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Predator driven diel variation in abundance and behaviour of fish in deep and shallow habitats of an estuary

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ABSTRACT

Our traditional understanding of the behaviour of large predatory fish and their smaller prey in estuarine ecosystems is often restricted by different gear types and visibility. In this study we determined the diel distribution and inferred movements of fish in an estuary in shallow and deep habitats (<1 m and 4 m deep respectively), using an unbaited acoustic camera (DIDSON). Baitfish (<100 mm TL) formed small and large shoals during the day in both shallow and deep habitats, compared to loose aggregations during the night or when they were inactive and not observed. Three larger size classes of fish (small, 100–300 mm Total Length (TL); medium, 301–500 mm TL and large >500 mm TL) were also more abundant during the day, likely due to general higher activity. This coincided with predatory activity with attacks by larger fish (301–500 mm and >500 mm) witnessed during the day but not at night. This heightened activity is the likely cause for changes in the schooling behaviour of the baitfish. The proportion of medium and large fish in the shallow habitat at night increased by over 50% as they moved from deeper areas of the estuary, showing the abundance of large predators in shallow water can be related to diel period. This highlights the pervasive top down influence even small numbers of predators can exert on the behaviour and distribution of estuarine fish assemblages.

1. Introduction

The interaction between predators and prey is a key ecological process influencing the distribution and behaviour of fish (Rose and Leggett, 1990; Hixon and Beets, 1993). Prey species can moderate their mortality rates by changing their behaviour, such as forming schools (Magurran and Pitcher, 1987; Rangeley and Kramer, 1998) or alter their distribution and seek areas where mortality is reduced in structurally complex habitats (Sogard and Olla, 1993). Interactions between predator and prey fish may also be mediated by a range of factors such as stressful abiotic conditions (Suthers and Gee, 1986; Menge and Sutherland, 1987; Greig et al., 2013) or changing light and turbidity of the water column (Reid et al., 1999; Wegner et al., 2013).

Many piscivorous fish use sight and visibility to locate and capture their prey and altered visibility can change the distribution and behaviour of estuarine predators and prey (Becker et al., 2013). Diel periods can result in changes in the composition of fish communities within certain estuarine habitats (Rountree and Able, 1993; Hagan and Able, 2008; Becker et al., 2011a). This has implications for the way in which we recognise both the value of particular habitats for fish and the functional role they play. Shallow littoral regions of estuaries may be important to small prey species and juveniles as larger predators are thought to be depth limited (Ruiz et al., 1993; Paterson and Whitfield, 2000). There is increasing evidence however, that predators do enter these habitats for significant portions of time (Baker and Sheaves, 2006; Becker et al., 2011a). The value of shallow areas as refuge for prey species or foraging grounds for predators may depend on light levels. Prey may be constrained to shallow waters during the day by visual predators but not at night (Clark et al., 2003), since predatory fish may enter shallow waters (Baker and Sheaves, 2006). Antipredator behaviour such as schooling may also have less importance at night if predators are less active (Ryer and Olla, 1998). Therefore the distribution and behaviour of fish within estuaries in relation to risk and diel cycles in light is poorly understood. The way we perceive habitat use and behaviour of fish, particularly predator–prey interactions, may be a function of our bias towards day time observations and shallow water sampling.

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Intermittently closed and open lakes and lagoons (ICOLLs) are common in temperate regions with high energy coastlines, low tidal ranges and intermittent rainfall (Roy et al., 2001). In particular, they are located in southern Australia, South Africa and parts of the north east Atlantic, such as Portugal (Allanson and Baird, 1999; Roy et al., 2001). Typically, the geomorphology of ICOLLs includes a deeper central basin and shallow fringing littoral habitats (Roy et al., 2001). Therefore ICOLLs are an ideal location for observations of how fish distribute themselves among shallow and deep habitats, between day and night.

Recent advances in acoustic technology, including the high resolution sonar (DIDSON) now allow scientists to observe the abundance and size distribution of fish in a range of freshwater and marine habitats (Boswell et al., 2008; Becker et al., 2011b). The ability to create up to 21 frames sec^{-1} means free flowing videos can be created and the behaviour of fish observed (Handegard et al., 2012; Becker et al., 2013). Since the DIDSON operates independent of light and bait plumes, it is a powerful tool for studying the behaviour and distribution of actively moving fish in turbid environments and at night. It is also able to collect comparable data on small and large fish, overcoming bias problems in using a traditional single gear type, or comparison difficulties when multiple gears are deployed. The species composition however, can only be inferred by video, complementary netting data (Becker et al., 2011a,b), or associated literature – as in this study.

Using the DIDSON acoustic camera, our aim was to observe the distribution of fish within unvegetated shallow littoral (>1 m) and deeper offshore (3–4 m) habitats of an ICOLL during the day and night. We expect more observations of larger fish at deep sites, especially during the day when their activity levels are higher due to a reliance on light to capture prey.

Our second aim was to observe the distribution and behaviour of prey fish in relation to depth and diel period. We expect that the abundance of small shoaling baitfish (<100 mm) will be significantly higher in shallow waters due to the protection from predation this area affords, especially during the day.

2. Methods

2.1. Study location

Smiths Lake is a large (≈10 km^2) ICOLL, located on the warm temperate, mid north coast of New South Wales, Australia (152°28′51″ E, 32°23′26″S). The lake consists of a deep central basin (≈3–4 m) with fringing shallow littoral habitats (<1 m) consisting of bare sand and seagrass beds composed of a combination of *Zostera capricorni* and *Ruppia* sp, along most of its length (Fig. 1). The mouth region contains large shallow sand flats with a few braided channels which lead to a shifting intermittently open entrance channel. Due to surrounding topography, the catchment of the estuary is small, with the main lake being fed by a number of small creeks. The mouth of Smiths Lake opened several weeks prior to deployments in 2012 and 2013 and remained open for the duration of the fieldwork.

2.2. Field deployments

Fieldwork was conducted during April 2012 and 2013. Deployments of the DIDSON were made at four sites within Smiths Lake (Fig. 1), two of these sites were located within the deep central basin (4 m deep), and two sites located within shallow littoral areas (≈1 m deep). Because no structure is present within the deep central basin, we chose unvegetated littoral habitat sites so that depth was not confounded with any form of habitat structure. During 2012, two replicate deployments were made at the four sites during the day (09:00 h–16:00 h), and again during the night (20:00 h–01:00 h). Deployments among sites was randomized and no site was sampled twice in a single day or night. In 2013 an identical sampling regime was employed, however three replicate deployments were conducted. Each deployment consisted of positioning the DIDSON and ensuring that a clear image, free of visual obstructions was captured. The DIDSON itself was attached to a small frame with the sonar orientated so it was pointed slightly

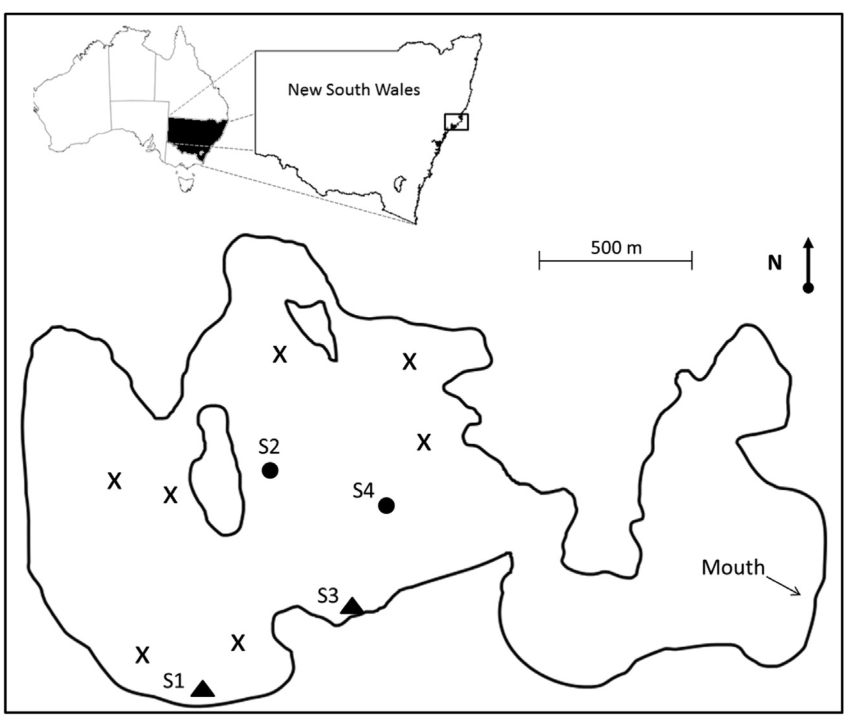

Fig. 1. Smiths Lake showing the Shallow sampling sites S1 and S3 (black triangles) and Deep sampling sites S2 and S4 (black circles). Water quality readings were taken at the seven locations marked with an X. The black box shows the location of Smiths Lake on the New South Wales coastline.