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Aquaculture and urban marine structures facilitate native and non-indigenous species transfer through generation and accumulation of marine debris

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A B S T R A C T

Both the invasion of non-indigenous marine species (NIMS) and the generation and accumulation of anthropogenic marine debris (AMD) are pervasive problems in coastal urban ecosystems. The biosecurity risks associated with AMD rafting NIMS have been described, but the role of aquaculture derived AMD has not yet been investigated as a biosecurity vector and pathway. This preliminary study targeted 27 beaches along the Coromandel Peninsula, New Zealand, collecting debris from belt transects. Plastic (specifically plastic rope) was the dominant AMD present on beaches. The most common biofouling taxa were hydroids, bryozoans, algae and polychaetes, with one NIMS pest species, *Sabella spallanzanii*, detected fouling plastic rope. Our findings demonstrate that aquaculture is an AMD (plastic rope) generating activity that creates biosecurity risk by enhancing the spread of NIMS. The rafting of *S. spallanzanii* on AMD generated at aquaculture facilities is currently an unmanaged pathway within New Zealand that needs attention.

1. Introduction

Coastal waters are under pressure from a multitude of anthropogenic stressors such as non-indigenous marine species (NIMS) (e.g., Ojaveer et al., 2015), expanding aquaculture (e.g., Cook et al., 2008; Hinojosa and Thiel, 2009; Cottier-Cook et al., 2016), coastal infrastructure (e.g., Galil et al., 2015; Aguilera et al., 2016), coastal hardening (e.g., Airoldi et al., 2005), and increased anthropogenic marine debris (AMD), especially plastics (e.g., Thiel et al., 2013; Vegter et al., 2014; Xanthos and Walker, 2017). On occasion, stressors act in concert to amplify a problem in either an additive or synergistic fashion. For example, artificial breakwaters can act to accumulate and trap AMD (e.g., Aguilera et al., 2016) and to facilitate the spread of NIMS (e.g., Bulleri and Airoldi, 2005; Glasby et al., 2007).

Aquaculture facilities represent urban marine structures in near-shore coastal environments and are known to produce plastic debris (e.g., Forrest et al., 2009b; Andréfouët et al., 2014; Hong et al., 2014). These facilities are also associated with NIMS through cultivation and release (accidental or intentional) (e.g., Hewitt et al., 2006; Cook et al., 2008; Mineur et al., 2014), and/or hitch-hiking on, and biofouling of, cultured species and equipment (e.g., Locke et al., 2007; McKindsey et al., 2007; Thiel et al., 2013). Thus, there is a distinct possibility that biofouling species, including NIMS, associated with aquaculture equipment such as ropes and buoys, may be transported if this equipment is detached or discarded from the aquaculture infrastructure - the generated debris may act to raft NIMS into the surrounding coastal environments.

Dispersal of species through attachment to, or association with, mobile natural debris has been widely demonstrated (Helmuth et al., 1994; Hobday, 2000a; Gutow, 2003; Barnes et al., 2006; Nikula et al., 2010; Kuhlenkamp and Kind, 2013). Similarly, anthropogenic debris is often fouled by species (e.g., Barnes and Fraser, 2003; Gregory, 2009; Vegter et al., 2014) and can passively drift due to wind and surface currents, to create human-mediated rafting opportunities for NIMS (e.g., Aliani and Molcard, 2003; Breves et al., 2014; Holmes et al., 2015). It appears unlikely that a fouling community that forms on natural debris will be similar to a fouling community that forms on artificial substrates (e.g., Tyrrell and Byers, 2007; Goldstein et al., 2014; Leonard et al., 2017).

If aquaculture debris creates rafts that are fouled with NIMS, then the local and regional secondary dispersal of introduced species is likely to occur in an unregulated manner. Thus, the aim of this paper was to

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explore the accumulation of anthropogenic marine debris (AMD) on beaches, both with and without urban structures, and the potential of aquaculture debris to act as a transfer mechanism for biofouling species, particularly NIMS. We undertook a preliminary study on the Coromandel Peninsula, in the Hauraki Gulf, New Zealand. In this region, a mixture of beaches with and without urban marine structures such as piers, jetties, boat ramps, groins and rocky rip-rap exist and aquaculture infrastructure (specifically, mussel aquaculture) is concentrated close to shore. The study investigated the prevalence of biofouled aquaculture debris on nearby beaches to determine the contribution of aquaculture derived debris as a secondary transport vector of NIMS in coastal waters. Specifically, we targeted the New Zealand pest species *Sabella spallanzanii*, which is present on aquaculture facilities in and around the Hauraki Gulf (K. Walls pers. comm.). To help set the scene for this study, we also investigated the AMD issue in this region, noting the prevalence, types and potential source of debris and phyletic associations with the AMD types. This is a preliminary study to first determine if aquaculture generated AMD could be a transport mechanism of concern for pest marine species.

2. Materials and methods

Anthropogenic marine debris (AMD) was collected from 27 beaches on the western Coromandel Peninsula, bordering the Hauraki Gulf in the north and the Firth of Thames in the south (Fig. 1), between December 2015 and January 2016 (austral summer). The Hauraki Gulf is a recognised high value area for New Zealand (e.g., Campbell and Hewitt, 2013; James and Shears, 2012) and a number of the beaches along the Coromandel Peninsula recognised as Significant Natural Areas under Regional Council management. The presence or absence of urban marine structures was recorded for individual beaches. Beaches were classified into three zones based on their proximity to aquaculture facilities: i) Southern zone (n = 9; sites 1–9); ii) Middle 'aquaculture' zone (n = 9; sites 10–18); and iii) a Northern zone (n = 9; sites 19–27). On average, the southern zone beaches were 26.6 ± 2.60 km away from the nearest aquaculture facility. Similarly, beaches in the northern zone were 28.3 ± 2.96 km away from the nearest aquaculture facility. The beaches in the middle zone were closest to aquaculture facilities with an average absolute distance of 8.8 ± 0.96 km.

One 50 m × 2 m belt transect (100 m^2) was sampled at each beach, with the starting point randomly placed along the strandline of the immediate prior tide event. The transect was laid parallel to the shoreline, to the right when facing the water. Sampling occurred on spring tides, to increase the potential of deposited AMD (due to the greater period of beach inundation by tidal waters during a spring tide cycle) and targeted the last high tide only, to provide a measure of AMD deposition based on one-tidal cycle. This sampling design ensured relatively hydrated biofouling communities upon the collected debris that could subsequently be more readily identified to taxonomic unit. All visible AMD within the belt transect was collected, with the exception

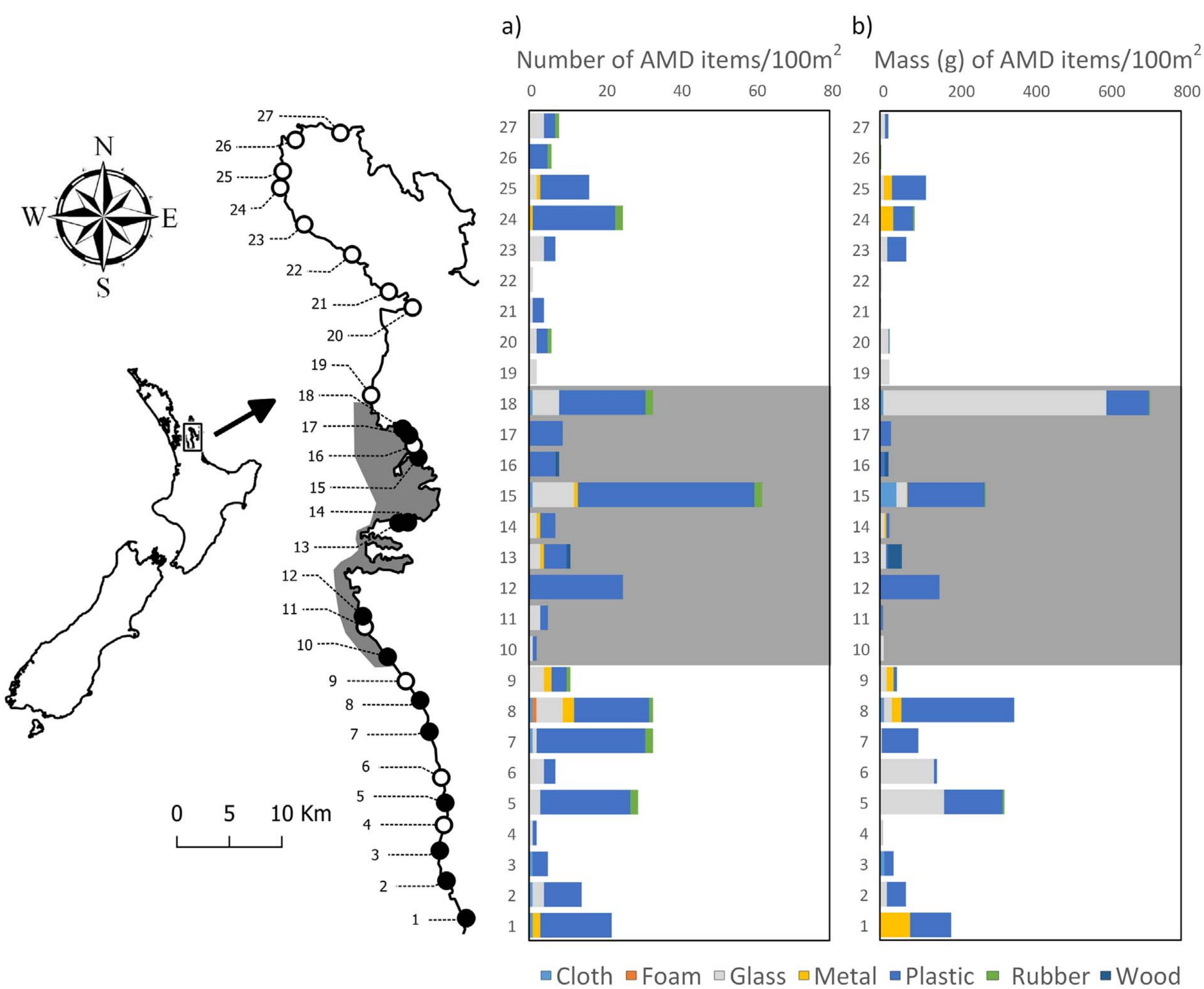

Fig. 1. Beaches sampled for anthropogenic marine debris (AMD) on the western Coromandel Peninsula, New Zealand. Sites 1–9 (inclusive) are the southern zone; sites 10–18 are the middle zone adjacent to aquaculture facilities (dark grey); and sites 19–27 are the northern zone. All sites border the Hauraki Gulf. Sites (circles) are coded for the presence (black) or absence (white) of urban marine structures. Panels provide AMD accumulation by broad categories for: a) number of AMD items per beach transect by site; b) mass of AMD items per beach transect by site.