern of the risk (Kerry and Riddle, 2009).

Reports of accidental spatial impacts on the terrestrial environment (i.e. landscape or habitat degradation and expansion of physical footprint) are scarce (Poland et al., 2003), but known to have occurred (Tin et al., 2009). Monitoring of popular tourism landing sites and within the vicinity of stations shows incidental impacts such as compaction of soils and trampling of vegetation (see: Tejedo et al., 2009, 2016; Tin et al., 2009). There is however limited baseline data to distinguish any cumulative increase with new incidents. Despite this lack of evidence, with 267 979 tourism visitor landings in 2015–16, and 109 COMNAP-listed national facilities across Antarctica (COMNAP, 2016; IAATO, 2017), it is expected cumulative incidental impacts occur.

Thus incidents resulting in contamination or disturbance are known to occur, are not uncommon, and impact the Antarctic environment and its values; but how do they occur, how often do they have more than an inconsequential impact, and are they preventable? This paper presents the analysis of the pathways and impacts of contemporary environmental incidents for a large national Antarctic program, and the first overview examination in general since COMNAP (2002). In 2002, Australia became the first Antarctic Treaty party to implement a ISO14001 based Environmental Management System (EMS) for all of its operations (Maggs, 2002). As part of the systematic approach to environmental management under its EMS, the Australian Antarctic Division (AAD) developed an online reporting system (Incidents, Hazards and Improvement Suggestions Reporting System -IHIS) to aid the continual improvement of its operations. Staff are required to log incidents and near misses regardless of size. This reporting culture provides a sizable dataset to analyse. Here we examine six years of data from this system looking for trends in the cause of environmental incidents and lesson learned that might be valuable for Australia and other operators in Antarctica.

2. Materials and methods

The AAD introduced IHIS, an intranet-based system, to log incidents, near misses, and improvement suggestions. Within IHIS an environmental incident is defined as 'an unexpected occurrence that has had, or could have, an adverse effect on the environment'. Each IHIS report activates a tiered response and subsequent corrective actions (See Fig. 1). The intent of IHIS within the EMS, is the fast reporting of information to allow timely mitigation action, as well as enabling the review of existing practices to prevent future occurrences across all operations.

IHIS reporting is required as soon as practicable following an incident (Fig. 1). Each report in IHIS initially captures the type of incident, details about the incident, location, and initial description of impact (if applicable) directly from the people engaged in the activity in which an incident has occurred. After submission, each IHIS report is classified by type (incident, near miss or improvement) and given two ratings; first on potential and then actual level of impact by AAD's environmental managers. The incident's features are also reviewed against quantifiable parameters (for example: litres of fuels spilled), and within a qualitative consequence scale (Table S1) to derive an impact rating. Impact ratings range from NI (no applicable impact), through Insignificant, Low, Medium, High, to Critical. We reviewed data on environmental incidents from these reports occurring between 31 December 2009–18 February 2016 (6.2 years).

One hundred and ninety-five reports of incidents occurring across the four Australian Antarctic and sub-Antarctic stations, as well as *en route* post-quarantine biosecurity incursions detected at sea, were examined. Reports of near misses with no actual impact were not examined. Twelve reports were contemporary impacts from incidents occurring prior to the review period. These reports were included for their cause, but separated (marked *historic*) for their impact data to delineate them from incidents occurring during the review period. We classified the incident reports along the following categories: biosecurity incursion, bird strike, fuel/chemical spills, waste, wildlife disturbance, and footprint (spatial disturbance impacts).

Additional supporting data of fuel/chemical spills were also compiled including estimated spill quantity data from an existing unpublished review (Frost, 2013) and unpublished data. Estimates were not available or applicable for some incidents. Incident