Amazonia: the new frontier for plastic pollution

B Kelly

Figure 1. Dense carpet of garbage floating in one of the poorest regions of the city of Manaus (Middle Amazon basin, Brazil).

Brazil's Amazon region is currently subject to increasing deforestation as well as hydropower development, mining, and other activities associated with adverse environmental impacts (Fearnside 2016). Now an insidious new threat has emerged – discarded plastic.

Brazilian government policies to promote economic growth in Amazonia triggered an increase in the region's population, from 1.4 million to 15.9 million inhabitants in less than a century (IBGE 2018). These people are distributed across more than 450 municipalities, 70% of which lack urban planning and efficient waste management (Becker 2005). Few communities have adequate landfills, and much of their trash ends up in rivers (Figure 1). Plastic constitutes 15.7% of the total solid waste produced in Amazonia, a percentage more than double the national average (MMA 2015). It has been estimated that each person in Brazil generates more than 1 kg of solid waste every day (Jambeck *et al.* 2015), and 19.4% of this waste is not collected by municipalities (ABRELPE 2015). On the basis of data from the latest solid-waste management statistics for the Amazon region (MMA 2015), population census estimates (IBGE 2018), and per-capita waste generation (Jambeck *et al.* 2015), we conservatively estimate that 182,085 metric tons of plastic are being discarded into Brazil's Amazonian environment each year. Although an unknown fraction of this mismanaged waste is retained within the river system (eg trapped in the flooded forest), this estimate of plastic waste – which potentially is transported by the Amazon River to the Atlantic Ocean – is five times as high as a previous estimate (Lebreton *et al.* 2017). Even if this amount were to represent an overestimate, the Amazon now ranks as the world's second most polluted river in terms of plastic, only behind China's Yangtze River (Lebreton *et al.* 2017). The Amazon Basin, which covers 4.7% of the world's land area and harbors only 0.4% of the global population, is thought to be responsible for generating 10% of the total amount of plastic waste found in the world's oceans. The Amazon River – with the world's largest freshwater discharge, ranging between ~80,000 $m^3 s^{-1}$ (in October–November) and ~250,000 $m^3 s^{-1}$ (in May–June) – produces a 1.3×10^6 km^2 plume that extends more than 1500 km into the Atlantic Ocean (Coles *et al.* 2013). This plume carries large amounts of sediments, nutrients, and now plastic debris. Driven by seasonal winds and currents, the plume generally flows northward into the Caribbean and eastward toward the subtropical gyre and Africa. Given that plastic loads from the Amazon Basin may therefore impact much of Western Atlantic Ocean, this problem merits international attention.

From the largest cities, such as Manaus and Belém, to the smallest indigenous villages, most Amazon settlements are located in riparian areas across more than 80,000 km of navigable waters. The region's torrential rains, coupled with increasingly frequent and severe floods, wash plastic waste into streams and rivers. Our preliminary surveys in the Amazon estuary have revealed that accumulations of solid waste range from 27 to 113 items per meter of vegetated bank, of which 96% is plastic, predominantly disposable bottles and shopping bags. The documented densities are comparable to those described for wind-exposed mangrove forests on the Caribbean island of Bonaire (Debrot *et al.* 2013).

This "mountain" of plastic waste, much of it trapped within flooded forests, eventually degrades into microplastics that can be incorporated into the soil and/or carried back into the water, thus posing another threat to Amazonian biota. Recent pilot studies in the lower Xingu River and the Amazon estuary revealed microplastic particles in the digestive tracts of 13 freshwater and 14 marine fish species, 20 of which are commonly consumed by humans (Pegado *et al.* 2018; Andrade *et al.* 2019). Once ingested by a fish, these microplastics may then be transported to muscle or other tissues, where the particles may be retained for the fish's entire lifespan (Karami *et al.* 2017). The effects of human consumption of microplastics are largely unknown, but evidence of immunotoxic responses has been reported (Seltenrich 2015). In addition, persistent organic pollutants (POPs) have the ability to adhere to synthetic polymers, which may further contaminate seafood (Rochman *et al.* 2015). Given that the Amazon has the world's highest per-capita fish consumption (Isaac *et al.* 2015), this poses a public-health concern.

Dumping trash, including plastics, into rivers in the Amazon Basin is the result of poor public policies and a general lack of environmental awareness. There is an urgent need for environmental education, investments by state and municipal governments in sanitary and waste treatment infrastructure, and a reduction of single-use plastic items, as well as research on not only the types of microplastics present in the environment, but also their toxicity and bioaccumulation potential. Given that federal environmental regulations are unlikely to increase in the near-term (Fearnside 2018), Amazonian residents need to pressure state and municipal governments to address the problem. Continued failure to contend with plastic pollution in the Amazon has consequences that are far-reaching, because much of this plastic eventually reaches the Atlantic Ocean. The problem of plastic pollution has been well documented and publicized for the marine realm, as well as for rivers in Asia. New evidence of discarded plastics in the vast Amazon Basin clearly demonstrates the magnitude and complexity of this global environmental challenge.

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Science communication in a post-truth world: promises and pitfalls

The mass decline of biodiversity (Ripple *et al.* 2017) in this post-truth era (Lewandowsky *et al.* 2017) means that reliable and influential conservation science communication is more important than ever. In this era, truths and lies are increasingly difficult to distinguish, posing a major challenge to science communication (Lewandowsky *et al.* 2017). As a result, conservation scientists and managers are grappling with new ways of countering misinformation and sharing factual information. Facebook, Twitter, YouTube, Instagram, blogs, online news outlets (eg *The Conversation*), webcomics, and satirical articles all provide communication opportunities, but we still have a poor understanding of which of these are most effective, and when and where to best communicate science.

New technology, including algorithms that detect false information, and proactive campaigns against misinformation, may help combat the effects of fake news (Iyengar and Massey 2019). Somewhat unsettling and problematic, however, is that research suggests fake news is spread on social media because humans, not algorithms, choose to circulate false information, because it is perceived as novel (Vosoughi *et al.* 2018). As a result, exceptionally creative, funny, or unconventional (Figure 1) communications that surprise or shock audiences may reach more people because they are more engaging, even if not factual. In 2017, science-related Facebook pages with the highest online engagement (numbers of