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Response of a seagrass fish assemblage to improved wastewater treatment

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ABSTRACT

We compared the structure of a seagrass fish assemblage near a sewage outlet before and after improvements to wastewater treatment. To determine whether responses by the fish assemblage were due to changes in water quality or to other factors, comparisons were made with the structure of a fish assemblage from a nearby site unaffected by sewage effluent. Total species richness, density and biomass of fish, decreased at both sites over the 30-year period. An increase in mean trophic level near the sewage outlet following improvements in water quality indicated that wastewater treatment had another important effect. This result is consistent with the reductions in food webs supporting pelagic and benthic fishes that typically accompany decreases in nutrient inputs. Although improvements to wastewater treatment explained much of the variation in the structure of the fish assemblage at PC, our results also suggest that fishing and climate change, at both sites.

1. Introduction

Seagrass meadows are sensitive ecosystems under pressure from developments in the coastal zone (Duarte, 2002; Boudouresque et al., 2009; Waycott et al., 2009). Increased nutrients and particulate organic matter in sewage effluent from growing coastal populations is a problem of particular significance (Reish and Bellan, 1995; Airoldi and Beck, 2007; Stamou and Kamizoulis, 2009). The effects of such wastewater on soft-bottom and rocky reef ecosystems have been reported widely (Grigg, 1994; Otway et al., 1996; Hall et al., 1997; Smith et al., 1999; Reopanichkul et al., 2009), including from locations in the Mediterranean Sea (Guidetti et al., 2002, 2003; Azzurro et al., 2010). Typically, sewage pollution results in decreased biodiversity close to the point source (Reish and Bellan, 1995; Smith et al., 1999) and an increase in pelagic zooplanktivorous and omnivorous fishes as the effluent disperses (Hall et al., 1997; Guidetti et al., 2003).

Many countries have introduced improved treatment of wastewater to reduce the visual and ecological impacts of sewage effluent. However, relatively few studies have examined the changes in coastal fauna following installation of improved wastewater treatment systems (but see Bellan et al., 1999; Soltan et al., 2001; Perez et al., 2005; Ribeiro et al., 2008; Ourgaud et al., 2013). This study was conducted near Marseille, the second largest city in France. The population of Marseille and its urban conurbation, which now exceeds 1,800,000, produces 10,500 m^3 of sewage effluent per hour. This wastewater is discharged directly into Cortiou cove on the rocky coast to the east of the city (Fig. 1). The sewage outlet at Marseille is close to extensive areas of *Posidonia oceanica* seagrass habitat. This seagrass species grows to depths of 30–40 m in clear water and forms extensive meadows (Harmelin and True, 1964; Boudouresque et al., 1990, 2009, 2012; Pergent et al., 2012). These meadows support a high diversity of fish and invertebrates, and play important ecological, sedimentary and economic roles in the coastal zone of the Mediterranean Sea (Kikuchi and Pérès, 1973; Den Hartog, 1977; Kikuchi, 1980; Boudouresque and Meinesz, 1982; Harmelin-Vivien, 1983; Pollard, 1984; Pergent-Martini et al., 1994; Francour, 1997; Procaccini et al., 2003; Boudouresque, 2004; Personnic et al., 2014) and the species composition, trophic structure, diel migrations and seasonality of fish assemblages associated with *P. oceanica* are well known (Bell and Harmelin-Vivien, 1982, 1983; Deudero et al., 2008; Francour, 1997; Guidetti, 2000; Harmelin-Vivien, 1982, 1983; Harmelin-Vivien et al., 2000a; Kalogirou et al., 2010; Moranta et al., 2006; Seytre and Francour, 2013).

Until 1987, the wastewater from the sewage outlet at Marseille was untreated and included industrial and domestic effluents

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(Bellan et al., 1999). A primary treatment plant was then installed, which removed >70% of the organic matter (OM) and contaminants (Arfi et al., 2000). Since 2008, the wastewater from Marseille has received additional biological (tertiary) treatment which retains >90% of the dissolved and particulate organic matter. However, currently no fourth treatment, said "finishing" treatment is established to retain all metallic and organic contaminants. Here, we report changes to the fish assemblage associated with a *P. oceanica* seagrass meadow near the sewage outlet at Marseille following improvements to the wastewater treatment plant, and evaluate the extent to which these changes were due to better water quality.

2. Materials and methods

2.1. General approach

To assess the effects of improvements in water quality on the species richness, density, biomass and trophic structure of the fish assemblage associated with the *P. oceanica* seagrass habitat at Marseille, we used a 'before vs after, control vs impact' (BACI) sampling design. This design provided the opportunity to identify the relative importance of the effects due to improvements in wastewater treatment, and any other factors that may have altered over time, on the fish assemblage near the sewage outlet. The BACI sampling design involved comparing (1) the key features of the fish assemblage in the site near the sewage outlet ("Plateau des Chèvres") before wastewater was treated (1980) with key features of the assemblage four years after the commencement of tertiary treatment (2012); and (2) the key features of the fish assemblage near the sewage outlet with those of a 'control' assemblage from a seagrass meadow in an area unaffected by sewage effluent ("Côte Bleue") in 1980 and 2012. A better sampling design would have included comparisons with a seagrass meadow that remained under the influence of untreated sewage but no such site existed. The results of a fish survey at Plateau des Chèvres in 2000 have also been included to provide insight into the possible effects of primary wastewater treatment on the fish assemblage near the sewage outlet, albeit without the benefit of a comparison with a control site.

2.2. Study area

The two *P. oceanica* seagrass sites used for this study were located in the Bay of Marseille (Fig. 1). The site impacted by wastewater was at Plateau des Chèvres (PC) close to the sewage outlet at Cortiou in the south of the bay. The fish assemblage at PC was directly exposed to nutrient-rich wastewater (Arfi et al., 2000; Bellan, 1970; Bellan et al., 1980). The control seagrass meadow was at Côte Bleue (CB) in the north of the bay.

2.3. Sampling method

The fish assemblages were sampled with a small (1.5 × 0.5 m) beam trawl, with a stretched mesh size of 8 mm, purpose-built to catch fish from the *P. oceanica* seagrass ecosystem (Harmelin-Vivien, 1981). Fish were collected during the day and at night because of the diel differences that occur in activity rhythms, feeding behaviour and position in the water column for fishes associated with *P. oceanica* seagrass meadows (Harmelin-Vivien, 1982) (Fig. 2). At PC, sampling consisted of four trawls of 15 min duration during the day and the night in summer 1980 (Bell and Harmelin-Vivien, 1982) and five trawls of 10 min duration during the day and the night in winter. In 2000 and 2012, five trawls of 10 min duration were made during the day and the night in both summer and winter at PC. The trawls were made between depths of 8 and 18 m at a constant towing speed of 1.5 knots. The combined surface area covered by four 15-min trawls at PC in summer was ~4200 m^2 in 1980, whereas the combined surface area covered by five 10-min trawls at all other times was ~3500 m^2. The sampling at CB in summer and winter 1980 followed the same protocol used at PC. The sampling at CB in 2012 was also based on five 10-min trawls during the day and night in summer and winter. The catch from each trawl was separated into fish species, the number of each species was counted and the total length of each individual fish was

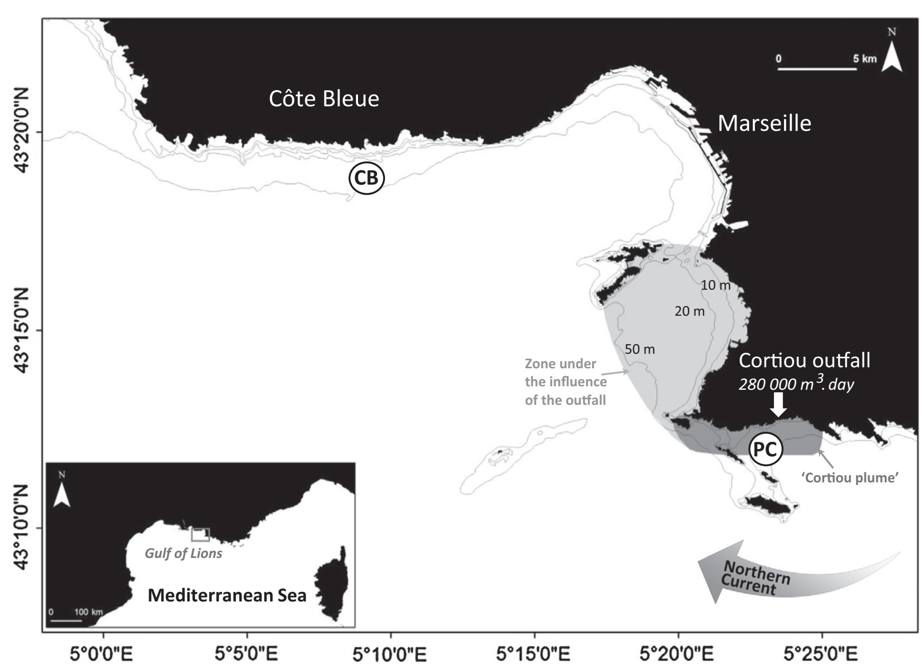

Fig. 1. Location of study sites and Cortiou area (in grey = zone under the influence of the sewage outfall (after Fraysse et al., 2013).

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