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Diversity surrogates for estuarine fish assemblages in a temperate estuary in New South Wales, Australia

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HIGHLIGHTS

- Fish assemblages were evaluated for 8 distinct habitats in a temperate estuary.
- Significant spatial differences occurred among habitats.
- Differences in fish diversity among 2 key habitats persisted over time.
- There were significant correlations between abiotic variables and fish assemblages.
- Habitats and abiotic variables provided useful surrogates for fish assemblages.

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ABSTRACT

The efficacy of fish diversity surrogates is central to their utility in conservation planning and management. Here we examine the linkages among a range of biotic and abiotic surrogates for estuarine fish diversity within the Port Stephens estuary in NSW, Australia. We examine the effectiveness of using biotic habitats as surrogates for diversity, and examine whether this surrogacy persists through time. The study was conducted using fish assemblage data gathered across eight *a priori* identified biotic habitat types. Significant differences in fish assemblages, species richness, and functional richness were detected among 26 out of 28 biotic habitats pairs, and these differences persisted for over 1 year within key *Dendronephthya australis* (soft coral) and filter feeder habitats, demonstrating the potential for biotic habitats to be used as surrogates for estuarine fish diversity. Significant correlations between abiotic variables (i.e. depth, location, substrate type, and substrate complexity) and fish assemblages were also established. Overall, the results demonstrate that both abiotic variables and biotic habitats can be used as surrogates for fish diversity in the study estuary, and combining both these types of predictor variables can provide a high level of discrimination among estuarine fish assemblages. The use of both abiotic variables and biotic habitats in conservation planning can, therefore, improve representation of estuarine fishes within marine protected areas.

1. Introduction

Understanding diversity, and relationships between diversity and habitats, is central to conservation planning (Margules and Pressey, 2000; Tear et al., 2005), and the management of ecosystems (Grumbine, 1994). Key information includes relationships between species and habitats, as well as the distributions of rare and threatened species (Margules and Pressey, 2000). Regional biodiversity (Gamma diversity), is frequently partitioned into Alpha diversity, measuring the diversity of species within habitats, and Beta diversity measuring the effective number of distinct habitats occurring within regions (Whittaker, 1960). This partitioning allows exploration of factors driving patterns in species assemblages both within and among habitats, and has led to the establishment of improved understanding of the relationships between habitats and their constituent species assemblages for a wide range of phyla including; vegetation (Whittaker, 1960), birds (Fretwell and Calver, 1969), mammals (August, 1983), and fish (Malcolm et al., 2010; Rees et al., 2014; Sheaves, 2016).

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Assessing relationships between fish and marine habitats is particularly challenging due to the highly variable nature of fish assemblages in space and time (Willis et al., 2000; Birt et al., 2012), and habitat shifts during the ontogeny of many species, whereby individuals occupy different habitats at different points in their life cycle (Harasti et al., 2014a,b). To overcome problems associated with assessing fish–habitat relationships, managers of marine ecosystems often use abiotic factors (e.g. depth, substrate type) as surrogates for fish diversity (Mumby and Harborne, 1999; Malcolm et al., 2011), as they can be measured relatively inexpensively, compared with fish assemblages, using visual and acoustic technologies (Anderson et al., 2009). Nonetheless, surrogates are only useful management tools if they accurately correlate with the assemblages of interest, are independent of each other, have a wide geographic range, and are amenable to survey (Smith, 2005).

Studies have shown the surrogacy potential of abiotic variables (e.g. depth, location, and substrate type Friedlander and Parrish, 1998; Rees et al., 2014) and biogenic habitats (Mumby and Harborne, 1999; Harborne et al., 2008) for fully marine fish assemblages. However, relatively few studies have examined the effectiveness of such surrogates for fish diversity in estuarine ecosystems, potentially due to variability among estuarine systems (Sheaves, 2016). Establishing reliable surrogates is especially important within estuaries as they contain highly diverse ecosystems that are threatened by a range of anthropogenic stressors (Lotze et al., 2006). Thus, there is a clear need for a more detailed understanding of how abiotic variables and biogenic benthic habitats including sand, hereafter termed 'biotic habitats' perform as surrogates for fish diversity in estuarine systems.

Improved understanding of surrogates for fishes within estuaries is also needed for planning of marine protected areas (MPAs), where adequate information about species distributions is often unavailable, leading to inefficient MPA design (Ban et al., 2011; Malcolm et al., 2012). Marine protected areas are seen as key tools for protecting biodiversity (Coleman et al., 2013; Kelaher et al., 2014), as they provide areas of refuge from human impacts such as over-fishing, pollution, and coastal clearing and development (Agardy, 1994; Mumby and Steneck, 2011). To be effective, surrogates need to be critically evaluated (Smith, 2005) and, ideally, surrogates should be assessed through time to ensure their continued effectiveness when temporal shifts in species assemblages occur (Favreau et al., 2006).

We investigated variation in fish diversity (measured as multivariate assemblage data, species richness, and functional richness) among distinct biotic habitats within the Port Stephens estuary in NSW, Australia, testing the primary hypothesis that fish diversity differs significantly among biotic habitats, and thereby that biotic habitats provide useful surrogates for fish diversity in the study estuary. Furthermore, temporal patterns in fish diversity within key habitats were examined, to assess the temporal stability of the surrogacy. In addition, to improve understanding of the relative importance of abiotic factors (depth, substrate type, location, and substrate complexity) as surrogates, we examined the relationships between these variables and fish assemblages, testing the secondary hypothesis that abiotic variables provide effective surrogates for fish diversity in the study estuary.

2. Material and methods

2.1. Study area

The study was conducted on the southern side of the Port Stephens estuary (Fig. 1) which contains a range of temperate estuarine habitats (Davis et al., 2015; Poulos et al., 2015) and a high diversity of biota (Smith et al., 2010; Poulos et al., 2013). The estuary is subject to strong tidal flows which ensure that salinity in the study area is essentially marine (i.e. 35 to 35.5 psu) (DPWS, 1998). The entire Port Stephens estuary lies within the 98,000 Ha Port Stephens-Great Lakes Marine Park (PSGLMP), the largest MPA within the state waters of New South Wales (NSW) (NSWMPA, 2010). Two sets of surveys were conducted. Firstly, surveys to examine the effectiveness of biotic habitats, and abiotic variables, as surrogates for fish diversity were carried out in January/February 2015 (summer 2015) within eight *a priori* defined habitat types (Davis et al., 2015) (Table 1), with 6 replicate transects sampled from randomly selected starting locations within previously mapped areas for each habitat type (Davis et al., 2015).

Secondly, surveys to examine temporal stability of habitat surrogacy were undertaken for 3 month periods (hereafter periods), from June 2014 (winter 2014) to August 2015 (winter 2015), in two *a priori* selected key habitats (i.e. the soft coral *Dendronephthya australis* and filter feeder), with 12 replicate transects sampled within previously mapped areas for each habitat type. Filter-feeder and *D. australis* were selected as key biotic habitats as the presence of large areas of these habitats within an estuarine system was thought to be relatively unique; *D. australis*, in particular, was thought to be under threat from anthropogenic impacts (Poulos et al., 2013; Harasti, 2016; Smith and Edgar, 2014); and previous research indicated that these habitats contain highly diverse fish assemblages and protected species (Poulos et al., 2013).

2.2. Survey methodology

Underwater visual census (UVC) surveys were conducted at slack water on high tide using the methodology developed by Smith et al. (2008). Briefly, each survey consisted of randomly positioned replicate transects within predefined areas for the specified habitat type. To ensure independence, transects were separated from each other by a distance of at least 10 m. Each transect involved counting fish in a 25 m × 5 m strip along the transect tape, to a height of 5 m above the substratum, with larger (>50 mm) non-cryptic demersal and pelagic fish surveyed as the tape was laid, to improve counts of species that actively avoid divers (Dickens et al., 2011). Benthic and cryptic fish were surveyed by conducting a subsequent thorough search of the substrate to avoid biases in estimates of the abundance of cryptic species, which have been shown to occur in transect areas of this size (Brock, 1982; Lincoln-Smith, 1989). The benthic and cryptic fish search included searching through vegetation, as well as examining crevices and the underside of movable rocks, over a period not exceeding 30 min per transect. Vertical photo-quadrats (covering an area approximately 0.7 m × 0.5 m) were taken at five equally spaced points along each transect, and water depth and an assessment of substrate complexity were recorded for each point. From each photo-quadrat, the percentage cover of rock substratum was calculated, providing a quantitative assessment of the proportion of hard substrate to soft sediment on each transect. Substrate complexity was qualitatively assessed in situ as the height change of the substrate within each quadrat, based on the method proposed by Gratwicke and Speight (2005), using a geometric scale (1 < 5 cm, 2 = 5–10 cm, 3 = 11–20 cm, 4 = 21–40 cm, 5 = 41–80 cm, 6 > 80 cm). Values of percentage rock substrate, depth, and substrate complexity were averaged for points on each transect and subsequently used for assessment of abiotic variable surrogacy. Water temperatures were continuously monitored at two locations spanning the study site using Onset Hobo U22-001 temperature loggers (www.onsetcomp.com accessed 18 August 2015) to provide data on temperature variations over time.