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Fish functional traits are affected by hydrodynamics at small spatial scale

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ABSTRACT

The Mediterranean damselfish *Chromis chromis* is a species with a broad distribution found both in the Mediterranean Sea and Eastern Atlantic as far south as the coast of Angola. We hypothesized that the species may have significant functional morphological plasticity to adapt along a gradient of environmental conditions. It is a non-migratory zooplanktivorous species and spends the daytime searching for food in the middle of the water column. Therefore, local hydrodynamics could be one of the environmental factors affecting traits of *C. chromis* with repercussions at the population level. We compared the body condition, individual growth and body shapes of damselfish collected under two different hydrodynamic conditions (low ~10 cm s^{-1} vs. high ~20 cm s^{-1}). Specimens showed higher body condition under high-hydrodynamics, where conditions offered greater amounts of food, which were able to support larger individuals. Individuals smaller than 60-mm were more abundant under low-hydrodynamics. Morphometric analysis revealed that high-hydrodynamics were favored by fish with a more fusiform body shape and body traits developed for propellant swimming.

1. Introduction

Hydrodynamics affects many ecological aspects of aquatic habitats, such as seagrass landscapes (Robbins and Bell, 2000; Gaylord et al., 2002), larvae dispersal (Eckman, 1990; Crimaldi et al., 2002) and plankton distribution (George and Edwards, 1976). Hydrodynamics can make the availability of food unpredictably variable in abundance and patchily distributed challenging the ability of secondary consumers to get sufficient food to permit the overtime persistence of local populations (Frechette et al., 1989; Beaulieu, 2003; Sarà, 2006). However, high hydrodynamics can increase the prey encounter rate (Rothschild and Osborn, 1988; Gabel et al., 2008) and provide ephemeral patches of increased food availability although at some point, the conditions become too high-energy and make feeding functional traits such as food searching and manipulation more difficult. Thus, hydrodynamics can modify the fish activity costs due to swimming performance requirements through the impairment of feeding behaviors (Stoll and Fisher, 2010). The search for food in particular is an important functional trait (Shoener, 1986; Sarà et al., 2014) whose effects have rebounds in terms of the energy budget of any fish. The amount of energy spent for searching is usually paid on food through a major quota of energy spent for food searching due to environmental changing conditions affecting *in ultimis* somatic maintenance and fish life history traits such as growth and reproduction (*sensu* Kooijman, 2010). To live under unpredictable changing environmental conditions, fish have to optimize the energetic ratio between income and costs; a phenotypic response to hydrodynamic variability may be a solution (Sfakiotakis et al., 1999; Lauder and Drucker, 2004) as when fish adapt their body shape to the hydrodynamics of sites in which they live (Cakic et al., 2002). Santos et al. (2011) found morphological divergences at the intraspecific level between individuals living in river channels and lagoons. Under quicker currents (i.e. river), individuals are more fusiform, reflecting a functional (behavioral and morphological) plasticity (Cunico and Agostinho, 2006; Pulcini et al., 2008; Borazjani and Sotiropoulos, 2010). Thus, it is reasonable to assume that broadly-distributed species living under changing environments can adapt some traits (i.e. have phenotypic plasticity;

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sensu Rosenweig and Lomolino, 1997; Lefebvre et al., 1997) by which they are able to live along a gradient of different environmental conditions (Losos et al., 2004). Here, we used a classical morphometric analysis (Cheverud et al., 1983) to test whether two different hydrodynamics conditions elicited different expressions in functional trait patterns in a zooplanktivorous model fish, *Chromis chromis*. (Actinopterygii: Perciformes: Pomacentridae; Fasola et al., 1997; Guidetti, 2000), at small spatial scale (few kms).

Damselfish is an useful model for this purpose as it is a strictly territorial non-migratory species (the home range is thought to be only few hundreds of meters from where they build their nests; Picciulin et al., 2004) that abundantly inhabits Mediterranean subtidal habitats from few meters to more than 35 m (Aguzzi et al., 2013). It reproduces in summer up early autumn in Southern Mediterranean, diurnally relies on zooplankton, spends most daytime for food searching at the middle column (Pinnegar et al., 2007; Bracciali et al., 2012, 2014). As most zooplanktivorous fish, *C. chromis* has limited energetic reserves and need to feed continuously (Boddeke, 1963; Charnov et al., 1976) during both larval/juvenile (Macpherson and Raventos, 2005) and adult (Dulcic and Kraljevic, 1995) stages. Thus, local oceanographic conditions affecting food availability may emerge as primary factors indirectly influencing life history of this species (Macpherson and Raventos, 2005). Here, we hypothesized that hydrodynamics at small spatial scale (at the scale of km) plays a role of effector in determining both individual growth (via food encountering-energetic costs ratio) and body shape – by affecting swimming performance and water column position in our Mediterranean damselfish.

2. Materials and methods

2.1. Study area and a-priori oceanographic contextualization

The study was conducted in the Egadi Marine Protected Area, on the Island of Marettimo (Egadi Archipelago, western Sicily) in two areas with different hydrodynamic conditions located less than 5.0 km from one another (Fig. 1). Cammello Bay on the north coast was a sheltered site exposed to the north-east and characterized by a gently sloping bottom and a maximum depth of 20 m. In contrast, Punta Basana was situated on the southern coast, where study site is exposed to the main current of the open sea Sicilian Strait, and characterized by a steeply sloped bottom and a maximum depth of 40 m. The hypothesis of different hydrodynamics was generated from the observation made at the beginning of 2007 that two sites had different water current velocities when a Valeport current meter was kept in situ in both sites for four days in three occasions (January, March and June 2007). This field dataset was later used to validate seasonal hydrodynamics patterns as downloaded from MyOcean daily database (http://marine.copernicus.eu). Field observed and satellite derived hydrodynamics data were highly confident and two sites resulted to have water current velocity on average 10.1 ± 4.9 cm s^{-1} and 17.2 ± 5.2 cm s^{-1}, respectively in Cammello Bay (hereafter LOW-HYDRO) and Punta Basana (hereafter HIGH-HYDRO) (Table 1). Contextually, to test the hypothesis that different hydrodynamics would have been able to generate different trophic conditions affecting functional and life history traits in damselfish, experimental trophic conditions were set by measuring some water column variables. Water samples were collected through a Niskin bottle at middle water column (~10 m) to measure suspended chlorophyll-a, total (TSM), inorganic (ISM) and organic matter (POM). Once brought back to the laboratory, water samples were filtered on Whatman GF-F 0.45 μm fiberglass filters and stored at −20 °C. POM was estimated by ignition loss and chlorophyll-a through the classical acetone extractive method, according to details reported in many companion studies (e.g. Sarà et al., 1999, 2003; 2011). Unfortunately, we did not collect zooplankton at the time of this study, and then the chosen water column variables indirectly described the amount of suspended food available for zooplanktivorous species as damselfish. Thus, we did some assumptions to support our experimental hypothesis, as follows (i) chlorophyll-*a* concentration, a proxy of the phytoplankton biomass, can be in turn used as a proxy of trophic substrates for zooplankton (e.g. ciliates; Stromberg et al., 2009) and (ii) some zooplankton species, such as cladocerans and copepods being the main feeding resource to *C. chromis*, have similar fatty acids

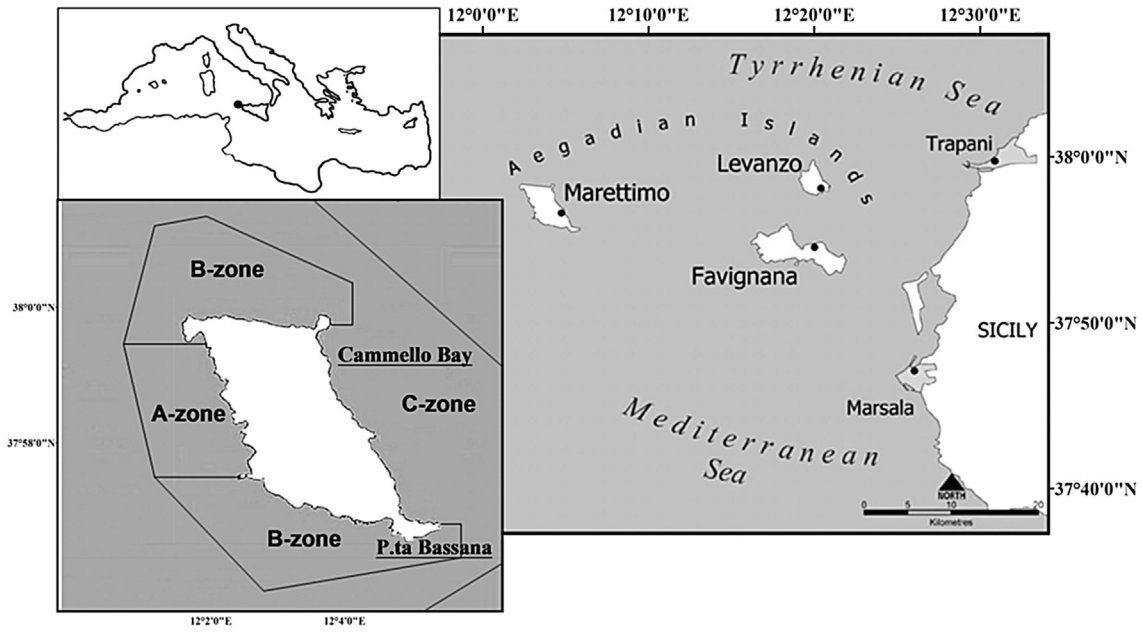

Fig. 1. Location of the Island of Marettimo. The map shows the position of the LOW-HYDRO site of Cammello Bay and the HIGH-HYDRO site of Punta Bassana.