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Diel activity and variability in habitat use of white sea bream in a temperate marine protected area

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ABSTRACT

Fish populations are often comprised of individuals that use habitats and associated resources in different ways. We placed sonic transmitters in, and tracked movements of, white sea bream (*Diplodus sargus sargus*) in the no-take zone of a Mediterranean marine protected area: the Torre Guaceto marine protected area, (Adriatic Sea, Italy). Tagged fish displayed three types of diel activity patterns in three different habitats: sand, rocky reefs and "matte" of the seagrass *Posidonia oceanica*. Individuals were more active during the day than at night. Overall, white sea bream displayed a remarkable behavioural plasticity in habitat use. Our results indicate that the observed behavioural plasticity in the marine protected area could be the result of multiple ecological and environmental drivers such as size, sex and increased intra-specific competition. Our findings support the view that habitat diversity helps support high densities of fishes.

1. Introduction

The distributions and movements of marine fishes are strongly influenced by density dependent processes and by the availability of shelter, food and spawning grounds (Dickson et al., 2005; Kuefler and Haddad, 2006). In turn, the mobility of a fish species can influence the degree of connectivity among habitats types (Kaunda-Arara and Rose, 2004; Dorenbosch et al., 2007; Vega Fernández et al., 2008). Thus, connectivity among habitats is affected by overfishing and severe habitat degradation (Palumbi, 2004; Worm et al., 2006), which can greatly drive down populations (Starr et al., 2007).

An understanding of habitat uses and daily activities of adult fish is crucial for conserving fish populations (Holland et al., 1996). Habitat uses and diel activity patterns vary greatly among species (Chapman and Kramer, 2000), and also at a population level within a species. Intra-specific variation in habitat use of fish has been attributed mostly to ontogenetic shifts (Nagelkerken et al., 2000; Huijbers et al., 2008; Afonso and Hazin, 2015). Some studies have shown that movements of individuals can vary within a population (Egli and Babcock, 2004; Hammerschlag-Peyer and Layman, 2010) and that spatial partitioning can occur, within groups of individuals using different habitats (Morbey et al., 2006; Kobler et al., 2009; Koeck et al., 2013). Also, some studies have reported the existence of substantial plasticity in fish movements with respect to habitat use and daily activity (Roughgarden, 1972; Reebs, 2002; Hammerschlag-Peyer and Layman, 2010; Bolnick et al., 2003; Koeck et al., 2013), supporting the hypothesis that some species described as generalists could actually be composed of a heterogeneous array of specialists (West, 1988; Bolnick et al., 2002; Loury et al., 2015). As a consequence, the identification of habitat relationships among groups of individuals can help support spatial

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conservation measures such as marine protected areas (MPAs; Starr et al., 2007) and fishery management strategies (Smith et al., 2001; Bolnick et al., 2003).

The white sea bream *Diplodus sargus sargus* (Linneaus 1758) is widely distributed in shallow waters (0–50 m depth) of the Eastern Atlantic, Mediterranean and Black Seas (Whitehead et al., 1986). The white sea bream is omnivorous (Stergiou and Karpouzi, 2002; La Mesa et al., 2010) and mostly associated with rocky bottoms and, to a lesser extent, seagrass beds (Bini, 1968; Tortonese, 1975). The species plays a key ecological role in rocky reef habitats by controlling the grazing pressure exerted by sea urchins on macroalgal assemblages (Sala et al., 1998; Guidetti, 2006), and, when in large densities, preventing a shift from macroalgal forests to urchin barrens (Sala et al., 1998; Guidetti, 2006). The white sea bream feeds during the day on natural reefs (Abecasis et al., 2009, 2013; Koeck et al., 2013) but feeds at night when occupying artificial reefs installed on sandy bottoms (D'Anna et al., 2011; Koeck et al., 2013). The species is also an important target of both recreational and commercial fisheries (Lloret et al., 2008). Although the white sea bream can display high site fidelity (Di Lorenzo et al., 2014), it is highly mobile and can travel tens of km in a few weeks or months during both juvenile and adult phases (D'Anna et al., 2004; Abecasis et al., 2009; Di Franco et al., 2012; Koeck et al., 2013).

The white sea bream is regularly observed at higher densities and sizes inside MPAs when compared with rocky reefs open to fishing outside the MPA (Guidetti, 2006; Guidetti and Sala, 2007; Guidetti et al., 2008; Di Franco et al., 2013). The Torre Guaceto MPA (located along the Apulian Adriatic coast, SE Italy) is one of the most successful Mediterranean MPAs in terms of fish biomass recovery (Sala et al., 2012; Guidetti et al., 2014). The Torre Guaceto MPA contains a variety of habitat types (Fraschetti et al., 2005) and the white sea bream is abundant on rocky, sandy and *Posidonia oceanica* seagrass habitats within the MPA (Guidetti et al., 2006; Bussotti and Guidetti, 2011). The goals of our study were to describe the patterns of habitat use and the diel activity of white sea bream population inside the Torre Guaceto MPA.

2. Materials and methods

2.1. Study area

This study was carried out in the larger of two no-take zones (NTZ) of the 2212.77 ha Torre Guaceto MPA (SW Adriatic Sea; Fig. 1). The MPA was established in 1991 but existed without any enforcement and management body until 2001. The larger NTZ covers about 138.60 ha and is contiguous with a partial (buffer) reserve ('Zone B') that covers 161.04 ha. The smaller NTZ contains 46.00 ha. The NTZs and buffer zone are surrounded by a 1867.13 ha general reserve that allows some fishing ('Zone C', Fig. 1). In Zone C, both commercial and recreational fishing are allowed, but only under authorization of the MPA management body and are subject to stringent restrictions.

The largest NTZ includes six main habitat types (Fig. 2): rock (hard bottom with erect photophilic macroalgae covering ~30% of NTZ); barren grounds (hard bottom covered by ~10% encrusting coralline algae); *P. oceanica* bed (patches of the seagrass *P. oceanica* covering ~8% of NTZ); *P. oceanica* "dead matte" (a persistent structure made of intermingled rhizomes and sediment trapped within them that covers ~26% of the NTZ); sand (sand patches with variable percentages of mud covering ~24% of the NTZ); and *Cymodocea nodosa* bed (a single patch of the seagrass C. nodosa; covering ~2% of the NTZ) (Fraschetti et al., 2005). The NTZ stretches from the shoreline to the depth of about 12 m.

2.2. Tagging and tracking

We surgically implanted acoustic transmitters in 20 white sea breams, ranging in length between 24.5 and 30 cm total length (TL) (Table 1). The minimum size of fish tagged was determined by the size of the acoustic tags, based on the suggestion by Winter (1996) that the ratio of tag weight to fish weight should not exceed 2% (see Table 1).

White sea bream do not exhibit sexual dimorphism, thus we were not able to record the sex of the tagged fish. Individuals were captured from 15 February to 15 March 2011 using longline fishing gear that was always deployed in the center of the NTZ at a depth of about 5 m. Once a fish was caught, we removed the hook and when necessary, degassed the swim bladder with a hypodermic needle (Thoreau and Baras, 1996). Fish were later anaesthetized with 0.2 ml/l 2-phenoxy-ethanol solution and placed in a V-shaped berth where a miniaturized transmitter (VEMCO mod. V9-2L-A69-1303; nominal delay time 60 s, range 30–90 s) was surgically inserted into the peritoneal cavity of each fish according to the methodology suggested by Thoreau and Baras (1996). A small incision (1 cm) was made on the ventral body wall of the fish between the pelvic fins and the anus and a transmitter was placed into the peritoneal cavity. After the tag was inserted, we closed the wound by placing one stitch in the center of the incision using a non-absorbable filament (braided silk). Tagged fishes were initially held in a tank filled with aerated seawater in order to aid in recovery from anesthesia and released about 1.5 h after being caught. Individuals were identified by the unique code that was transmitted by each tag. After monitoring tagged fish to ascertain that they were in good conditions, fish were released at one location within the NTZ.

An array of 13 omnidirectional receivers (VEMCO VR2) was deployed between 5 and 12 m depth from 14 February to 27 July 2011. Receivers were anchored to the seafloor with 60 kg concrete blocks and suspended with floats in the middle of the water column. Receivers were located approximately 250 m apart from each other to cover the entire study area. Range testing of the tags and receivers was conducted according to methods proposed by Giacalone et al. (2005) to ensure that the detection ranges of adjacent receivers were overlapping (Fig. 1). The receivers were kept in the area for the entire study period: from 14 February to 27 July 2011, a total of 161 days. Data collected during the first week were excluded from analyses to avoid recording possible alterations of the behavior of the tagged fish due to handling (Giacalone et al., 2005).

We estimated the positions of tagged fish by using the mean-position algorithm technique first proposed by Simpfendorfer et al. (2002). This algorithm is based on the detections recorded by multiple overlapping receivers and delivers the geographical coordinates of the center of activity (COA) of tagged fish. The COA provides the geometric center of the area used by a fish in a predefined time interval (20 min in our case). FiSAR, a custom-made software developed by Giacalone et al. (2006), was used to obtain the geographical coordinates of the COA. The 20 min time interval was chosen in order to increase the accuracy of the COA estimates for each fish when using transmitters with a nominal delay of approx. 1 min and a 250 m receiver grid (Giacalone et al., 2005). The percentage of positions detected for each individual in any given habitat type was used as a proxy for use of space. Diel activity was assessed from COAs (Reebs, 2002 and references therein). For analytical purposes, we divided diel activity into three phases of the day (see data analysis section). COAs resulting from signals recorded by just 1 receiver station, i.e. when fishes moved close to the zone B/C boundary, were excluded from the analysis. To increase the accuracy of location estimates at the boundaries of NTZ, we only