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Effects of diel period and tow duration on estuarine fauna sampled with a beam trawl over bare sediment: Consequences for designing more reliable and efficient surveys

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Abstract

The effects of diel period and tow duration (5, 10 and 20 min) on samples of estuarine fauna in a beam trawl, were tested over bare sediment in Tuggerah Lake (New South Wales, Australia). Mean catch rates (numbers of fish caught 5 min^{-1}) were significantly larger at night for the total numbers of individuals and abundant, economically important species of fish and invertebrates (e.g. *Gerres subfasciatus*, *Metapenaeus macleayi*, *Penaeus plebejus*). Greater proportions of larger fish were also caught at night for some species (e.g. *G. subfasciatus*, *Acanthopagrus australis*, *Rhabdosargus sarba*), but not across all tow durations. Multivariate analyses detected dissimilarities in the composition and structure of assemblages between diel periods, which were driven by species caught predominately, or in larger proportions, at night. Short tows (5 min) were more efficient than longer tows (10 or 20 min) for sampling the diversity of species (i.e. most species were caught in the first 5 min of a tow). There were, however, no clear or consistent patterns relating to the effect of tow duration on the catch rates of other variables, the size ranges of abundant species, or the structure and composition of assemblages. Our data confirm that at night, bare sediment is an important habitat for a wide size- and species-range of estuarine fish and invertebrates. In future, more cost-effective and reliable information concerning these taxa would be achieved by sampling with the beam trawl at night, using tow durations of 5 min. We also highlight a problem inherent in the design of many studies of diel variation of fauna (i.e. the potential non-independence of data among day and night periods) and discuss its solution.

Keywords: diurnal variations; estuaries; brackishwater fish; tow time; unvegetated habitat; south-eastern Australia

1. Introduction

Diel variation of fauna in estuarine, inshore and oceanic waters has been well documented (e.g. Ross et al., 1987; Walsh, 1988; Gray et al., 1998). Differences in patterns of distribution and abundance between day and night periods are, however, often inconsistent among taxa and habitats owing to a number of factors such as: (1) size- and species-specific variation in the behaviour of fish and invertebrates in relation to predators, competitors and prey (Burrows et al., 1994; Pillar and Barange 1997; Gibson et al., 1998; Nagelkerken et al., 2000); and (2) the type of sampling gear that is used (Olin and Malinen, 2003; Guest et al., 2003). The effects of these (and other) factors have important consequences for the accuracy and precision of samples obtained from ecological and fishery-independent surveys. Ideally, the decision to sample during the day, night, or both, should be determined a priori using properly designed experiments (Andrew and Mapstone, 1987; Underwood, 1997). Nevertheless, many studies have relied (and continue to rely) on daytime sampling, simply for pragmatic reasons (e.g. cost, safety and past practice).

In estuarine systems, many studies have used small, fine-meshed seine nets and beam trawls to examine diel variation of fish and invertebrates in seagrass beds (reviewed by Guest et al., 2003). In general, these types of gears are selective

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for small fish and crustaceans. Less is known of the effects of diel period across wider size ranges of organisms (including species of economic importance) and in other habitats within estuaries, such as bare sediment (e.g. Gray et al., 1998; Miller and Skilleter, 2006).

For towed sampling gears, such as trawls, the duration of tows is another factor that may affect the diversity, abundance and size ranges of retained fauna (Godo et al., 1990; Somerton et al., 2002); which also has implications for designing reliable and cost-effective sampling strategies. For example, reducing tow duration and increasing the number of replicate trawls may: (1) increase the precision of surveys (Pennington and Vølstad, 1991); (2) decrease the need for subsampling when catches are very large (Somerton et al., 2002); and (3) potentially reduce the mortality of sampled organisms.

Pilot experiments should be the preferred method of determining appropriate tow durations for trawling gears that are used as sampling tools (e.g. Kennelly et al., 1993). Unfortunately, for many trawl surveys, the effect of reducing the duration of tows has not been investigated until a number of years after their commencement (e.g. Godo et al., 1990; Wieland and Storr-Paulsen, 2006). In some cases, despite the benefits of using shorter, more-efficient tows, the original longer tows have been retained in order to preserve the continuity of the time series of data (Somerton et al., 2002).

Previous studies examining the effects of tow duration have mostly focussed on deep-water trawling grounds in the northern hemisphere (e.g. Godo et al., 1990). Although tow duration often has no effect on the mean sizes of fish and crustaceans, catch-per-unit-of-effort (CPUE) is generally higher for shorter tows (Godo et al., 1990; Somerton et al., 2002; Wieland and Storr-Paulsen, 2006). These results may not, however, be applicable to the fauna of other aquatic environments (e.g. estuaries); or to other types of towed gears (e.g. beam trawls).

In this experiment, we tested the hypotheses that diel period and tow duration affected catch rates, assemblages and size ranges of estuarine fauna retained in an experimental beam trawl. We then used the results of this pilot work to decide on an appropriate diel period and tow duration for future sampling with the beam trawl.

2. Materials and methods

2.1. Study area

The experiment was done in Tuggerah Lake (151°30′E; 33°21′S) in central NSW. Tuggerah Lake is a relatively large (70 km^2 surface area), shallow (average depth of about 2 m), microtidal, barrier estuary that consists of a central mud basin (Roy et al., 2001). Marine- and fluvial-delta sands are also located along the seaward and landward margins, respectively (Roy et al., 2001). Although substrates within Tuggerah Lake are predominately unvegetated and planar (Roy et al., 2001), the seagrass *Zostera capricorni* grows around the fringe of most of the shoreline and in some protected bays. The estuary also supports valuable commercial and recreational fisheries.

2.2. Design of experiment

Three sites separated by 1–5 km were selected over predominately flat, unvegetated sediment. Replicate sites were included to provide greater generality of results, as many previous studies investigating the effects of diel period have only sampled at a single site or location within an estuary (e.g. Guest et al., 2003). Sampling was done using a 3-m, stainless-steel beam trawl that was configured with 41-mm diamond-shaped mesh in the body and 20-mm mesh hung on the bar (i.e. square-shaped) in the codend.

A total of 9 days and 9 nights (3 days and 3 nights at each of 3 sites) were sampled over a 6-week period during May and June, 2006. To avoid non-independence of data (see Underwood, 1997), replicate days and nights were sampled at random, but not within the same 24-h period. Tows during the day were done between 0700 and 1300 h and at night between 1800 and 0100 h. On each sampling occasion (a day or night period), four non-overlapping replicates of each tow duration (5, 10 and 20 min), were done at a randomly selected site. The order of tows was also assigned at random.

The beam trawl was towed at speeds of about 1.2 m s^{-1} in depths of water ranging from 1.5 to 2 m. After each replicate tow was completed, the contents of the codend were emptied onto a tray and sorted by species. Collection of data included: the total numbers of individuals of each species; and the sizes of economically important finfish (fork length (FL) to the nearest 0.5 cm), crabs (carapace width to the nearest mm) and prawns (carapace length (CL) to the nearest mm).

2.3. Analyses of data

2.3.1. Univariate

A four-factor analysis of variance (ANOVA) model was used to test for differences in standardised CPUE (defined as the number of individuals captured 5 min^{-1} and analysed for numbers of individuals, numbers of species and the six most abundant species of economic importance) among sites (random factor), between diel periods (day vs. night; fixed factor), among sampling periods (random factor nested in site and diel period) and among tow durations (5, 10 and 20 min; fixed factor). We standardised data by sampling effort (i.e. numbers 5 min^{-1}) because we were interested in testing hypotheses about the efficiency (i.e. catch rates) of different tow durations, rather than about which tow duration caught the most individuals or species.

Prior to standardising CPUE for the number of species it was necessary to correct for differences in the number of individuals caught among the different tow durations. Longer tows often catch more individuals. This is a problem because the likelihood of collecting more species increases when more individuals are collected (Simberloff, 1972; Gotelli and Colwell, 2001). So, we performed rarefaction analysis (Simberloff, 1972) using PAST (Palaeontologigal Statistics; Hammer et al., 2007). Rarefaction uses the number of species collected in the sample with the largest number of individuals, to generate the expected number of species in samples with smaller numbers of individuals (Simberloff, 1972; Gotelli