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Case Study

Comparing methods used in estimating biodiversity on sandy beaches: Pitfall vs. quadrat sampling

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ABSTRACT

We compared the two most commonly used sampling methods, pitfall trapping and quadrat sieving, to study community diversity and talitrid abundance on sandy beaches. They are both widely used methods, however they are related to different behaviors: surface activity (pitfall traps) and burrowing in the substrate (quadrat sieving). To detect bias intrinsically generated by the use of different sampling methods, we applied both methods on a set of five beaches in New South Wales, Australia. The set included non-contiguous beaches, exposed and sheltered, more or less affected by recreational use. The results indicated a high fluctuation in biodiversity features. However, the most human-frequented beaches were grouped together by Multi Dimensional Scaling, and substrate-modifiers talitrid amphipods (sand-hoppers), played a major role in this scaling. The analysis of similarities (ANOSIM) indicated the roles of exposure and human recreational use in shaping the community, while the methods (quadrats vs. traps) resulted in higher fluctuation within samples than between, and informative outliers. Generalized Linear Models developed to estimate the probability of capture of talitrids by sampling method pointed to a higher probability to capture both sand-hoppers and beach-hoppers with the quadrat method. We finally suggest: (1) the comparative use of both sampling methods whenever possible, to capture multiple information and avoid bias in biodiversity estimates; and (2) an *ad-hoc* strategy when dealing with target populations. In particular, attention should be paid when targeting co-occurring talitrid species characterized by different ecology and behavioral traits: sand-hoppers (substrate modifiers) appeared to be more sensitive than beach-hoppers (non-substrate modifiers) to the impacts considered. In terms of biodiversity assessment the methods were equal, but for talitrid sampling quadrat sieving was more efficient.

1. Introduction

1.1. Sampling mobile macrofauna on sandy beaches

Sandy beaches are dynamic environments, affected by the uneven ebb and flow of material and energy (McLachlan and Brown, 2006). Sandy beach fauna inhabiting the supralittoral zone of sandy beaches has developed specific physiological adaptations in response to such fluctuating environment. Behavioral adaptations are of paramount importance to cope with environmental physical constraints (Brown, 1996). The arthropod component of a sandy beach community is affected by environmental constraints such as temperature, humidity and food availability, which determine the uneven distribution of the inhabiting fauna across the supralittoral over time and space (McLachlan and Brown, 2006, and references within). Overall, there are several behavioral characteristics shared by sandy beach macrofaunal species which include: mobility, burrowing capability, rhythmicity, orientation capability and plasticity (Schlacher et al., 2008, and references within). As a general pattern, the feeding activity occurs during the night while, during the day, the fauna is buried in the substrate or sheltering under the wrack (Colombini et al., 2013). This rhythmicity, combined with potential in mobility, reduces the risks of predation and dehydration, both of which are higher during the day. The resultant periodic fluctuations and consequent patchiness are a challenge for those who aim at reducing bias when sampling, for both biodiversity and environmental quality assessments. On top of natural fluctuations, disturbances drive the system to a shift in ecological

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conditions (Glasby and Underwood, 1996; Schmitt and Osenberg, 1996) and, as an immediate consequence, sandy beaches resident fauna is likely to change its behavioral or life-history traits before the extreme consequence, i.e. species loss (Scapini, 2014). Disturbances can be natural or anthropogenic–continuous (press) and punctual (pulses) (Osenberg and Schmitt, 1996). The occurrence of pulse disturbances can be periodical. In this case, the synchrony between the disturbance, its impact and the developmental stages of the resident biota can lead to remarkably different effects for sandy beach fauna (Ottaviano and Scapini, 2010). Human recreation on sandy beaches is an usually time-limited disturbance with seasonal periodicity (Swarbrooke and Horner, 2007), and its impacts beyond the direct trampling can be linked to activities such as litter increase or wrack removal on the supralittoral (Defeo et al., 2009).

Sampling on sandy beaches should take into account faunal ecology on one hand, and the impacts of disturbance on the other hand, to achieve sound and reliable results. Sampling has to be planned in terms of timing and approach: randomized or systematic/supralittoral considered as a surface or as a linear unit. However, the likelihood of different macrofaunal mobility and activities which are sources of variability in their occurrence over the day should be taken into account. This aspect is strictly related to the sampling method, as further detailed in the next paragraph.

The two main methods to collect mobile arthropod fauna are to date: (a) pitfall trapping, capable of collecting individuals during their active periods (Naylor and Kennedy, 2003); (b) corer/quadrat sampling and subsequent sieving, capable of collecting individuals buried in the substrate (Schlacher et al., 2008). These methods are widely used, and the outcomes are the background for population and biodiversity studies from the local to the macro scale (Schlacher et al., 2008). Literature targeting best estimates of biodiversity measures in terms of area sampled is available (Jaramillo et al., 1995; Schoeman et al., 2008; Schooler et al., 2014), and provided relevant information regarding suitable extrapolation methods to reduce the bias in observed species richness estimated by quadrat sieving. Mantzouki et al. (2012) compared instead the area and pitfalls methods by applying them to salt marshes populations of the talitrid *Orchestia gammarellus*, pointing out comparable power of the methods for abundance and differences in the accuracy of population cohort estimates. In this case, methods were compared in relation to a target species, while both pitfalls and quadrat sampling are suitable to provide data at community level. Our study intends to provide information about the comparison of the two methods and their suitability in providing data related to sandy beach arthropod community and target species within.

Although each method has its own strengths and weaknesses related to area of capture, efficiency and possible damage to the specimens, they can both be applied in a systematic or randomized sampling approach, depending on the width and surface of the supralittoral area under study, and on the assumption of the minimal spatial unit to be sampled (Schlacher et al., 2008). Beaches with different substrate characteristics might not offer the choice of a sampling method (e.g. sieving cannot be applied to a pebble beach). However, sampling strategy has to be carefully considered when dealing with sandy beach communities, due to their movements in space and time. The most proper sampling strategy will limit eventual bias due to different behavior of different species, and allow the achievement of reliable estimation of biodiversity and/or monitoring of key species.

1.2. Talitrids and arthropod fauna as targets for impact studies

Among sandy beach macrofauna, talitrids are keystone species according to Mills et al. (1993), i.e., their removal from the ecosystem is expected to permanently change the community functionality.

Therefore, talitrid abundance, diversity and behavior were proposed as bioindicators of sandy beach quality, and to assess the effect of different impacts from tourism to urbanization, beach erosion and construction of solid structures (Wesławski et al., 2000; Fanini et al., 2005; Veloso et al., 2008; Defeo et al., 2009; Barca-Bravo et al., 2010). Behavior was moreover found to be finely tuned to the characteristics of the environment at a local level (Fanini et al., 2009a, 2012).

However, Bousfield (1982) proposed an ecological repartition of talitrids between sand-hoppers, or substrate modifiers, as they burrow in the sand, and beach-hoppers, or non-substrate modifiers, as they shelter in stranded wrack. At night, they are both expected to move across the supralittoral to forage on fresh wrack (Jaramillo et al., 2003; Colombini et al., 2013; Bessa et al., 2014a, 2014b). Different zonations, related to different habitats features, were recorded when sand-hoppers and beach-hoppers were found in sympatry (Pavesi et al., 2007; Gambineri et al., 2008; Lastra et al., 2010; Colombini et al., 2013). Such an allocated use of the supralittoral habitat might lead not only to different zonation, but also to different sensitiveness to impacts of these two ecological categories. In the case of co-occurrence of both sand-hoppers and beach-hoppers, the consideration of 'talitrids' as a general category might thus generate a bias in the study outputs. The two categories could be used instead as a set of multiple indicators (*sensu* Dale and Beyeler, 2001), as they are linked to different niches on sandy shores.

Impact assessment approaches also deal with biodiversity. In the case of the beach-dune ecosystem, arthropod biodiversity has been used as an indicator to measure medium and long-term effects (Chapin et al., 1998), due to the primary role of these animals on sandy beaches and to their strict link with their home range, which subjects them to symptomatic variations in case of alterations of the environment (Chapin et al., 2000; Colombini et al., 2003 for sandy beaches). Biodiversity on sandy beaches was found to be non-independent of beach morphotype: dissipative and less exposed beaches are more benign and host a higher number of species (Defeo and McLachlan, 2005) than reflective beaches. On the other hand, measures of biodiversity are commonly accepted indicators which are effectively communicated to managers and stakeholders–even if this is mainly in terms of biodiversity loss. To estimate biodiversity, species numbers and other biodiversity measures, such as Shannon Wiener H' diversity and Pielou J' evenness, have commonly been used (Peet, 1974; Pimm et al., 1995).

Finally, to assess the quality of a beach-dune system, as well as its resilience, the multiple indicators approach is likely to be the most appropriate (Noss, 1990). The analysis of a target taxon (e.g. talitrids, taking into account their ecological categories) and the broader biodiversity (e.g. arthropod fauna diversity), if considered together, are more informative than either of the two, taken separately. They can be sampled together and subsequently analyzed as multiple indicators, enhancing the strength of the study and the likelihood to detect impacts affecting different ecological compartments or acting at different organization levels. Manuals and guidelines targeting beach managers and stakeholders (e.g. Salas et al., 2006; McLachlan et al., 2013) provide a suite of indexes based on biodiversity and on suitable taxa, to be selected consistently to the goal of the study. There is however no suggestion related to the sampling method(s), which is case-sensitive too.

In this study we compared sampling strategies in the supralittoral by using pitfall traps and quadrat sieving on a set of five beaches in New South Wales (NSW), Australia. We selected beaches subject to different rates of natural exposure and human recreational use. This choice was made to highlight eventual differences between the sensitiveness of the two sampling methods to different conditions–in our case related to beach exposure and human trampling–to which the beach-dune ecosystem may be subject.