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Beach-cast debris surveys on Triangle Island, British Columbia, Canada indicate the timing of arrival of 2011 Tōhoku tsunami debris in North America

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ABSTRACT

We conducted beach-cast debris transect surveys on Triangle Island, British Columbia, Canada in 2012–2017 to (1) establish a baseline against which to track future changes in stranded debris on this small, uninhabited island; and (2) time the arrival in western North America of debris released by the 2011 Tōhoku tsunami. Most (90%) of the six-year total of 6784 debris items tallied was composed of Styrofoam or plastic. The number of debris items peaked in 2014 (waste Styrofoam, rope) and 2015 (waste plastic, wood), and cumulative totals for all debris types were ca. 50% higher in 2014–15 than in 2012–13 and 2016–17. The peaks in 2014–15 probably represented the arrival of the bulk of the tsunami debris, based on close correspondence with forecasting models and debris surveys elsewhere. A fuller understanding of the movement of the Tōhoku tsunami debris will require information from other beach monitoring programs.

1. Introduction

Marine debris of anthropogenic origin washes up on shorelines in even the most remote corners of the globe (Walker et al., 1997; Bergmann et al., 2017), and this ubiquitous pollution can have environmental, social and economic consequences (Cheshire et al., 2009; Krelling et al., 2017). For several decades, beach-cast debris monitoring programs have been conducted around the world to track the magnitude of the problem (Dixon and Cooke, 1977; Rees and Pond, 1995). Results of these monitoring programs, which often rely on citizen scientists (Rosevelt et al., 2013; Hong et al., 2014), reveal that the composition, size, distribution and abundance of marine debris vary both spatially and temporally (Madzena and Lasiak, 1997; Agustin et al., 2015). The variation is caused both by anthropogenic factors such as the distance to point sources of pollution (Jayasiri et al., 2013; Poeta et al., 2014), and by natural factors such as beach substrate type (Moore et al., 2001; Thiel et al., 2013) and the strength and direction of prevailing winds and currents (Storrier et al., 2007; Ribic et al., 2012). Variation in the levels of marine pollution can also be driven by rare but significant events such as oil spills (Soriano et al., 2006), hurricanes (Romanok et al., 2016) and tsunamis (Goto and Shibata, 2015), and potentially important drivers such as these should be carefully considered when interpreting the results of beach-cast debris surveys (Ribic et al., 2010).

On March 11, 2011, an earthquake of magnitude 9.0 struck off the northeastern coast of Japan, triggering an enormous tsunami. The devastation that ensued included the loss of over 15,000 human lives and the destruction of property including wastewater treatment plants and the Fukushima Dai-ichi nuclear power plant (Mimura et al., 2011). An estimated 5 million tonnes of debris were released from the land and coastal zone, 70% of which sank quickly, leaving 1.5 million tonnes to disperse into the North Pacific Ocean (Government of Japan, 2012). The seaward release of this massive quantity of debris raised a host of environmental concerns, foremost among them being the potential for contamination of marine food webs by radiation (Madigan et al., 2012; Buesseler et al., 2012) and toxic chemicals (Jang et al., 2017; Mizukawa et al., 2017), and the invasion of new ecosystems by marine biota native to Japanese waters hitch-hiking on the tsunami debris (Carlton et al.,

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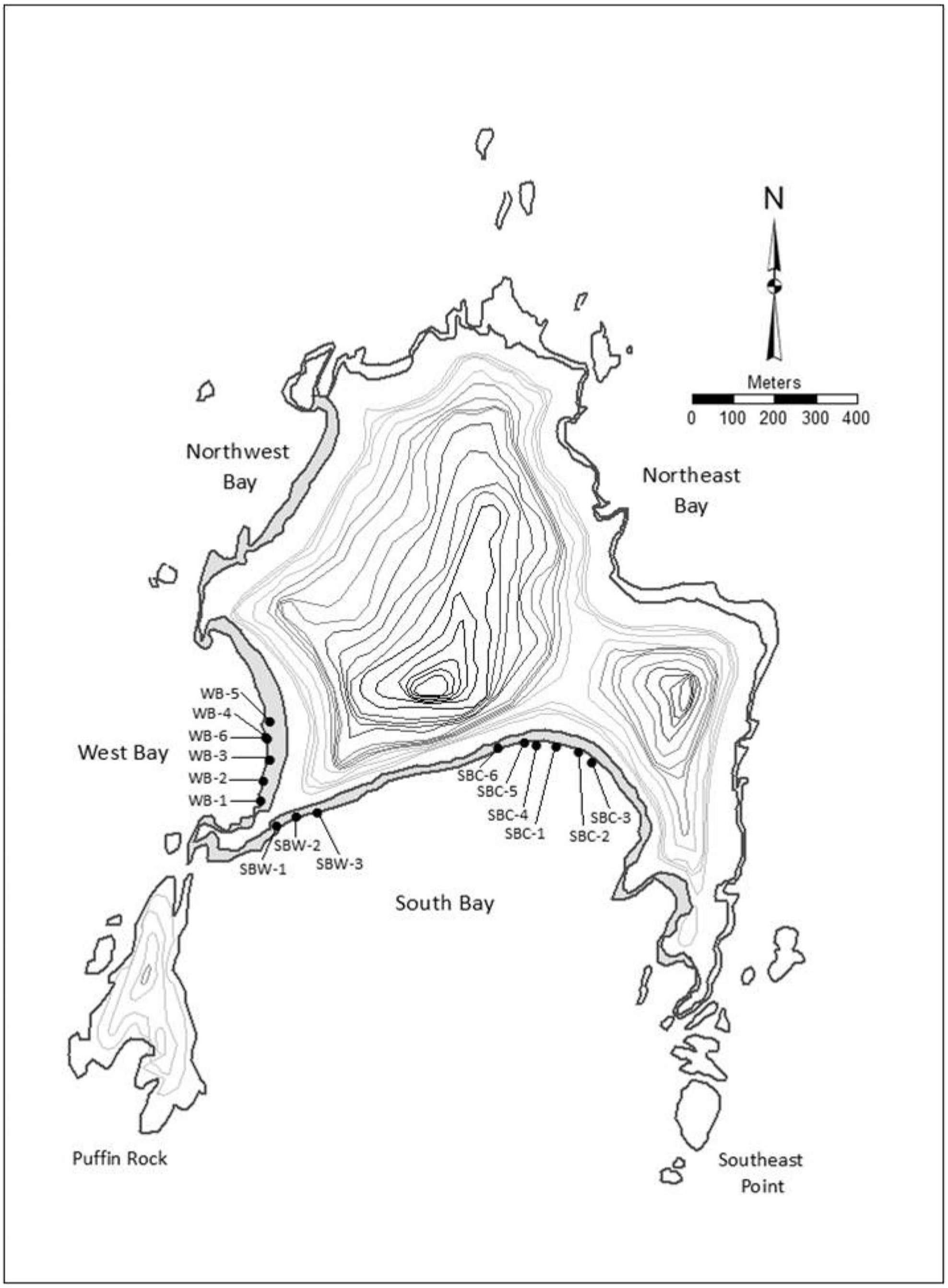

Fig. 1. Contour map of Triangle Island, British Columbia, showing the starting points of the 15 beach-cast debris transects surveyed in 2012 to 2017. SBC = South Bay Central; SBW = South Bay West; WB = West Bay.

2017; Therriault et al., 2018).

Computer modeling in the immediate aftermath of the earthquake predicted that the bulk of the Tōhoku tsunami debris would disperse quickly over the first year to accumulate within the North Pacific Gyre, but that some would eventually be shed and continue east (Lebreton and Borrero, 2013). International efforts have been underway since 2011 to both hindcast and forecast the movement of the debris (NOAA Marine Debris Program, 2015), with a primary objective being to time its arrival on the North American continent. The LeBreton and Borrero model predicted that the release of just 1% of the tsunami debris from the North Pacific Gyre could result in the deposition of up to 1 kg of debris per metre of shoreline in western North America, and NOAA Marine Debris Program (2015) predicted that the arrival of the bulk of the debris would be apparent in beach surveys conducted in that region.

The first tsunami debris arrived in winter 2011–2012, and consisted of large, conspicuous, high-windage objects such as upright fishing vessels (NOAA Marine Debris Program, 2015). However, the forecasting models predicted that the bulk of the debris, comprised of items transported mainly by ocean currents rather than winds, would arrive mainly after spring 2014 and continue for several years thereafter (Kawamura et al., 2014; Maximenko et al., 2015). Clarke-Murray et al. (2018) drew on data from two independent but complementary beach-cast debris monitoring programs to document a near 10-fold increase in the influx of whole “indicator debris” items (Ribic et al., 2012) to coastal areas of northern Washington State in 2013–2015 relative to a 2001–2012 baseline. Those authors also reported a steady increase over the period from 2012 to 2015 in the landings of large (> 30 cm), medium-to-high windage objects such as large Styrofoam pieces from