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Research paper

The role of connectivity and physicochemical conditions in effective habitat of two exploited penaeid species

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ABSTRACT

The value of estuarine habitats is often measured by their contribution to the adult component of the population, but a broader suite of attributes can also contribute to nursery function. Identifying and quantifying these elements allows habitat repair to be effectively targeted toward improving ecosystem function for desirable species. We present a study that incorporates stable isotopes and quantitative sampling to investigate the relative importance of different estuarine areas for juveniles of exploited prawn species within the context of habitat rehabilitation, and the potential drivers of these relationships. Eastern King Prawn (*Penaeus* [*Melicertus*] *plebejus*) and School Prawn (*Metapenaeus macleayi*) were studied for two years in the lower Hunter River estuary, on the temperate east coast of Australia. The higher salinity areas near the lower end of the estuary were most important for Eastern King Prawn, and marsh systems in the lower estuary were only important for the species where there was good connectivity with oceanic water. Areas along the estuary were important for juvenile School Prawn, especially marsh habitats, and relative abundance tended to increase with increasing distance along the estuary. Designation of effective juvenile habitat for School Prawn may have been affected by high fishing mortality in fished areas, but this requires further investigation. Salinity, depth, turbidity and distance along the estuary were all important indicators of prawn distribution. The implications of these patterns for current and future habitat rehabilitation in temperate Australia are discussed.

1. Introduction

Continued reliance on ecosystem services derived from estuaries has led to a new era of habitat protection, rehabilitation and restoration efforts in recent decades (Rogers et al., 2015). However, the relatively high cost of repair (e.g. Bayraktarov et al., 2016) gives impetus to the need to effectively target these efforts toward areas that are likely to produce the greatest benefits (for example, increases to fisheries productivity). Notwithstanding the role of habitat repair in managing coastal retreat (e.g. in North America, Scyphers et al., 2011), in some cases the most important ecosystem services derived from habitat repair are the increased productivity of high value exploited species (Creighton et al., 2015), but the greatest benefits will only be possible where repair is appropriately targeted based on species life-history patterns and recruitment dynamics. Consequently, estuarine habitat repair should take into account the relative nursery value of different areas within the estuary for species of interest.

The value of estuarine habitats is often measured by the contribution of recruits from these habitats to adult or exploited stocks (e.g. Beck et al., 2001; Dahlgren et al., 2006). This is a well-researched paradigm, but the mechanistic aspects contributing to habitat value needs greater attention. Sheaves et al. (2015) outline a set of attributes which contribute to the value of habitats, and discusses how combining various experimental and survey approaches can improve our assessment and ability to appreciate the interactions among the broader suite of attributes that can contribute to nursery function. A few of these attributes include the supply of natural recruits to a particular habitat (e.g. Taylor et al., 2017), physicochemical variation and the limitations imposed by an organisms physiology (e.g. Payne et al., 2015), structural habitat requirements of particular species (e.g. Ochwada et al., 2009), and connectivity between juvenile and adult or spawning habitats (e.g. Sheaves and Molony, 2001). Identifying and quantifying these elements will not only allow habitat repair to be effectively targeted, but will also help inform the structural requirements of repair necessary to improve or restore ecosystem function for desirable species.

Eastern King Prawn (*Melicertus plebejus*) and School Prawn (*Metapenaeus macleayi*) are two of the most valuable species of penaeid prawns exploited in eastern Australia. Both species display a penaeid

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Type-II lifecycle (see Dall et al., 1990), and rely on estuarine habitats during their juvenile phase. Adolescent prawns of both species display a predictable emigration from the estuary to the sea that is generally synchronised with the period around the last quarter of the lunar cycle, primarily during the months January – March (Racek, 1959; Ruello, 1971). Following emigration, School Prawn spawn in inshore areas usually adjacent to the mouth of the estuary from which they originated, or adjacent estuaries to the north (Ruello, 1977). In contrast, Eastern King Prawn move through the inshore area and migrate toward spawning areas further north (Montgomery, 1990). School Prawn are highly exploited in their estuarine and inshore phase (Glaister, 1978), whereas Eastern King Prawn are primarily exploited during their offshore migratory phase (Gordon et al., 1995). The abrupt and predictable emigration of prawns through the mouth of estuaries provides a useful bottleneck in space and time to concentrate sampling of adolescent prawns moving from estuarine nurseries to join the adult and/or exploited stock. Calculating the relative contribution of different areas or habitats within the estuary to these emigrating animals provides information useful for assessing nursery habitats within the estuary (Taylor et al., 2016), but as identified above this information will be most valuable when other attributes of the species-habitat relationship are also measured.

This manuscript presents a study on the relative importance of different juvenile habitats for exploited penaeid prawns within the context of habitat repair in temperate Australia, to better understand the outcomes of previous habitat rehabilitation efforts, and to inform future rehabilitation for the benefit of these species. Specifically, this study sought to:

- Evaluate putative effective juvenile habitats for penaeid prawns across the lower and mid-sections in the Hunter River estuary;
- Evaluate the distribution of juvenile penaeid prawns within the lower Hunter River estuary, and potential drivers of this distribution;
- Qualitatively evaluate the potential impact of habitat repair in the lower Hunter River estuary for exploited penaeid prawns.

2. Materials and methods

2.1. Study area

The Hunter River estuary is a wave-dominated barrier estuary located on the mid-northern coast of New South Wales, Australia (−32.9054, 151.7749). The estuary is fed by two major river systems, the Hunter River which drains the southern catchment, and the Williams River which drains the northern catchment. Both parts of the catchment are dominated by a combination of agriculture, forest and national park. The lower estuary is heavily urbanised and includes the world's largest coal export port. Despite this, the lower estuary has abundant mangrove and saltmarsh habitats (Fig. 1), which can be divided into three main areas: 1) Tomago wetland to the north; 2) Kooragang wetland, which is nested between the north and south arms of the lower estuary; and 3) Hexham wetland in the south. In addition, the estuary includes expansive shallow embayments located off the main channel in the north arm (Fullerton Cove and Fern Bay), and these are surrounded by extensive mangrove habitat (Fig. 1). There is no seagrass present within the estuary.

The bifurcate channels in the lower estuary, and the off-channel embayments (Fullerton Cove and Fern Bay) make the Hunter River estuary a hydrologically complex system. The south arm of the estuary is heavily tidally dominated and characterised by an oceanic salinity regime. The upstream point of connection with the north arm represents a network of deltaic islands interspersed by very shallow channels, and consequently there is little influence of brackish water from the middle and upper estuary into south arm. Conversely, the north arm has a relatively contiguous channel from the mouth along the entire estuarine gradient. Consequently, there is a much greater influence of freshwater inflow from the upper estuary and a clear salinity gradient along the north arm under regular conditions (Fig. 1). The estuary supports a substantial fishery, dominated by School Prawn (Ruello, 1973), but also provides habitat for juvenile Eastern King Prawn who later recruit into the offshore trawl fishery (Ruello, 1971). There is also considerable harvest of various finfish and crab species (Taylor and Johnson, 2016), with most fishing effort (for both fish and crustaceans) concentrated in the north arm of the estuary and the off-channel embayment's.

By the latter half of the 20th century the wetland systems in the lower Hunter River estuary had become severely degraded through development, grazing, and/or the installation of dykes and floodgates that removed connectivity between wetlands and the main estuary channels. Several rehabilitation projects have been carried out on these systems in recent decades, initially targeting the Kooragang wetland (undertaken from 1990 to 1996, Williams et al., 2000), followed by Tomago (undertaken from 2007 to 2011, Rayner and Glamore, 2010), and Hexham (from 2008 to 2013, Boys, 2016). These rehabilitation projects have largely involved restoring connectivity of these marsh and mangrove habitats to the estuary, thus allowing tidal flushing of the habitats. It is important to note that the repair of these locations (especially Tomago and Hexham) is relatively recent, and the systems are still undergoing changes which may have future implications for their productivity.

2.2. Sampling design and collection

Sampling for this study was conducted over the 2013/14 and 2014/15 austral summer and autumn. Sampling in both years included collection of material for stable isotope analysis (hereafter referred to as the stable isotope study), and in the second year sampling included a quantitative assessment of juvenile prawn abundance across the lower estuary. Noting the primary focus of this study was Eastern King Prawn, the rationale was to initially undertake a broader survey examining potential nursery value across the lower and middle sections of the estuary, and then use this information to conduct a more focussed quantitative survey in areas identified as important for this species. Consequently, the results from the first year stable isotope study were used to inform the quantitative assessment of prawn abundance in the second year, and thus sampling occurred across different spatial scales in 2014/15.

2.3. Stable isotope study on emigrating prawns

Stable isotopes were used to identify from which areas and repaired habitats in the lower estuary emigrating prawns originated (as per Taylor et al., 2016). This approach involved sampling prawns from putative nursery habitat areas to characterise the stable isotope signature of those areas, and assigning the origin of prawns captured as they emigrated from the estuary among those putative nursery habitat areas on the basis of their isotopic similarity. Eighteen putative nursery habitat areas were sampled across the lower estuary in 2013/14, and a subset of 13 of these nursery habitat areas were sampled in 2014/15 (Fig. 1). Samples for stable isotope analysis were collected from these putative nursery habitat areas in the last quarter of the January lunar month in the 2013/14 and 2014/15 season using ~100 m tows with a 26B-6C sled net (1 × 0.4 m mouth, 4 m length, 26 mm diamond mesh body and 6 mm octagonal mesh cod-end). Sled samples were immediately placed on ice and then frozen for laboratory processing. In addition, Eastern King Prawn and School Prawn were collected by trawler at the mouth of the estuary as they emigrated to the sea on 3–6 nights during the last quarter of the January and March lunar months. These samples were used as a proxy for prawns joining the adult population, and thus the areas from which these emigrating prawns originated were used to assess the relative contribution of areas