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# Establishing precise estimates of abundance in patchy habitats of the marine nearshore

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ABSTRACT

Exploratory investigations of optimal sampling designs are a critical component of the decision-making process in ecology where inherent natural variation can lead to erroneous conclusions if left unexamined. Pilot studies and exploratory analyses that investigate the precision of sampling regimes may reduce the chances of erroneous results and can be used to optimise processing time in larger ecological research programs. In our study, we calculated optimal precision estimates for sampling macroinvertebrates and ichthyofauna in surf-zone wrack accumulations by investigating the precision of the mean for sub-samples of seine nets and also for the number of replicate seine nets to guide future sampling regimes. We discovered that the processing time for individual seine net samples could be reduced by 50% using sub-sampling and that time to process replicate seine net samples could be reduced by 25% while maintaining acceptable precision. In future, we suggest that the use of pilot studies with similar exploratory approaches should be less of an exception and more a critical component of ecological investigations, particularly in under-studied or newly-developing areas of research. Further, these types of exploratory approaches are crucially important in a variety of extremely patchy environments where variability is likely to be high.



## 1. Introduction

Habitat patchiness is encountered in many terrestrial and aquatic ecosystems (Fahrig, 2003; Fischer and Lindenmayer, 2007), often a result of habitat fragmentation due to human modification, biological invasions and natural climatic events. This inherent patchiness creates a number of challenges for ecologists who wish to investigate such habitats and the associated fauna, depending on the extent of patchiness within a habitat. Firstly, patchy habitats tend to have inherent habitat heterogeneity that is made up of a mosaic of multiple microhabitats (Robson and Chester, 1999). Different microhabitats within a patch may attract different faunal assemblages as has been observed in a variety of ecosystems including terrestrial invertebrates in grasslands (Reid and Hochuli, 2007), invertebrates in freshwater streams (Effenberger et al., 2008), and beetles in rainforest canopies (Wardhaugh et al., 2013). The most challenging problem for ecologists is the combined heterogeneity of habitat patches and the associated fauna, particularly when they wish to investigate larger-scale processes at an ecosystem level. This heterogeneity can only be captured by increasing the intensity of sampling. For most ecological sampling programs, it is widely accepted that an increase in the number of replicate samples usually results in, up to a point, lower standard error and improved sampling precision (Andrew and Mapstone, 1987; Bros and Cowell, 1987). Ideally, in any ecosystem studied, large numbers of habitat patches should be sampled to gain the most precise dataset for habitat structure and the associated fauna but, in reality, this is usually impractical. The majority of research programs are limited by time, resources and funding which constrain the associated sampling efforts, thus an optimal sampling design should fit within such limitations but also be extensive enough to satisfy sampling precision requirements.

The basis of field ecological studies is an attempt to capture the natural variability in organism abundances at various spatial and temporal scales. Often, large field-based sampling programs can quickly consume allocated time and resources whenever species diversities and abundances are extremely variable. Sampling programs targeting such assemblages often involve sub-sampling

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whole samples so that some reliable estimate of assemblages can be obtained within the time and resources available (Sebastien et al., 1988). Sub-sampling is a useful way to reduce the time required for laboratory processing of samples but the associated potential for lower sampling precision must be considered and evaluated explicitly. Andrew and Mapstone (1987) highlighted some of the pitfalls associated with sampling for organism abundances using different sample sizes and emphasized the need for pilot studies in order to gain the most precise but also practical estimates from sample data. The pitfalls include the potential inability of small sampling units to obtain a reasonable indication of relative abundances at larger scales and the chance of increased observer fatigue and decreased precision with very large sampling units (Downing, 1989; Riddle, 1989; Andrew and Mapstone, 1987). Both problems can lead to the over-estimation of species with large abundances and under-estimation of rarer ones (Andrew and Mapstone, 1987). During the 1980s, multiple researchers (e.g. Pihl and Rosenberg, 1982; Andrew and Mapstone, 1987; Downing, 1989; Riddle, 1989) highlighted the need for more forethought to identify optimal sampling designs (e.g. by using pilot studies) and that the use of precision estimates can aid in the decision-making process. More specifically, complacency in sampling design without pre-planned exploration of levels of variability is risky and increases the chances of encountering Type II errors (where no effect is detected due to lack of statistical power when in fact it should be; Fairweather, 1991, Mapstone, 1995, Zuur et al., 2010). Fairweather (1991, p. 559) highlighted the potential dangers of ignoring statistical power without pre-planned pilot studies, which can “lead to false and dangerous complacency”, particularly where environmental impacts are being investigated. The outcome of this complacency is limited conclusive evidence of ecological relationships and thus a reduced the ability to detect environmental effects, which is not only a drain on time and resources but may ultimately lead to significant environmental harm (Fairweather, 1991).

In patchy habitats, such as those where organism abundances range from completely absent from some patches through scarce to very abundant in others, pilot studies should be an integral part of the process of sampling design. Pre-planning in this way is essential to define a manageable number of whole replicates and sub-sample sizes that will yield appropriate estimates of the population and reduce the chance of making Type II errors. One of the more extreme examples of a patchy habitat in both time and space is the accumulation of detached and drifting macrophytes (commonly referred to as ‘wrack’) found in the nearshore zone of sandy beaches usually after large storms or swells (Lenanton et al., 1982). Compared to more permanent habitats such as living kelp forests or seagrass meadows, drifting wrack accumulations constantly change structure in space and time, particularly in surf zones where there is constant water movement (e.g. due to wave action, tides and storms). Studies that have investigated wrack arrival into the surf zone highlight the role that such macrophytes play as an important habitat role for fish and macroinvertebrates long after detachment from the seafloor (Robertson and Lenanton, 1984; Crawley and Hyndes, 2007). Yet, compared to studies of attached macrophytes living *in situ* and the habitat function that they provide for fish and macroinvertebrates, the research effort placed on understanding the role of drifting wrack as a habitat in the nearshore zone has been small (e.g. van der Merwe and McLachlan, 1987; Marin Jarrin and Shanks, 2011; Crawley et al., 2006). This may be partly due to the extreme patchiness and temporary nature of wrack accumulations in the nearshore zone which makes it difficult to sample efficiently.

In the few previous studies that have investigated wrack accumulations as habitat in the nearshore zone, seine nets were the preferred method for sampling of fish and macrophyte components (Robertson and Lenanton, 1984; Crawley et al., 2006). A benefit of using seine nets is that they enable a large sample of the wrack material to be captured so that an entire drifting habitat patch can be processed for macrophyte volumes, fish abundances and macroinvertebrate abundances. The shortcomings of sampling entire wrack accumulations include that they are mobile and continuous habitats that vary considerably in volume, and very large volumes often cannot be efficiently processed in the laboratory. Therefore, decisions should be made to sub-sample for macrophytes and macroinvertebrates in order to gain precise estimates of relative abundances and distributions, so that sampling effort can be reduced without reducing the ability to answer the intended hypothesised ecological questions.

The aim of this study was to use a sequence of steps (Fig. 1) to establish precision estimates of seine-net replication for fish abundances and sub-sample sizes of macroinvertebrate abundances and macrophyte volumes from whole seine net samples. Exploration of the data in this way would provide a baseline of the optimal number of seine net replicates and associated sub-sample sizes required for future studies of wrack and associated fauna in beach surf zones. Also, our study highlights the general importance of exploring preliminary data when the decision to sub-sample is made for any proposed research in other patchy habitats.

## 2. Materials and procedures

### 2.1. Study area

Field surveys were conducted at each of five randomly-selected sandy-beach sites along the metropolitan Adelaide coastline in Gulf St Vincent, South Australia from August to September 2011 (Fig. 2). All of the sites sampled are classified as intermediate beaches (Short, 2001) and form part of a 28-km long sandy-beach system that has been highly modified and disconnected over time by the construction of jetties, seawalls, groynes, breakwaters and marinas (Short, 2012). Gulf St Vincent has large sub-tidal seagrass meadows that are the dominant form of macrophyte (primarily *Posidonia* spp. but also *Amphibolis* spp. and *Heterozostera tasmanica*, among others) compared to macroalgae (Edyvane, 1999, 2008), which is proportionally reflected in the wrack that is regularly washed ashore (Duong, 2008). Along this coastline, wrack does also include other items that occasionally wash ashore including Porifera, bryozoans, dead animal fragments and anthropogenic litter.

### 2.2. Field surveys

At all sites, sampling was conducted in the surf zone on a sandy bottom with living seagrass meadows at least 30 m away. Wrack accumulations were opportunistically sampled and were identified as clearly defined patches within the surf zone of sandy beaches. Sampling consisted of eight replicate seine-net hauls per site as the maximum number that could be achieved within one sampling day, which were taken to capture whole wrack accumulations and associated fish and macroinvertebrates. However, sorting of macrophytes and macroinvertebrates is much more time consuming, hence the need to sub-sample these two components in this study. A seine net (10 m long, 2 m depth, central 0.5 m bellow, with 4 mm mesh size) was deployed in the surf zone and dragged through wrack accumulations. Each net haul was emptied out onto a tarpaulin laid out on the beach to ensure that the entire wrack accumulation could be searched for fish. All fish were collected from the entire sample and placed in 10-L buckets of aerated seawater before handling for species identification and measurement of standard lengths. Some fish that had lost equilibrium were euthanized with AQUI-S before being preserved in 10% buffered