Estuarine, Coastal and Shelf Science 94 (2011) 164–171

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Influence of habitat structure and nature of substratum on limpet recruitment: Conservation implications for endangered species

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ARTICLE INFO

Article history:
Received 20 December 2010
Accepted 19 June 2011
Available online 24 June 2011

Keywords:
limpets
Patella ferruginea
recruitment
habitat structure

ABSTRACT

Habitat complexity has been recognised to exert a significant influence on the abundance and diversity of benthic invertebrates. This issue is especially important for the management of endangered species. The recruitment of limpet species was monitored monthly for one year on natural and artificial surfaces. Control plots showed the highest mean number of species and individuals settled per plot, followed by rough then smooth plots. Control plots presented the highest mean diversity values followed by rough and smooth plots. Recruits of the endangered limpet *Patella ferruginea* were mainly observed during the spring, from April to June. Recruitment seemed to be influenced by both the heterogeneity and nature of the substratum. *P. ferruginea* repopulation programmes involving the translocation of recruits on experimental plates should be conducted using similar materials to the natural substratum, such as granite or limestone, rather than plastic, avoiding surfaces with low levels of heterogeneity, and taking into account that translocation of adults is not feasible due to the high mortality observed.

1. Introduction

Although it has been discussed in detail, there is little consistency in the definition and measurement of habitat structure (Beck, 1998). Habitat structure is composed of two major factors: complexity and heterogeneity. Complexity encompasses variation in habitat structure attributable to the absolute abundance of individual structural components (pools, crevices or pits) and has been referred to by many terms (e.g. topographic complexity, rugosity, substratum heterogeneity), whereas heterogeneity encompasses the variation in habitat structure attributable to variation in the relative abundance of different structural components (Beck, 1998, 2000). Habitat structure generated by surface irregularities such as pits, crevices, grooves and other projections has been recognised to exert a significant influence on the abundance and diversity of benthic invertebrates (Dudley and D'Antonio, 1991; Douglas and Lake, 1994; Downes et al., 1995; Taniguchi and Tokeshi, 2004). In fact, more highly structured habitats contain more species than simpler ones, a pattern that has been documented in terrestrial, freshwater and marine environments and for both vertebrate and invertebrate species (Bell et al., 1991). The mechanism that works directly on species richness itself is niche diversification, such that a greater diversity of niches in complex and heterogeneous habitats allows resource partitioning and therefore coexistence (e.g. Schoener, 1974). Although much information can be found regarding the influence of habitat structure on the density and distribution of gastropods (see Underwood and Chapman, 1989; Chapman, 1994; Chapman and Underwood, 1994; Beck, 1998, 2000), there is a lack of knowledge about the influence of habitat structure and the nature of the substratum on limpet settlement, with the exception of findings reported by Underwood (2004) on *Cellana tramoserica* and *Patelloida latistrigata*. Recruitment is a key potential determinant of population structure and dynamics and therefore the relative influence of habitat structure and the nature of the substratum on recruitment is of great interest from a conservation perspective. Such information is valuable for endangered species such as *Patella ferruginea*, which is considered as being "at risk of extinction" (Guerra-García et al., 2004; Espinosa et al., 2006, 2009; Moreno and Arroyo, 2008). Here we explore whether habitat structure determines limpet recruitment using artificial substrata with different degrees of complexity and heterogeneity. Moreover, we compare recruitment in terms of the number and structure of assemblages on these artificial substrata with those recorded on natural substrata. An additional objective was to examine the possibility of transplantation of the endangered Mediterranean species *P. ferruginea* using artificial surfaces.

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doi:10.1016/j.ecss.2011.06.005

Table 1
Factors controlling limpet's recruitment on the shore.

	Explanatory models	Hypothesis
(1)	Habitat structure is the most important factor irrespective of the type of substrate.	Treatments with high substrate structure will receive a greater amount of recruits.
(2)	Nature of substrate is the most important factor irrespective of the habitat structure.	The recruits received will be always greater in a type of substrate and no differences will be found between treatments with the same substrate.
(3)	Both factors are influencing.	Differences will be found between levels of habitat structure but also between types of substrates.

2. Materials and methods

2.1. Experimental design

In order to record limpet recruitment in the rocky intertidal zone, the settlement of recruits of different limpet species on experimental surfaces was monitored monthly for a year from January to December 2007. Three treatments were considered: control (natural substrata present in the study area), rough (plates with different sized pits) and smooth (plates without pits) (note the different explanatory models in Table 1). It is important to note that we explored the influence of habitat structure as the sum of both complexity and heterogeneity, according to Beck (2000), but that the relative weight of each factor was beyond the scope of the present work. The size of each study surface was 30 × 40 cm (see Beck, 2000, as used in gastropods). Settlement plates have been widely used in ecological studies in order to characterize and quantify the settlement and recruitment of benthic organisms (Mundy and Babcock, 2000; Thomason et al., 2002; Glassom et al., 2004; Perkol-Finkel and Benayahu, 2007). For control treatments, rock surfaces were cleared using a hammer and chisel and further burned with a propane gas torch to eliminate encrusting, endolithic and epilithic algae and macrofauna (Bulleri, 2005) and thus match the initial conditions of the artificial plates. The tendency for many species to recruit less abundantly onto the newest substrata may be attributable to qualitative and/or quantitative differences in microfouling films, which have been widely documented to be important in promoting the settlement and metamorphosis of a variety of invertebrate larvae (Brancato and Woollacott, 1982; Kirchman et al., 1982; Maki et al., 1988). Each control plot was marked in two diagonally opposite corners by drilling small holes (Underwood, 2004). Rough and smooth surfaces were made of PMMA (Poly-methyl-methacrylate) plates, similar to other plots used in related experiments (see Beck, 2000), and mounted flush with the surrounding rock using stainless steel screws that were countersunk into the plates and screwed into the rock. The slope of all plots was in the range 30–60° to avoid confusing results derived from different slopes. Ten replicates of each treatment were established systematically following Murray et al. (2002) (see Fig. 1) to ensure the independence of errors and avoid 'pseudoreplication' in the midlittoral zone (0.75–1 m above zero tidal level). The plates were designed to have levels of habitat structure similar to those found in rocky intertidal habitats following a method adapted from Beck (2000) (Fig. 2), using profile gauges to obtain rock profiles (Frost et al., 2005). These profiles, with a maximum length of 13 cm, were later used to calculate the topography of the substrata using fractal dimensions (Mandelbrot, 1967). This methodology consists of consecutive recalculations of the total perimeter (P) of each rock profile using progressively smaller steps (λ). The total profile perimeter (L) can be expressed as: $L = (\lambda \times$ number of steps taken) + (any remaining distance smaller than the λ taken: rest) (Fig. 3). A total of 10 profiles were taken for each plot as this number maintains 95% confidence intervals when estimating the fractal dimension (D) on rocky shores (Frost et al., 2005). The removal of intruder limpets from both control and experimental plates was undertaken monthly in order to avoid confusion with new recruits in subsequent sampling periods. Although the specimens were not tagged because of their small size, it was possible to identify them

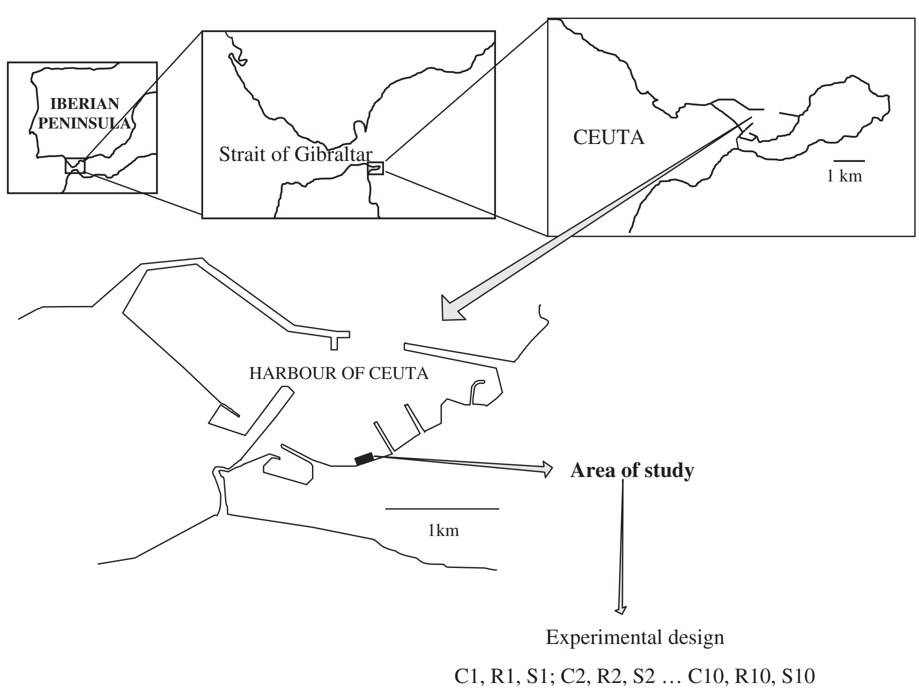

Fig. 1. Map of the study site showing the experimental design. The systematic distribution of replicates is shown. C: control; R: rough; S: smooth. Numbers refer to the different replicates.