Biological Conservation 219 (2018) 89–95

Contents lists available at ScienceDirect

Biological Conservation

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

Short communication

Promoting restoration of fish communities using artificial habitats in coastal marinas

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ARTICLE INFO

Keywords:
Marina
Biohut
Ecological restoration
Grouper
Marchica lagoon
Mediterranean

ABSTRACT

Rapid urbanization has become an area of crucial concern in conservation, owing to urban infrastructure impacts on natural ecosystems. Urban infrastructures are often poor surrogates for natural habitats, and a diversity of eco-engineering approaches has been trialed to enhance their ecological value.

Marinas are among the most common human-made infrastructures found on the shoreline, and cause substantial habitat destruction within the sheltered coastal areas previously used as nursery grounds by many fish species. The present study aimed at testing the suitability of installing artificial habitats (Biohut®) in marinas to reinforce the nursery function of the Marchica coastal lagoon, which historically hosts many species of juvenile groupers, including the endangered dusky grouper *Epinephelus marginatus*.

Our hypothesis – that artificial habitats, by increasing habitat complexity, enhance the ecological value of a marina – was strongly supported by our results. The Biohuts hosted a high relative density of juvenile dusky and comb groupers in comparison with natural habitats. They can, therefore, be considered as a reservoir for juvenile groupers, including the endangered dusky grouper, and are suitable to reinforce the nursery function of this coastal lagoon.

Subsequently, Biohuts can act as a ready-made nursery area to support the creation of small marine reserves that can reinforce the grouper population re-colonization along the coast of North Africa, which is considered to be the region from which the individuals populating the north western Mediterranean originated, and thus provide for long-term recovery of the endangered dusky grouper.

1. Introduction

Coastal regions are home to a large and growing proportion of the world's population. Over 70% of the world's largest cities are located within 100 km of the coast (Duarte et al. 2008). Of the many human activities presently contributing to habitat loss and species extinctions, urbanization is generally considered to have one of the greatest impacts across local to regional scales (Lotze et al. 2006; Grimm et al. 2008). Along urbanized coastlines, marine infrastructure is increasingly being constructed for a range of purposes, including coastal protection (e.g. seawalls, breakwaters, groynes), boating or recreational activities (e.g. marinas, piers, pontoons), supply of energy or resources (e.g. oil, gas platforms) and enhancement of fisheries yield (e.g. artificial reefs) (Strain et al. 2018). As a result, marine infrastructure impacts significantly on natural ecosystems in a variety of ways, including habitat loss and fragmentation, modification of ecological connectivity, ecosystem functioning and services, and the physico-chemical environment (Fischer and Lindenmayer 2007; McKinney 2008; LaPoint et al. 2015; Bishop et al. 2017).

Ecological restoration aims to return a system to a functional approximation of its pre-degraded state. One intent is "to establish a functional ecosystem of a designated type that contains sufficient biodiversity to continue its maturation by natural processes and to evolve over longer time spans in response to changing environmental conditions" (Clewell et al. 2000). Among many approaches, eco-engineering – the inclusion of ecological principles in the design of infrastructure to enhance its ecological value (Bergen et al. 2001) – can benefit terrestrial and marine environments alike (Chapman and Underwood 2011;

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https://doi.org/10.1016/j.biocon.2018.01.013
Received 15 February 2017; Received in revised form 3 January 2018; Accepted 12 January 2018

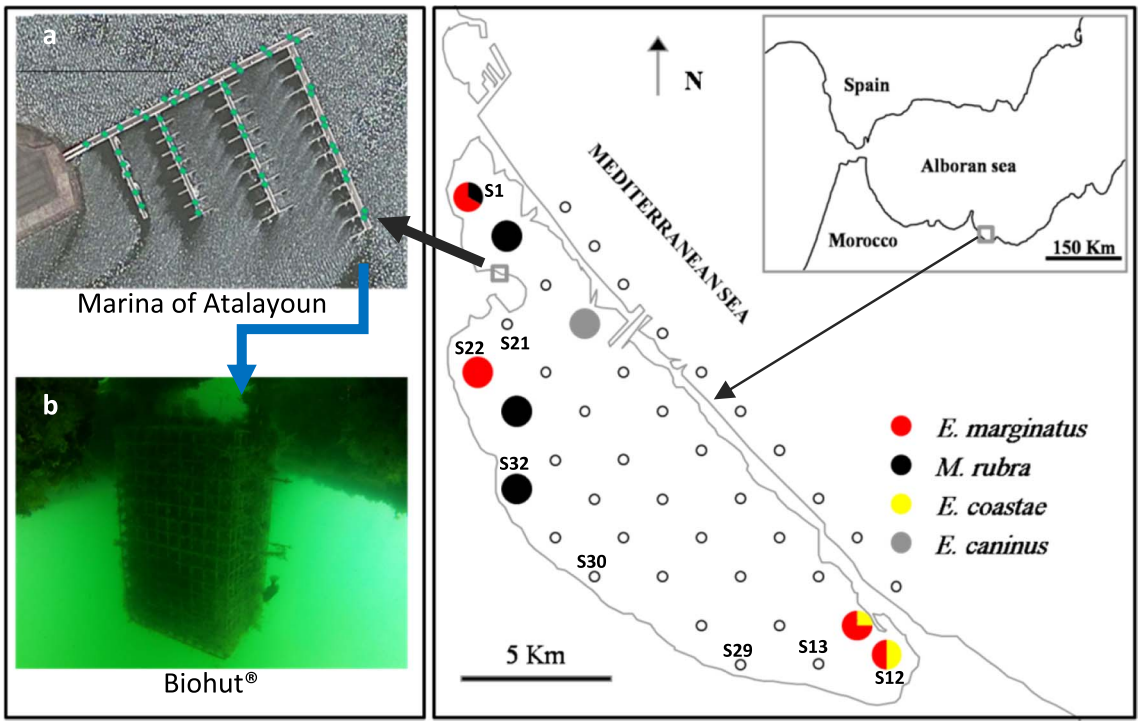

Fig. 1. Map showing the network of experimental fishing stations and the Biohuts installations. (a) Marina of Atalayoun; underwater visual counting area. (b) Pontoon on a Biohut cage fixed under a floating pontoon.

Francis and Lorimer 2011). In this context, as artificial structures are often poor surrogates for natural habitats, a diversity of eco-engineering approaches has been trialed to enhance their biodiversity, with varying success (Strain et al. 2018).

Marinas are among the most common human-made marine infrastructures, and can cause substantial habitat destruction within sheltered coastal areas previously used as nursery grounds by many fish species (Bouchoucha et al. 2016). Therefore, the need to reduce the impact of these infrastructures and even to enhance their ecological value is becoming urgent as their number is predicted to increase worldwide. Recently, the deployment of artificial microhabitats (Biohuts) (Fig. 1a) in marinas and ports (Bouchoucha et al. 2016; Mercader et al. 2017) as an ecological restoration action aiming at restoring the nursery function through habitat complexification, revealed that such artificial habitats enhance the diversity and density of juvenile fish by providing shelter from predators, thereby boosting the marina's and/or port's nursery value.

Nearshore ecosystems, such as coastal lagoons, are areas of high productivity (Duarte and Chiscano 1999) that support a range of natural services and functions highly valued by society (Gönenç and Wolflin 2005), including their role as nurseries. The present study aimed at testing, for the first time, the suitability of installing artificial habitats in marinas to reinforce the nursery function of a coastal lagoon. The study site is the Marchica Lagoon, which is unique in the Mediterranean for historically hosting many species of groupers, including the endangered dusky grouper (Lozano Cabo 1953; Aloncle 1961; Pérez-Ruzafa et al. 2007). The choice of the Marchica lagoon is supported by the fact that (1) it's the only lagoon on the Mediterranean coast of Morocco and (2) artificial habitats (Biohuts) were recently installed into a Marina built inside the lagoon. We hypothesized that increasing habitat complexity in the marina would enhance the diversity (Browne and Chapman 2011, 2014) and population density of juvenile groupers by providing shelter from predators (Bulleri and Chapman 2010), thereby boosting the lagoon's nursery value (Beck et al. 2001) and promoting its role in conservation of endangered groupers.

2. Materials and methods

2.1. Study site

The Marchica lagoon, also called the lagoon of Nador, is the second largest (115 km^2, 25 km long and 7.5 km wide) lagoon in northern Africa and the only coastal lagoon on the Mediterranean coast of Morocco (Fig. 1). The lagoon has a maximum depth of approximately 8 m and is separated from the Mediterranean Sea by a 25 km long sandbar. This sandbar is crossed by one artificial opening (300 m wide and 6 m deep) that ensures the renewal of water.

In addition to its ecological (Site of Biological and Ecological Interest since 1996; Ramsar Site since 2005) and socio-economic value (mainly artisanal fisheries), the lagoon is under pressure from a complex mixture of human-mediated stressors (increasing urbanization through multiple tourism projects around the lagoon, pollution by local uncontrolled fecal water effluents, urban discharges, sewage from a water treatment station, and slaughterhouse residues, etc.) (Ruiz et al. 2006).

2.2. Key features of groupers

Groupers (Pisces: Serranidae, subfamily Epinephelinae) are important top level predators both in temperate and tropical waters, where they play an important role in maintaining the ecological balance of marine ecosystems (Goeden 1982; Parrish 1987). Eleven species are known in the Mediterranean and belong mainly to the *Epinephelus* and *Mycteropera* genera. Most groupers are protogynous hermaphrodites. Individuals typically begin their reproductive life as females but change to males with age. Sex reversal seems to occur when individuals are 9–16 years old and about 60–90 cm long (total length) (Bruslé and Bruslé 1975, 1976; Chauvet 1988; Bruslé 1995). Large individuals are exclusively male and can measure up to 120 cm long and weigh up to