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Altered fish community and feeding behaviour in close proximity to boat moorings in an urban estuary

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ABSTRACT

Coastal urbanization has led to large-scale transformation of estuaries, with artificial structures now commonplace. Boat moorings are known to reduce seagrass cover, but little is known about their effect on fish communities. We used underwater video to quantify abundance, diversity, composition and feeding behaviour of fish assemblages on two scales: with increasing distance from moorings on fine scales, and among locations where moorings were present or absent. Fish were less abundant in close proximity to boat moorings, and the species composition varied on fine scales, leading to lower predation pressure near moorings. There was no relationship at the location with seagrass. On larger scales, we detected no differences in abundance or community composition among locations where moorings were present or absent. These findings show a clear impact of moorings on fish and highlight the importance of fine-scale assessments over location-scale comparisons in the detection of the effects of artificial structures.

1. Introduction

Growing human populations are causing a wide range of impacts on marine habitats in urban areas. Overfishing, pollution, recreational boating and ocean sprawl have all led to habitat degradation in urbanized coastal environments (Whitfield and Becker, 2014; Heery et al., 2017). Nearshore ecosystems are frequently altered by the addition of artificial structures (Dugan et al., 2011; Heery et al., 2017), resulting in large shifts in the composition and function of associated communities (Dafforn et al., 2015).

The replacement of natural marine habitats with artificial structures such as breakwaters, piers and docks, marinas, jetties, pilings, pontoons, seawalls and boat moorings has resulted in large changes in the physical structure of marine habitats (Heery et al., 2017). These hard structures are often added to locations of low structural complexity, such as soft sediment habitats (Vaselli et al., 2008; Airoldi et al., 2015). The communities inhabiting artificial structures commonly differ from natural substrates due to both biological and physical processes that can differ between the two habitat types (Bulleri and Chapman, 2010; Dafforn et al., 2012). Overwater structures decrease benthic light availability (Able et al., 1998; Glasby, 1999) and reduce the growth and percent cover of macrophytes in soft sediments (Heery et al., 2017). They can alter local hydrodynamics (Perez-Ruzafa et al., 2006) and increase sediment pollution (e.g., metal contamination from antifouling paints associated with marinas, Dafforn et al., 2009; Airoldi et al., 2015). Altered habitat conditions frequently reduce species diversity (Bacchiocchi and Airoldi, 2003) and create favorable conditions and 'stepping blocks' for invasive species (Airoldi et al., 2015). In some circumstances, however, artificial structures can increase the structural complexity of habitats, thus increasing the surface area for settlement of sessile organisms (Perkol-Finkel et al., 2012). Through mimicking natural substrates, artificial structures with high physical complexity can be used to mitigate habitat loss in degraded systems (Pister, 2009; Bulleri and Chapman, 2010; Wetzel et al., 2014).

Detecting the ecological impacts of artificial structures frequently involves large-scale comparisons of modified habitats with areas that lack artificial structures. In highly urbanized estuaries, however, shorelines can be so heavily modified that very few locations lack artificial structures (Dafforn et al., 2015). Therefore, detecting the impacts of artificial structures will rely on assessments on smaller scales (i.e., with increasing distance from the structures), moving away from traditional location scale contrasts (Hedge et al., 2017). For example, breakwaters

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and marinas result in the accumulation of finer sediments due to the reduction of water flow in close proximity (< 10 m) to the modified habitats (Zanuttigh et al., 2005; Rivero et al., 2013).

Boat moorings are ubiquitous within sheltered embayments in urbanized estuaries and are examples of widespread artificial structures with known ecological impacts to organisms in close proximity, especially seagrasses (Walker et al., 1989; Unsworth et al., 2017). Growing populations in coastal areas are leading to increased boating activity and pressures to expand or improve boating infrastructure (Whitfield and Becker, 2014; Mayer-Pinto et al., 2015). Most commonly, moorings consist of a large concrete block and a heavy anchor chain attached to a lighter chain or rope connecting to a surface buoy and the boat (known as 'swing moorings', Unsworth et al., 2017). Changes in wind and current direction move the boats and result in the anchor chain being dragged across the sediment. The chain scour removes benthic organisms (Walker et al., 1989; Harasti, 2016; Unsworth et al., 2017) and can change the physical and chemical composition of soft sediments in close proximity to moorings (Hedge et al., 2017).

The negative effects of boat moorings on seagrasses are well established, with chain scour reducing seagrass cover and leaving a barren halo of unconsolidated sediments around the mooring block that prevents regeneration and leads to further habitat loss (Hastings et al., 1995; Demers et al., 2013; Unsworth et al., 2017). Moorings can also reduce the light availability for seagrasses through shading and the resuspension of sediments, further reducing seagrass cover (Orth et al., 2006; Waycott et al., 2009). Despite the expectation that changes to seagrass cover and sediment properties would affect other components of the marine ecosystem, few studies have examined how moorings may interact with other organisms (see Lynch et al., 2015; Serrano et al., 2016; Silberberger et al., 2016; Hedge et al., 2017).

In this study, we quantify the relationships between the abundance, composition and feeding activity of the demersal fish community with distance to boat moorings on two spatial scales: within mooring fields and among locations. Fish are frequently associated with artificial structures (Wickham et al., 1973; Bohnsack, 1989), with many studies showing that jetties, artificial reefs, wharves, pontoons and breakwalls can support high abundances of some fish (e.g., Bohnsack and Sutherland, 1985; Rilov and Benayahu, 2000; Clynick, 2008; Folpp et al., 2013). These structures can support high abundances due to high concentrations of available food (Cresson et al., 2014) and mating opportunities (meeting point hypothesis, Freon and Dagorn, 2000). The potential exists for boat moorings to act as fish attractants, but the decline in seagrasses in close proximity to moorings could also deter fish (Edgar and Shaw, 1995). An understanding of how fish communities are affected by moorings in urban areas is needed given the important role they play as predators in soft sediments (Thrush, 1999). Any concentration of fish around artificial structures may alter predation pressure in nearby areas, and physical disturbance to the benthos may result in shifts in the distribution of fish utilizing soft sediment and seagrass habitats (Smith et al., 2011).

To assess the impact of multiple small boat moorings on benthic fish assemblages we asked the following specific questions: (1) How does the abundance, diversity, composition and feeding behaviour of the fish community vary with distance from boat moorings? (2) Is the fish community best explained by distance from moorings or seagrass cover? (3) On larger scales, how does the abundance, diversity, composition and feeding behaviour of the fish community differ between locations with and without moorings?

2. Methods

2.1. Study locations

The study was performed in Port Jackson, the main estuary of the city of Sydney, Australia (Fig. 1). Port Jackson is a highly urbanized estuary within the Greater Sydney region, which has a population of 4.8 million (Johnston et al., 2015; ABS, 2016). The estuary has many shallow embayments which contain extensive mooring fields (Mayer-Pinto et al., 2015). Boating is an important recreational activity and there will be an estimated 22,000 recreational vessels registered in the Port Jackson catchment by 2020 and over 5,500 boat moorings within the estuary itself (Transport for NSW, 2013). Six locations were sampled in the outer harbour of Port Jackson, all within 5 km of the estuary mouth and subject to high tidal flushing while protected from the ocean (Fig. 1). Clontarf (33°48′18.9″ S, 151°15′07.0″ E), North Harbour (33°48′00.9″ S, 151°16′09.3″ E), Hunters Bay (33°49′39.6″ S, 151°15′15.7″ E) and Manly Cove (33°48′05.9″ S, 151°17′05.8″ E) each contain an extensive mooring field. The mooring density across these locations is 0.0024 moorings/m^2, 0.0023 moorings/m^2, 0.0019 moorings/m^2, and 0.0022 moorings/m^2 respectively. Quarantine Bay (33°48′48.7″ S, 151°17′08.2″ E) and Rose Bay (33°51′39.8″ S, 151°16′05.3″ E) have no boating infrastructure. The sampling locations were within a depth of 1 to 12 m and dominated by soft sediment habitats. Only the location at Manly Cove contains extensive seagrass beds of three species (*Halophila australis*, *Posidonia australis* and *Zostera muelleri*). Hunters Bay contains sparsely distributed *H. australis* and seasonal patches of *Z. muelleri*. At Manly Cove, 23 seagrass friendly moorings are installed across the location (Fig. S1).

2.2. Variation in fish communities and feeding behaviour with distance to moorings

To test whether the presence of boat moorings is associated with altered fish communities and feeding behaviour, we used unbaited remote underwater video to survey fish within the four locations containing mooring fields. At each location, up to 20 cameras were placed at pre-determined sites within a 120 m diameter sampling zone, using a generalized random tessellation stratified design (GRTS, Stevens and Olsen, 2004). GRTS allows for fine-scale environmental sampling with sample sites evenly spread across the geographic space and with respect to environmental variables used as predictors. The predictor variables used here were distance from shore (as a proxy for depth), and the distance to nearest mooring. The positions of each mooring block on the seafloor were determined using high-resolution aerial imagery from Nearmap (www.nearmap.com.au). Where the mooring block could not be seen in the imagery due to high turbidity (30 of 147 moorings), the position of the mooring buoy at the surface was recorded at multiple time points and their centroid used as the position of the mooring block.

The sampling sites were loaded onto a real time kinematic (RTK) GPS unit and cameras were dropped from a boat at each site. The GPS position of each camera was recorded on deployment to ensure the highest possible spatial accuracy (Fig. 1). Camera units consisted of a GoPro Hero 4 Silver Edition in an underwater housing mounted on steel stands positioning the camera 25 cm off the seabed. Cameras were recovered 1 h after the final camera was deployed, and with known start and finishing times for each camera, along with their order of deployment, we were able to view the same time of day for each camera. Water visibility was measured once at each location and sampling day by holding a camera below the surface and lowering a 30 cm diameter Secchi disk attached to a rope with markings every meter.

Video sampling of fish communities was performed over two separate sampling times at each location, between April 2 and 13, 2015 and again between August 4 and 11, 2015. All observations were made between 0900 and 1600. A total of 186 cameras were deployed across the two sampling times. Due to occasional camera and stand malfunctions the number of cameras deployed at each location at each time varied between 15 and 20 (Clontarf, $n = 20$ and 15; Hunters Bay, $n = 18$ and 18; Manly, $n = 17$ and 18; North Harbour, $n = 16$ and 15).

The video footage was analyzed using EventMeasure software (www.seagis.com.au). One hour of footage was viewed from each of the deployed cameras with the first 5 min post deployment never analyzed to prevent boat disturbance affecting the fish community. Species