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Baseline

Tracing the source of marine debris on the beaches of northern New South Wales, Australia: The Bottles on Beaches program

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ABSTRACT

Identifying the source of marine plastic pollution accumulating on ocean beaches is often difficult as unidentifiable fragments of plastic usually predominate. In this study, we surveyed plastic bottles as a relatively identifiable subset of plastics on 30 km of beach along a 200-km section of the north coast of New South Wales, Australia. Source and product type (contents) were determined using barcodes, inscriptions/embossing, or bottle shape and characteristics. Country of origin and product type could be determined for two-thirds of the 694 bottles found. Just over half (51%) of these were of domestic origin with the remainder dominated by bottles from China (24%) and south-east Asian countries (21%). As most of the foreign bottles lacked marine growth, and are unavailable for purchase in the region, passing ships are hypothesised as the primary source.

Despite global recognition of the broadscale impacts of marine plastic pollution on wildlife (e.g. Vegter et al., 2014), aesthetics (Gregory, 1999; Williams et al., 2016), economies (McIlgorm et al., 2011) and human health (Thompson et al., 2009; Campbell et al., 2016), the rates of input to marine systems continue to rise (Thiel et al., 2013; Jambeck et al., 2015). Local and regional efforts to address the problem rely heavily on the identification of sources and, often, clean-up events that are spatially prioritised to target debris accumulation sites, mostly in intertidal settings (Corbin and Singh, 1993; Edyvane et al., 2004; Jambeck et al., 2007; Bravo et al., 2009; Sheavly, 2010; Martin, 2013). However, fragments of plastics are often the most abundant item making it difficult to identify likely sources or even the usage category (Ivar do Sul et al., 2009; Smith et al., 2014; Lavers and Bond, 2017).

For many years, environmental scientists have been operating under the paradigm that 80% of marine debris comes from terrestrial sources with only 20% from activities at sea (e.g. shipping, fishing). However, this has recently been challenged by a number of studies which suggest a greater proportion of plastic waste originates from marine activities (Topçu et al., 2013; Jang et al., 2014). Indeed, the actual ratio is likely to be highly location dependant (Ivar do Sul et al., 2011), and may vary considerably over small spatial scales with factors such as aspect (de Scisciolo et al., 2016) and proximity to primary, local delivery mechanisms (Santos et al., 2009).

In some regions, plastic bottles represent a considerable proportion of stranded debris (e.g. Santos et al., 2005a) and are also an item type for which the source may be more readily determined. For example, many bottles have distinctive shapes or readily identifiable features such as embossing on the bottle or on the lid. Clearly, where labels are still present, full information can be gained about product type (contents) and country of manufacture. These features suggest that drink bottles represent a useful subset of plastic waste with which to explore potential primary sources.

In this study, we worked with volunteer citizen scientists over a 200-km section of the New South Wales (NSW) north coast to collect plastic bottles and identify likely sources. We targeted all beach types (sandy to rocky), and sites in close proximity to population centres, as well as remote and/or inaccessible locations. Our primary objective was to determine the source of bottles as well as the most common product types and manufacturers.

The surveys were conducted over the section of the NSW coast from just south of Coffs Harbour north to Byron Bay (Fig. 1). We recruited volunteers through media articles (both conventional media and social media) as well as through a dedicated program at Southern Cross University that links the community with researchers (Live Ideas - http://www.liveideas.org.au/). Through this process, we recruited dog-walkers, beach walkers, primary school children as part of environmental activities, members of a 4-wheel drive club, as well as natural resource management professionals who collected whilst engaged in other activities. Where possible, a member of the study team met with volunteers ahead of the study to outline optimal search methods (i.e. searches that included the entire beach face and foredune areas). Volunteers were asked to collect any plastic bottles they found on beaches and record details of location and date: most of these surveys were

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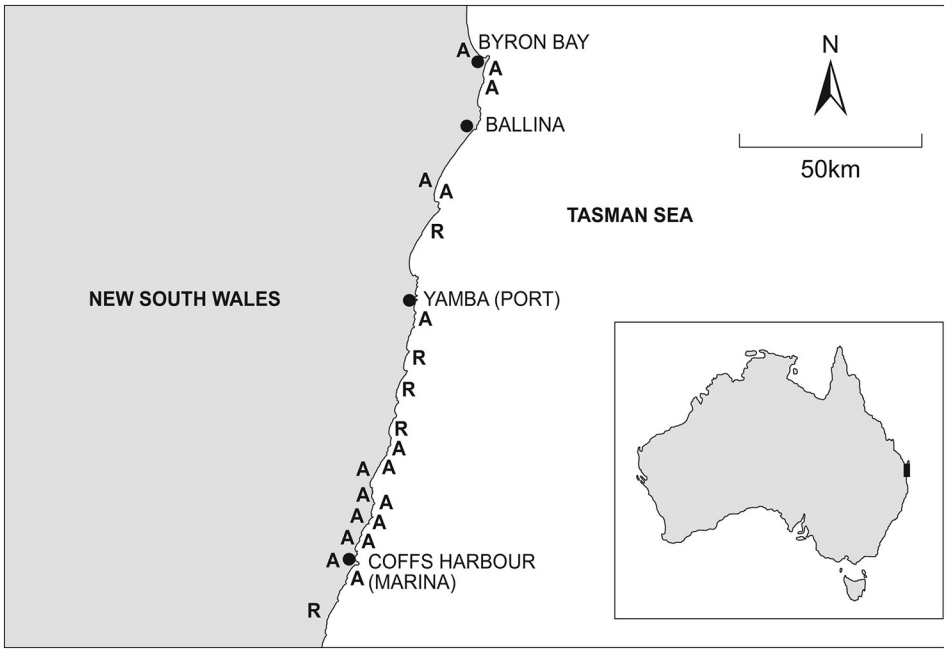

Fig. 1. Map of eastern Australia showing the extent of the study area and the approximate positions of the accessible (A) and remote (R) beaches from which bottles were collected.

therefore opportunistic and haphazard. To maximise the coverage of the program, the study team also made targeted collections on both accessible and remote beaches, the latter defined as those that are difficult to access either because of distance from urbanised areas, or through access being limited to off-road vehicles or a lengthy walk (e.g. Cooling and Smith, 2015). These were conducted by a combination of members of the study team and any volunteers that were available, and used the same, simple search method. We were fortunate to gain permission to access one beach from which public access is banned (part of a Royal Australian Air Force (RAAF) bombing range), which provided a collection that was free from any interference from beachgoers. Data were therefore collected from beaches which varied considerably in terms of accessibility and types of usage.

The sampling region includes only 2 urban centres with populations over 20,000 - Coffs Harbour (population = 70,000) and Ballina (25,000). Other important coastal towns include Byron Bay (9000) and Yamba (6000) (Fig. 1). There are no large commercial ports within the region although the Port of Yamba provides limited general trade services between the region and Norfolk and Lord Howe islands, New Zealand and other Pacific Islands, with a total of 18 vessel visits in 2015–2016 (Port Authority of NSW, 2016). Coffs Harbour has a small marina which caters for local vessels (recreational and commercial, including fishing), but the shallow entrance to the harbour restricts access to small vessels.

The region has a subtropical climate with maximum rainfall through the austral summer and early autumn (Jan to April). Onshore (north-easterly around to southerly) winds predominate (> 75% of the time from afternoon readings – Bureau of Meteorology, 2017) in the warmer months. Marine processes are often dominated by the East Australian Current, a southward-flowing boundary current (Roughan and Middleton, 2004) which has an increasing influence offshore (e.g. Malcolm et al., 2010; Smith, 2011) and is strongest over the summer (Malcolm et al., 2011).

Collections were performed over the period from June 2015 to January 2016 and consisted of repeated collections at beaches cleaned by volunteers during their regular activities (i.e. recreational visits to the same locations), as well as one-off surveys of remote beaches. Where possible, we converted data to density estimates per kilometre of beach: samples supplied by volunteers that lacked specific data about the length of the survey area were excluded from these calculations. The distribution of available density data was sufficient to provide a preliminary examination of differences between remote and accessible beaches. Due mostly to access issues in this region of low urbanisation and population density, surveys covered ~30 km of coast within the 200-km study area.

A database was created to record as many details as possible about each of the bottles. Where possible, product type (contents), manufacturer and country of origin were identified using information on the labels. However, most (78%) of bottles had lost their labels and so identification relied on identifiable features on the bottle or lid (text, embossing, symbols) or comparison against a reference collection assembled for the project. The database included information about the volume of each bottle, the colour of the lid, and photographs from the top and side for each reference bottle. A considerable proportion of bottles bore foreign script, and assistance to identify these items was obtained through crowd sourcing via social media, with images posted to an international network on Facebook. This proved effective in identifying the country of origin in every case. Each bottle was also scrutinised for evidence of marine growth. Where present, this was noted and identified to broad taxonomic group (e.g. bryozoans, algae) or to species in the case of goose barnacles.

While data analysis mostly comprised simple descriptive summaries of source, product type and evidence of biofouling, we also compared bottles densities and the proportion of bottles from foreign sources, between remote and accessible beaches using one-way analysis-of-variance where sufficient data were available (see above).

A total of 694 bottles was collected from 22 beaches (5 remote and 17 accessible – Fig. 1) which had a combined length of approximately 30 km. Volunteers contributed data from 2 remote and 8 accessible beaches with the balance surveyed by the study team. The country of origin could be determined for 505 bottles, mostly because of markings on the lid (n = 217) or the presence of a label (n = 158). Just over half of the bottles came from Australia (51%) (Fig. 2) with China (24.8%), Korea (6.5%), Malaysia (5.9%) providing the majority of the remainder. Only 6% of bottles showed evidence of marine growth, which mostly comprised goose barnacles (*Lepas anserifera*) and bryozoans. The majority of goose barnacles were small (capitulum < 5 mm) although 4 bottles were colonised by larger specimens with a maximum capitulum length of 20 mm. Products from the Coca-cola company were most common (33%) followed by Nongfu Spring water (11%) and Tingyi