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Microplastic sampling with the AVANI trawl compared to two neuston trawls in the Bay of Bengal and South Pacific☆

Marcus Eriksen [a,*], Max Liboiron [b], Tim Kiessling [c,d,e], Louis Charron [b], Abigail Alling [f], Laurent Lebreton [g], Heather Richards [h], Barent Roth [i], Nicolas C. Ory [c,d], Valeria Hidalgo-Ruz [c,d], Erika Meerhoff [c,d], Carolynn Box [a], Anna Cummins [a], Martin Thiel [c,d,e]

[a] 5 Gyres Institute, 3131 Olympic Blvd #302, Santa Monica, CA, 90404, USA
[b] Memorial University of Newfoundland, Geography Department, St. John's, NL, Canada
[c] Facultad Ciencias del Mar, Universidad Católica del Norte, Larrondo, 1281, Coquimbo, Chile
[d] Millennium Nucleus Ecology and Sustainable Management of Oceanic Island (ESMOI), Coquimbo, Chile
[e] Centro de Estudios Avanzados en Zonas Áridas (CEAZA), Coquimbo, Chile
[f] Biosphere Foundation, United States
[g] The Ocean Cleanup, Delft, The Netherlands
[h] San Francisco State University, San Francisco, CA, United States
[i] The New School, New York, NY, United States

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ABSTRACT

Many typical neuston trawls can only be used during relatively calm sea states and slow tow speeds. During two expeditions to the Bay of Bengal and the eastern South Pacific we investigated whether the new, high-speed AVANI trawl (All-purpose Velocity Accelerated Net Instrument) collects similar amounts and types of microplastics as two established scientific trawl designs, the manta trawl and the DiSalvo neuston net. Using a 335 μm net, the AVANI trawl can collect microplastics from the sea surface at speeds up to 8 knots as it “skis” across the surface, whereas the manta and DiSalvo neuston trawls must be towed slowly in a less turbulent sea state and often represent shorter tow lengths. Generally, the AVANI trawl collected a greater numerical abundance and weight of plastic particles in most size classes and debris types than the manta trawl and DiSalvo neuston net, likely because these trawls only skim the surface layer while the AVANI trawl, moving vertically in a random fashion, collects a “deeper” sample, capturing the few plastics that float slightly lower in the water column. However, the samples did not differ enough that results were significantly affected, suggesting that studies done with these different trawls are comparable. The advantage of the AVANI trawl over traditional research trawls is that it allows for collection on vessels underway at high speeds and during long transits, allowing for a nearly continuous sampling effort over long distances. As local surface currents make sea surface abundance widely heterogeneous, widely spaced short-tow trawls, such as the manta and DiSalvo trawls, can catch or miss hotspots or meso-scale variability of microplastic accumulations, whereas the AVANI trawl, if utilized for back-to-back tows of intermediate distances (5–10 km), can bridge variable wind conditions and debris concentrations potentially reducing variance and provide a greater resolution of spatial distribution.

1. Introduction

Efforts to collect surface microplastics have grown tremendously in the past several years, incorporating traditional, institutional, and citizen scientists (Hidalgo-Ruz and Thiel, 2015; Zettler et al., 2017). For monitoring floating plastics, neuston (surface)

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* Corresponding author.
E-mail address: marcus@5gyres.org (M. Eriksen).

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trawls are used to skim the surface of water in oceans, streams, and lakes where positively buoyant plastics (specific density lower than that of surrounding water) tend to concentrate. These trawls are often of similar design, with an opening to funnel the water into the net, a long net with fine mesh opening (typically 335 μm) to filter the water, a cod end to retain the collected materials (including the plastics), some system to keep the trawl at the surface of the water, and a rope system to attach the trawl to a vessel. Two common challenges that inhibit data collection by trawls include challenging marine conditions (weather, chop, etc), and lost opportunities to collect data while traveling between sampling stations or other locations. The AVANI (All-purpose Velocity Accelerated Net Instrument) trawl, a new design by Marcus Eriksen of the 5 Gyres Institute, offers a new method to sample microplastics at the sea surface. This trawl can be towed particularly at high speeds and over long distances, thus increasing opportunities to document the abundance and impact of microplastics in marine and freshwater environments. The new AVANI trawl can complement traditional trawls, such as the manta trawl and the DiSalvo neuston net used in this study. But new technologies must be validated against established ones to ensure samples are comparable.

The issue of plastic pollution has entered mainstream debate largely due to the increased utility of plastic and research describing environmental impacts. Global plastic production exceeded 300 million tonnes per year in 2014 (Plastics, 2015). While estimates vary as to how much plastic ultimately reaches the oceans (Thompson, 2006; Eriksen et al., 2014; Jambeck et al., 2015), the amount is expected to grow over the next decades as production continues to increase. The presence of plastic debris in marine ecosystems has been well documented (Colton et al., 1974; Law et al., 2010; Moore et al., 2001; Thompson et al., 2004; Cózar et al., 2014), including an increasing abundance of microplastics in all marine and freshwater ecosystems (Eriksen et al., 2013; Hoellein et al., 2014; Corcoran, 2015; Dris et al., 2015; Eerkes-Medrano et al., 2015).

The sources of microplastics are diverse, and include both primary and secondary plastics. Primary sources include preproduction pellets and powders (Mato et al., 2001), as well as polyethylene and polypropylene microbeads used in many personal care products such as facial scrubs and toothpastes (Gregory, 1996; Fendall and Sewell, 2009). Secondary sources originate from mechanical and photo-oxidative degradation (Singh and Sharma, 2008) of plastic items such as bags, bottles, fishing line, and nets into smaller fragments (Browne et al., 2007; Cole et al., 2011) and are also found in sewage effluent contaminated by fibers fragmenting from washing clothes (Browne et al., 2011; Hernandez et al., 2017; Napper and Thompson, 2016).

Given their small size, mobility, similarity to typical prey organisms, and widespread distribution, microplastics have high potential to be ingested by aquatic organisms (Browne et al., 2008; Graham and Thompson, 2009; Lusher et al., 2013; Ory et al., 2017). Direct effects of ingestion, such as inflammation, abrasions, or blockages and subsequent starvation are likely to be less pronounced with the smaller particle size, albeit this is not yet well studied (Rochman et al., 2016). Of concern are potential secondary effects, such as the ability of the plastic to transfer inherent or absorbed persistent organic pollutants (POPs) into the organism, leading to a variety of negative impacts (Browne et al., 2013; Rochman et al., 2013; Wright et al., 2013; Chua et al., 2014; Rochman et al., 2014; de Sa et al., 2015; Tanaka et al., 2015), although these effects are variable across species in laboratory tests (Koelmans et al., 2013; 2014; 2016). Because of these reasons, microplastic monitoring is of continued importance.

While most current studies have been done with traditional neuston trawls, their use is limited to comparatively calm sea states and moderately low trawl velocities. This potentially restricts the number of samples that can be obtained during a particular expedition. Therefore, the current study compares two traditional, wide but shallow-mouthed neuston trawls, the manta trawl and the DiSalvo neuston net with the AVANI trawl to ensure that data collected with the newer AVANI can be compared across studies.

2. Materials and methods

Two expeditions, one in the Bay of Bengal and one in the South Pacific, were conducted using the AVANI trawl and one other established scientific neuston trawl. In the Bay of Bengal, a manta trawl was used alternately with the AVANI trawl, whereas in the South Pacific the DiSalvo neuston net was deployed simultaneously with the AVANI trawl at discrete oceanic stations (Fig. 1).

The AVANI trawl (Fig. 2) has a rectangular aperture which is 60 cm high and 14 cm wide, divided into two compartments by an aluminum plate. The plate is on the same plane as the two skis that keep the trawl at the sea surface when towed so that the bottom compartment (20 cm high and 14 cm wide) is beneath the surface. The net is 4 m long and has a mesh size of 335 μm with a $30 \times 10\ cm^2$ cod end. The AVANI trawl may skim across the ocean surface or at times be nearly completely submerged under rough seas and at high speed.

The manta trawl (Fig. 2) has a rectangular aperture that is 16 cm high and 61 cm wide, and has a 3 m long 335 μm net with a $30 \times 10\ cm^2$ cod end. It has two large upward-angled wings, which are hollow to allow for flotation as well as pushing the front of the trawl upward while under tow.

The DiSalvo neuston net (Fig. 2) has a rectangular aperture that is 40 cm high and 80 cm wide, and has a 2.2 m long 300 μm net with a $30 \times 15\ cm^2$ collecting bag. It has one PVC pipe attached to each side which serve as floating devices that dictate the level at which the net sits in the water. Therefore, in calm conditions water is collected with only half of its opening, an area of 20 cm × 80 cm. This net has been used in Chile since the 1980s, first introduced by Louis DiSalvo (1988).

The main difference between the AVANI design and other neuston trawl designs such as the manta trawl and DiSalvo neuston net is that its opening is much taller than it is wide, creating a stable net opening that captures the surface of the water at high speeds. Video documentation of AVANI trawl performance is publically available and shows the trawl capturing the sea surface up to sea state 5 on the Beaufort scale (Eriksen, 2017).

The AVANI trawl was specifically designed for rough seas and high speeds that typically destabilize other neuston nets, causing them to leap above or descend below the sea surface. The tall, narrow profile on the AVANI trawl means that in more turbulent sea states, the net opening continually captures the surface layer during vertical movement. The AVANI trawl does not leap out of the water or dive below the sea surface, as frequently happens with other, traditional neuston trawls at higher speeds and sea states. Therefore, the AVANI trawl is an ‘efficient’ tool for sampling the sea surface at higher speeds and sea states. If trawled at 5 knots for about 60 min, the AVANI net would cover a total surface area of ~1300 m^2, whereas the Manta and the DiSalvo nets, if trawled at 2 knots for about 15 min, sample an area of 1130 m^2 and 1482 m^2, respectively.

The Bay of Bengal expedition was conducted aboard the S/V Mir in 2013 and was jointly organized between the 5 Gyres Institute and the Biosphere Foundation. The 11-day expedition began on May 25, 2013 from Galle Harbor, Sri Lanka, and sailed east to Phuket, Thailand (Fig. 1). 36 samples were collected using the AVANI and manta trawl (Table S1), one after the other. The 36 sample sites, 18 from each trawl, were not equidistant. Instead, they

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