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Shallow rocky nursery habitat for fish: Spatial variability of juvenile fishes among this poorly protected essential habitat

Adrien Cheminée *,[1], Mary Rider, Philippe Lenfant, Audrey Zawadzki, Alexandre Mercière, Romain Crec'hriou, Manon Mercader, Gilles Saragoni, Reda Neveu, Quentin Ternon, Jérémy Pastor

Université de Perpignan Via Domitia, Centre de Formation et de Recherche sur les Environnements Méditerranéens, UMR 5110 Perpignan, France
CNRS, Centre de Formation et de Recherche sur les Environnements Méditerranéens, UMR 5110 Perpignan, France

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ABSTRACT

Coastal nursery habitats are essential for the renewal of adult fish populations. We quantified the availability of a coastal nursery habitat (shallow heterogeneous rocky bottoms) and the spatial variability of its juvenile fish populations along 250 km of the Catalan coastline (France and Spain). Nurseries were present in 27% of the coastline, but only 2% of them benefited from strict protection status. For nine taxa characteristic of this habitat, total juvenile densities varied significantly between nursery sites along the coastline, with the highest densities being found on the northern sites. Recruitment level (i.e. a proxy of nursery value) was not explained by protection level, but it was moderately and positively correlated with an anthropization index. Patterns of spatial variations were taxa-specific. Exceptional observations of four juveniles of the protected grouper *Epinephelus marginatus* were recorded. Our data on habitat availability and recruitment levels provides important informations which help to focus MPA management efforts.

1. Introduction

Due to an ever growing global population and a general migration to coastal areas, oceans and seas are experiencing an unprecedented variety and magnitude of anthropogenic pressures. The Mediterranean, a semi-enclosed basin surrounded by inhabited land, is particularly susceptible to the effects of human induced pressures (Coll et al., 2010). This translates into a greater use of resources and increased modification of natural habitats, just to name a couple of the many consequences. In this context, coastal areas represent great stakes: they contain habitats essential for species life cycles as well as concentrating a maximum of anthropogenic disturbances.

Many coastal fish have a complex life cycle composed of a pelagic and a benthic stage. For many Mediterranean necto-benthic coastal species, eggs are released into the water column and generally hatch after two days, producing larvae that develop in pelagic waters for more than a month before migrating towards the shore (Di Franco et al., 2013). At the shore, post-larvae undergo "settlement", i.e. the transition from the pelagic larval habitat and establishment to the benthic juvenile habitat. Among juvenile habitats, nursery habitats are the one(s) that, for a particular species, have a greater "nursery value", i.e. contributes a greater than average number of individuals to the adult population on a per-unit-area basis in comparison to other habitats. The "nursery value" of a habitat results from a combination of four parameters: (1) the initial density of juveniles ("settlers"), (2) their survival rate, (3) their growth rate within these habitats and (4) their ability to move from the juvenile habitat and recruit into the adult habitat at the end of the post-settlement phase (Beck et al., 2001). The settlement period and juvenile nursery habitat can vary depending on the species to avoid inter-specific as well as intra-specific competition (Harmelin-Vivien et al., 1995).

In the Mediterranean, various Sparidae species of commercial and ecological importance use nurseries characterized as shallow coastal areas comprised of a heterogeneous rocky and sandy substrate (Garcia-Rubies and Macpherson, 1995; Harmelin-Vivien et al., 1995). In the case of *Diplodus* species, after about 4 to 6 months, when the juveniles have reached about 6 to 8 cm of total length (TL), the recruitment stage occurs. The now sub-adults ("recruits") leave the nursery habitat and disperse into the different and/or more diverse adult habitat(s) where they are integrated into shoals of older individuals (MacPherson, 1998; Vigliola and Harmelin-Vivien, 2001). The number of juveniles remaining in a nursery area before recruitment, at a given time, can be used to assess the nursery settlement success and final recruitment "level" (Macpherson and Zika, 1999), as a proxy of its nursery value, and can be compared between sites.

The alteration or transformation (let alone destruction) of a nursery habitat directly affects the life cycle of many species of fish by reducing

* Corresponding author at: Université de Perpignan Via Domitia, Centre de Formation et de Recherche sur les Environnements Méditerranéens, UMR 5110, 52 Avenue Paul Alduy, 66000 Perpignan, France.
E-mail address: adrien.cheminee@septentrion-env.com (A. Cheminée).
[1] Septentrion Environnement, Traverse Paul, Port des Goudes, 13008 Marseille, France.

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its nursery value, and ultimately is detrimental to conservation efforts (Cheminée et al., 2016; Harmelin-Vivien et al., 1995). Because nursery habitats are essential in the life cycle of fish and the renewal of adult populations, protecting them should be a priority. Nevertheless, data on nursery habitat localization and site nursery value are often missing, preventing coastal managers from efficiently focusing their conservation efforts (Cheminée et al., 2014).

We studied one type of Mediterranean nursery habitat for fish, consisting of shallow (0 to 2 m depth) heterogeneous rocky bottoms made of blocks, pebbles and sand. We aimed to assess at a large spatial scale (>200 km long stretch of coastline) (1) the availability of this key habitat, (2) the spatial variation of juvenile fish population descriptors among this habitat (i.e. between sites displaying this given habitat) and (3) their response to anthropization and protection levels. The overall goal was to better understand nursery habitat efficiency and provide key data and proposals to coastal managers.

2. Materials and methods

2.1. Study sites and sampling strategy

The sampled area spans 238.3 km of Mediterranean coastline from Leucate, France (FR) to Roses, Spain (ES). First, nursery sites were identified using aerial images and confirmed in situ (in a subset of sites) during surveying. Nurseries are defined as portions of the coast displaying suitable habitat according to the following criteria: protected from strong swell, shallow (0–2 m depth), gently sloping heterogeneous bottoms of mixed substratum composed of blocks, pebbles and sand

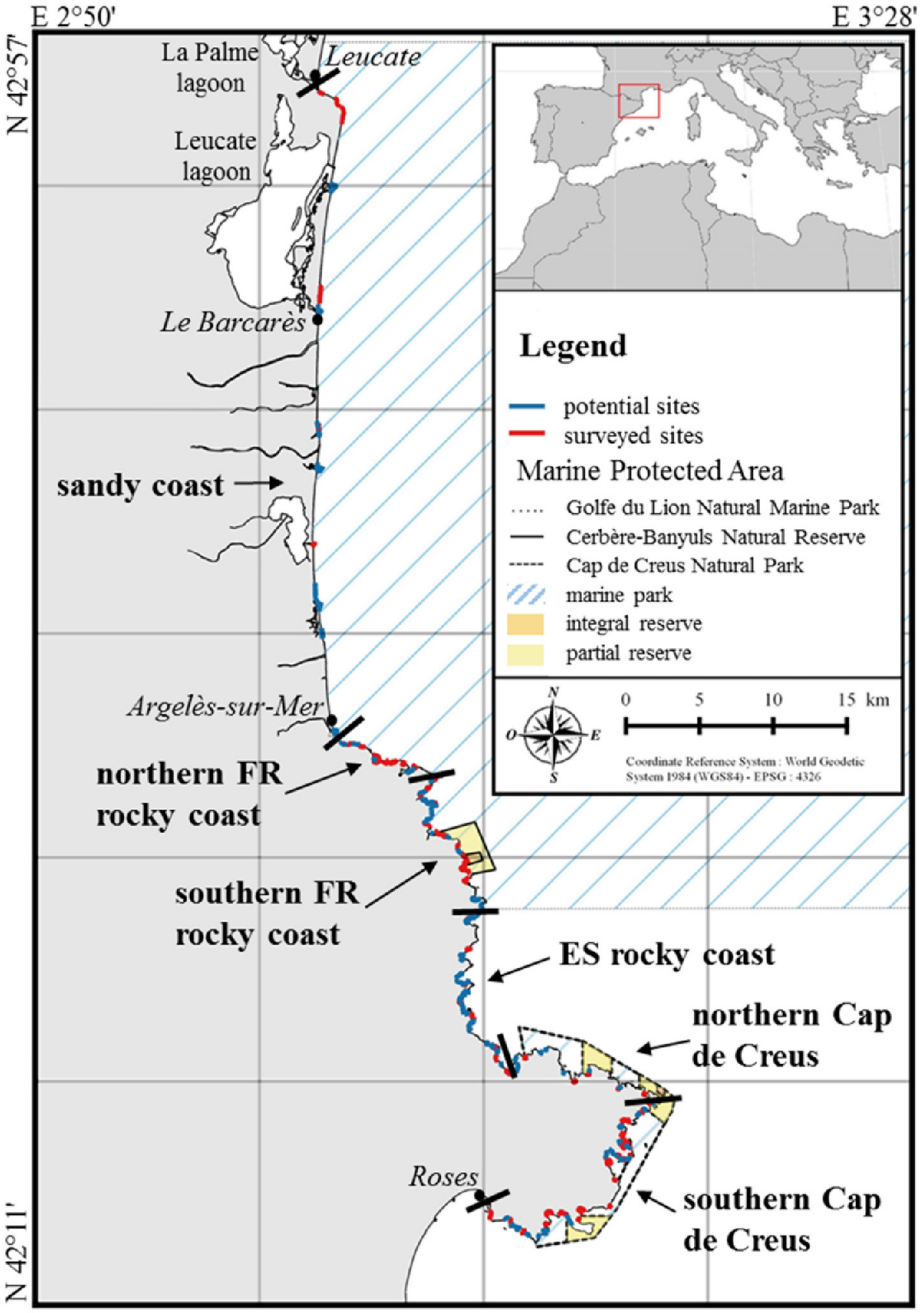

Fig. 1. Study area and all nursery sites that were identified along the coastline (red and blue stretches). Presented data comes from surveyed sites (in red). Other non-surveyed nurseries are indicated (in blue). Coastline was divided into 6 sectors for analysis (black arrows). Protection levels (Marine Protected Area zones) are identified (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

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