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Trophic relationships, feeding habits and seasonal dietary changes in an intertidal rockpool fish assemblage in the Gulf of Cadiz (NE Atlantic)

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ABSTRACT

This paper describes the use of resources and diet of nine resident fish species in the rocky intertidal zone of the Gulf of Cadiz and examines whether their populations are affected by trophic competition. A stomach content analysis of the nine species revealed that only one was herbivorous (*Parablennius sanguinolentus*), while the rest were mainly carnivorous (*Gobius bucchichi*, *Gobius cobitis*, *Gobius paganellus*, *Zebrus zebrus*, *Salaria pavo*, *Lepadogaster lepadogaster*, *Scorpaena porcus* and *Tripterygion tripteronotum*). The most frequently consumed prey were amphipods, isopods, polychaetes, decapods, chironomids, tanaidaceans, gastropods, copepods, cumaceans and ostracods. In most species, the occurrence of polychaetes and molluscs was higher in the cold season, whereas that of isopods, decapods, chironomids and fish increased in the warm season. In general, larger specimens consumed larger prey, with an increase in the occurrence of isopods, decapods and fish. An analysis of trophic niche breadth defined *G. cobitis* as generalist, *G. bucchichi* as opportunist and *S. porcus* as specialist, whereas the values obtained for the other species did not indicate a clearly defined strategy. Low diet overlap values and the segregation observed in several analyses indicated an adequate distribution of resources.

1. Introduction

Rocky intertidal ecosystems are highly productive (Leigh et al., 1987), especially in comparison with adjacent subtidal zones (Elliott and Dewailly, 1995). This abundance provides valuable feeding grounds for juvenile fish (Able et al., 1990; Costa and Elliott, 1991; Haedrich, 1983) visiting the area during high tide (Kanou et al., 2005; Morrison et al., 2002; Mumby et al., 2004; Nagelkerken and van der Velde, 2002; Pihl and Wennhage, 2002; Vinagre et al., 2006; Weerts and Cyrus, 2002). The diversity of this zone is in part conditioned by the capacity of species to optimise use of all the resources it offers, avoiding competition. Diet analyses of fish species in a community yield information on the latter's spatial and temporal structure (Green, 1979). Based on a determination and quantification of the diet of resident species, and analyses of dietary variation according to size and time of year, it is possible to define resource use and assess intra- and interspecific interactions that indicate whether there is evidence of competition. This not only facilitates the design of future restoration projects but also contributes to an understanding of the general functions of the ecosystem (Odum et al., 1995). Dietary composition essentially depends on the eating habits of each species and the availability of prey, but may also be the result of the season and feeding zones (Gibson, 1968, 1970, 1972; Zander and Hagemann, 1989; Zander and Heymer, 1992). The study area was located in a zone that is highly productive due to the dynamics of the coastal current in the Gulf of Cadiz (Ruiz and García-Lafuente, 2006); depending on the intensity and direction of winds, it is simultaneously affected by the processes occurring in the northern part (periodic fluvial discharges from the Guadiana, Tinto-Odiel and Guadalquivir rivers) and water exchange in the Strait of Gibraltar. This modifies the physicochemical and biological patterns in the zone, affecting salinity, sea surface temperature, amount of organic matter, turbidity and chlorophyll, etc.

The aim of this study was to (1) obtain information about the diet of the best represented species in the zone, in order to (2) gain further insight into the dietary habits and trophic relationships of the rocky intertidal fish assemblage in the Gulf of Cadiz.

2. Material and methods

Fish were collected monthly from April 2008 to March 2011 in a rocky intertidal zone in the Gulf of Cadiz, specifically at Caños de Meca (Fig. 1, MC: 36° 11′ N–6° 01′ W). Fish were caught during the daytime low spring tide, using natural clove essential oil as an anaesthetic at a concentration of 40 $mg*L^{-1}$ (García-Gómez et al., 2002; Griffiths, 2000). 83 intertidal pools were sampled and 2378 fish were caught. This work shows that diet is best represented in resident species (Table 1) that appear in at least 25% pools and represent 70.7% of total

Abbreviations: *Gbuc*, *Gobius bucchichi*; *Gcob*, *Gobius cobitis*; *Gpag*, *Gobius paganellus*; *Zzeb*, *Zebrus zebrus*; *Psan*, *Parablennius sanguinolentus*; *Spav*, *Salaria pavo*; *Llep*, *Lepadogaster lepadogaster*; *Spor*, *Scorpaena porcus*; *Ttri*, *Tripterygion tripteronotum*.

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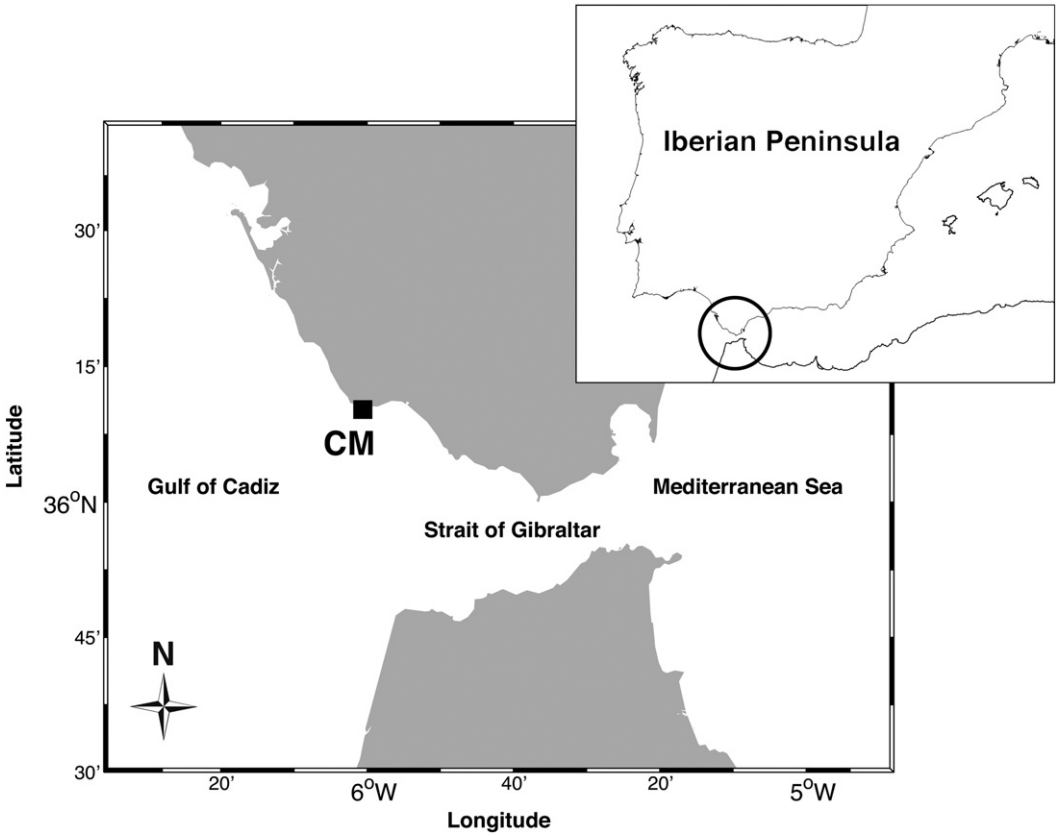

Fig. 1. Study location: Gulf of Cadiz, southwest of the Iberian Peninsula. CM: Caños de Meca.

catch. The total length (TL) of each specimen was measured to the nearest mm. Stomach contents were preserved in 70% alcohol. Prey determination was performed using a *Leica WILD M10* stereo microscope and consulting the Handbook of the Marine Fauna of North-West Europe (Hayward and Ryland, 1995). Diet analysis was performed based on the frequency of occurrence (%F: number of stomachs containing a given resource out of total stomachs analysed) (Guziur, 1976) and relative abundance (%*N*: number of prey of the same type out of total consumed prey). To assess feeding activity, the emptiness index was calculated as the number of empty stomachs out of the total number of stomachs analysed. To analyse dietary variation depending on time of year, the warm season was defined from June to October, when the Sea Surface Temperature (*SST*) exceeded 20 °C, and the cold season was the rest of the year. Data for the study of *SST* variation come from the National Oceanic and Atmospheric Administration (NOAA) of the United States. These have a resolution of 0.03° and are obtained by optimal linear interpolation, which is calculated as the monthly average of daily values (obtained through in situ measurements from ships and moored and drifting buoys, and from satellites) (Reynolds et al., 2002).

Niche breadth analysis was conducted using two indices. One was the Levins index (Levins, 1968) standardised by Hurlbert (1978), B_A

Table 1
Number of stomachs analysed (n) for each species, average size, standard deviation and size range.

Species	Family	n	TL average	SD	TL minimum	TL maximum
Gobius bucchichi Steindachner, 1980	Gobiidae	648	49.05	13.54	20.63	91.79
Gobius cobitis Pallas, 1811	Gobiidae	248	85.57	33.42	21.08	195.00
Gobius paganellus Linnaeus, 1758	Gobiidae	178	54.86	22.23	22.01	99.30
Zebrus zebrus (Risso, 1826)	Gobiidae	51	36.04	7.70	14.56	55.05
Parablennius sanguinolentus (Pallas, 1811)	Blenniidae	110	97.18	22.45	29.81	135.84
Salaria pavo (Risso, 1810)	Blenniidae	53	70.41	12.62	35.90	90.05
Lepadogaster lepadogaster (Bonnaterre, 1788)	Gobiesocidae	69	40.24	10.16	11.10	67.18
Scorpaena porcus (Linnaeus, 1758)	Scorpaenidae	106	90.04	48.37	29.29	226.00
Tripterygion tripteronotum (Risso, 1810)	Tripterygiidae	218	48.77	7.88	29.96	67.61

Note: Fishes total length (TL) in mm.