



Type and quantity of coastal debris pollution in Taiwan: A 12-year nationwide assessment using citizen science data

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ABSTRACT

Man-made coastal debris pollution is a growing concern for Taiwan. In 2004, Taiwanese environmental organizations led by the “Society of Wilderness” began gathering data on 19 categories of debris items collected during cleanup events. We present our analysis of the resulting 12-year dataset collated from 541 events held between October 2004 and December 2016. In total, 904,302 items weighing 131,358.3 kg were collected, and 63.6% and 27.2% of items were made of either plastic or plastic mixed with other materials, respectively. The five most commonly recorded debris categories were plastic shopping bags, plastic bottle caps, disposable tablewares, fishing equipment, and plastic drinking straws. We estimated that during the 12-year period on average between 3.7 and 7.9 million items weighing 560–1110 metric tons polluted Taiwan's coastline. We offer recommendations for improving the quality of data collected during Taiwan's cleanup events and report some policy changes due partly to previous reports of this dataset.

1. Introduction

Plastic pollution is a rapidly worsening environmental problem in terrestrial habitats (Thompson et al., 2009) but even more so in oceanic, coastal, and riverine habitats (Barboza and Gimenez, 2015; Bergmann et al., 2015; Gross, 2015; Wilcox et al., 2015). This problem is rapidly growing because global plastic production and waste generation have been growing exponentially, having reached approximately 335 million metric tons (MT) in 2016 (Geyer et al., 2017; PlasticsEurope, 2017). Of these, ~4.8–12.7 million MT are estimated to enter the oceans annually (Jambeck et al., 2015). This estimate is much greater than the reported global mass of floating plastic debris in the world's oceans which was estimated at 0.25 million MT (Eriksen et al., 2014). It is thus unknown what happens to the vast amount of plastic debris entering the oceans.

Once in the environment, plastic objects and fragments (1) cause the injury and death of animals through entanglement and ingestion, (2) damage and endanger shipping vessels, (3) visually and structurally damage oceanic, coastal, and riverine environments, including a negative effect on tourism and the economic costs of continuous cleanup operations, (4) spread invasive species, and (5) eventually break down to microplastics which can enter the food chain directly or contaminate it via the leaching of chemical ingredients (Gregory, 2009; Jang et al.,

2014; Koelmans et al., 2014; Seltenreich, 2015; Thompson et al., 2009; Vethaak and Leslie, 2016; Wilcox et al., 2015; Wilcox et al., 2016). As plastic objects fragment, they break into ever smaller pieces, which have been classified as macroplastics, mesoplastics, microplastics, and nanoplastics (Laglbauer et al., 2014; Lee et al., 2013).

Possible impacts on human health are: (1) accidents (see above); (2) the direct ingestion of microplastic particles via food, mostly seafood, and the possible resulting internal injury (Dehaut et al., 2016; Rochman et al., 2015); (2) the indirect contamination of air, food, and water with unhealthy substances leached from the plastics (Talsness et al., 2009; Thompson et al., 2009); and the possibility of microplastics serving as pathogen vectors (Vethaak and Leslie, 2016).

Concerns about plastic pollution should be especially pertinent to the Taiwanese public because (1) man-made debris pollution (which is predominantly macroplastic pollution) has reached pervasive and catastrophic proportions along Taiwan's coastline (Kunz et al., 2016; Kuo and Huang, 2014; Liu et al., 2013; Society of Wilderness, 2014; this study) and (2) a relatively high proportion of people's diet comes from seafood (Fisheries Agency, 2007–2012; National Library, 2017). However, despite the urgency and magnitude of the problem, only three scholarly articles have been published so far, one about microplastic (Kunz et al., 2016) and two about macroplastic pollution. Liu et al. (2013) surveyed four beaches on one Taiwanese island from August

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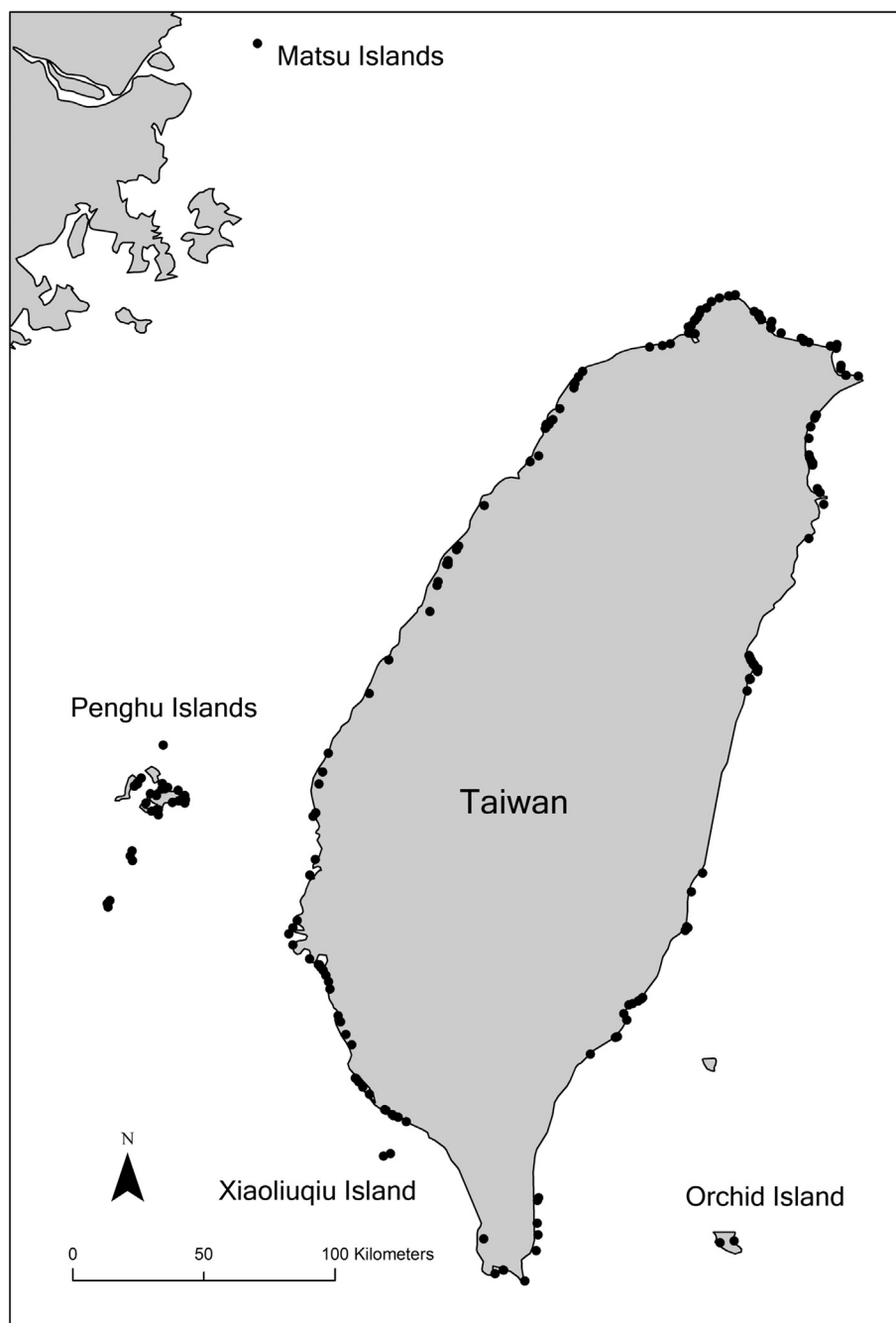


Fig. 1. Locations of 541 cleanup events conducted between October 2004 and December 2016 in Taiwan. Note that one event took place in the Matsu Islands, two events each on Xiaoliuqi [=Lamay] Island and Orchid Island, and 34 events on the Penghu Islands. Events on islands were excluded in some analyses (see main text). The map was made with ArcGIS version 10.1.

2009 to October 2011 and documented the types and proportions of debris types (of which 78.3% was macroplastics). Kuo and Huang (2014) surveyed six sites in northern Taiwan from June 2012 to May 2013 and documented the types, proportions, categories, and sources of debris types (of which 85.5% was macroplastics). Therefore, these two studies had a relatively limited spatiotemporal scope.

To highlight this emerging problem of coastal pollution, Taiwanese environmental non-governmental organizations (ENGOS) began education campaigns and coastal cleanup events in the 2000s. One ENGO at the forefront of this effort has been the “Society of Wilderness” (SOW, www.sow.org.tw) which began to organize coastal cleanup events in 2008 in order to (1) decrease coastal pollution, (2) involve and educate Taiwan's public and media (cleanocean.sow.org.tw), and

(3) document the types, numbers, and weights of debris items. Since there was no government-led or ENGO-led monitoring program, the SOW decided in 2008 to adopt the International Coastal Cleanup (ICC) sampling scheme which had been developed by the [Ocean Conservancy \(2018a\)](#) in the 1980s ([Wikipedia, 2018a](#)). Another reason to begin cleanup events was that the Taiwanese public was beginning to embrace environmental activities, e.g., Earth Day, and that there was therefore a demand for environmental activities. Consequently, the SOW studied the sampling scheme and debris categories developed by the ICC and adopted the methodology to Taiwan's unique situation (see [Materials and methods](#) for more details).

From the beginning, one of the aims of collecting these data was to be able to put pressure on the government to consider source reduction

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