Journal of Sea Research 117 (2016) 27–35

Contents lists available at ScienceDirect

Journal of Sea Research

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

Trophic structure of pelagic species in the northwestern Mediterranean Sea

Marta Albo-Puigserver [a,*], Joan Navarro [a,b,c], Marta Coll [a,d], Craig A. Layman [e], Isabel Palomera [a]

[a] Institut de Ciències del Mar (ICM-CSIC), Passeig Marítim de la Barceloneta, 37-49, 08003 Barcelona, Spain
[b] Estación Biológica de Doñana (EBD-CSIC), Avda. Américo Vespucio s/n, 41092 Sevilla, Spain
[c] Centre d'Ecologie Fonctionnelle et Evolutive, UMR 5175, CNRS — Université de Montpellier — Université Paul-Valéry Montpellier — EPHE, Montpellier, France
[d] Institut de Recherche pour le Développment, UMR MARBEC & LMI ICEMASA, University of Cape Town, Private Bag X3, Rondebosch, Cape Town 7701, South Africa
[e] Department of Applied Ecology, North Carolina State University, Campus Box 7617, Raleigh, NC 27695-7617, USA

ARTICLE INFO

Article history:
Received 18 February 2016
Received in revised form 30 August 2016
Accepted 13 September 2016
Available online 14 September 2016

Keywords:
Stable isotopes
Pelagic fish
Isotopic niche
Food web
Community structure
Seasonal
Trophic segregation

ABSTRACT

Ecological knowledge of food web interactions within pelagic marine communities is often limited, impairing our capabilities to manage these ecologically and economically important marine fish species. Here we used stable isotope analyses to investigate trophic interactions in the pelagic ecosystem of the northwestern Mediterranean Sea during 2012 and 2013. Our results suggest that European sardine, *Sardina pilchardus*, and anchovy, *Engraulis encrasicolus*, are consumers located at relatively low levels of the pelagic food web. Unexpectedly, the round sardinella, *Sardinella aurita*, appeared to be located at a higher trophic level than the other small pelagic fish species, although previous studies found similarity in their diets. Isotope data suggested that trophic niches of species within the genera *Trachurus* spp. and *Scomber* spp., were distinct. Atlantic bonito *Sarda sarda*, European hake *Merluccius merluccius* and European squid *Loligo vulgaris*, appeared to feed at higher trophic levels than other species. Despite some intraspecific seasonal variability for some species, community trophic structure appeared relatively stable through the year. These data provide an important step for developing models of food web dynamics in the northwestern Mediterranean Sea.

1. Introduction

Marine pelagic fisheries account for 26% of the world's total protein consumption (Tacon and Metian, 2009). With exploitation of these stocks increasing, there is a need to understand how the trophic structure may be shifting in pelagic systems (Pikitch et al., 2014). Yet, relative to coastal ecosystems, we have less knowledge of pelagic food webs and the trophic role of pelagic species (Miller et al., 2010). This is particularly true for small- and medium-sized pelagic fishes, which are ecologically and economically important species in marine ecosystems worldwide and represent >50% of the total landings in the Mediterranean Sea (Cury et al., 2000; Lleonart and Maynou, 2003).

Small pelagic fish species, such as *Sardina pilchardus* (European sardine) and *Engraulis encrasicolus* (European anchovy), account for significant biomass at intermediate trophic levels of Mediterranean Sea food webs and are the main prey resource for several marine predators (Coll et al., 2006; Cury et al., 2000; Pikitch et al., 2012, 2014). Medium pelagic fishes, such as mackerels and horse-mackerels, are also abundant in many pelagic food webs (Juan-Jordá et al., 2013; Lleonart and Maynou, 2003). These species can be prey species for higher trophic levels, as well as having top-down effects on small pelagic fish populations (Bayhan et al., 2013; Meneghesso et al., 2013; Trenkel et al., 2014).

Previous studies have described food web dynamics of the pelagic ecosystem in the Mediterranean Sea (see Bănaru et al., 2013; Coll et al., 2006; Corrales et al., 2015); however, little information about specific trophic interactions between small- and medium-sized pelagic fishes has been published. Likewise, although seasonal environmental variability has been shown to affect the population dynamics of small pelagic fishes, few studies have taken into account how this could affect trophic interactions (França et al., 2011; Lloret et al., 2001, 2004; Palomera et al., 2007). In this study we used stable isotope analysis to describe the overall community structure and examine the potential

* Corresponding author.
E-mail address: albo@icm.csic.es (M. Albo-Puigserver).

http://dx.doi.org/10.1016/j.seares.2016.09.003
1385-1101/

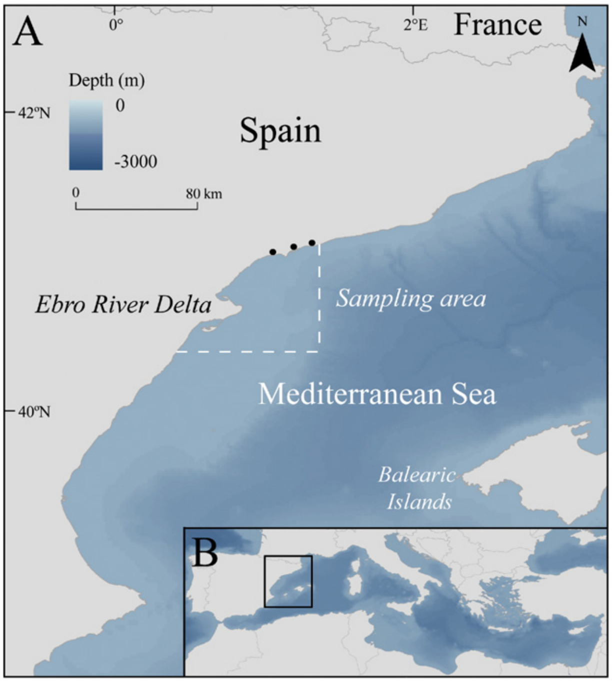

Fig. 1. (A) Map of the study area where the individuals were collected on the Ebro Delta continental shelf, northwestern Mediterranean. The sampling area (dashed line) and the fishing harbors where most of the samples were landed are indicated with (●). (B) Position of the study area in the Mediterranean Basin.

seasonal shifts in trophic interactions of 11 abundant pelagic species in the northwestern Mediterranean Sea. The main objectives were to analyze the specific trophic relationships between species and to compare the relative niche positions among seasons.

2. Material and methods

2.1. Study area

The study was conducted in the continental-shelf and upper slope area associated with the Ebro River Delta, from Cape Salou to Castelló de la Plana (Fig. 1; northwestern Mediterranean Sea). As a consequence of particular oceanographic conditions, including vertical mixing and river discharges, this area is an important fishing ground in the Mediterranean Sea (Coll et al., 2006; Lloret et al., 2004; Navarro et al., 2016). Moreover, it is an important area for threatened animals, including Balearic shearwater, *Puffinus mauretanicus*, Audouin's gull, *Larus audouinii* and loggerhead turtle *Caretta caretta* as well as other predators that also prey on small pelagic fishes (Arcos et al., 2009; Coll et al., 2015; Tomas et al., 2001). From May to October the ecosystem is characterized by a distinct thermocline and stratification of the water column, resulting in a reduction of nutrients in the photic zone (Salat, 1996). During the stratified season, riverine inputs are the main source of nutrients at the surface (Palomera et al., 2007; Salat et al., 2002). In contrast, from November to April, the water temperature is lower and the water column mixed, leading to higher nutrient availability at the surface (Salat et al., 2002).

2.2. Sampling

We sampled eleven species of small and medium pelagic fishes, squids and potential predators of small pelagic fishes (see Table 1). We only sampled adult individuals to avoid potential ontogenetic differences in the isotopic values, since fish species often have ontogenetic niche shifts (Bode et al., 2004; Chouvelon et al., 2012). A total of 443 individuals were collected (spring 2012, summer 2012, fall 2012 and winter 2013) from commercial vessels of the harbors of Tarragona, Torredembarra and Cambrils (Fig. 1), as well as from an experimental oceanographic cruise in winter 2013 (ECOTRANS Project, Institut de Ciències del Mar, CSIC). All individuals were immediately frozen after capture and stored at −20 °C and then the morphological measurements (total body weight and total body length) and tissue collection were conducted in the laboratory. During the experimental oceanographic cruise in winter 2013, samples of microplankton were collected with a calVET net (53–200 μm) and frozen and stored at −20 °C.

2.3. Stable isotope analyses

Over the last few decades, stable isotope analyses have been broadly used to study the structure of food webs and trace energy and mass flows in ecosystems (Layman et al., 2012). Particularly, ^{13}C and ^{15}N are stable isotopes commonly used to study trophic pathways. $\delta^{13}C$ may vary substantially among primary producers, but shows little change from prey to consumers; alternatively, $\delta^{15}N$ reflects stepwise enrichment with each trophic level. Therefore, $\delta^{13}C$ is often used as a proxy of the original source of dietary carbon and $\delta^{15}N$ as a proxy of relative trophic position (Layman et al., 2012).

A small portion of the dorsal muscle from fish species, and of the mantle from squid species, was dissected from each individual. All samples were freeze-dried, powdered and 0.28–0.33 mg of each sample was packed into tin capsules. Isotopic analyses were performed at the Laboratory of Stable Isotopes of the Estación Biológica de Doñana (www.ebd.csic.es/lie/index.html). Samples were combusted at 1020 °C using a continuous flow isotope-ratio mass spectrometry system (Thermo Electron) by means of a Flash HT Plus elemental analyser interfaced with a Delta V Advantage mass spectrometer. Stable isotope ratios were expressed in the standard δ-notation (‰) where $\delta^{13}C$ or $\delta^{15}N = ([R_{sample} / R_{standard}] - 1) \cdot 1000$ where R is ^{13}C:^{12}C or ^{15}N:^{14}N relative to Vienna Pee Dee Belemnite ($\delta^{13}C$) and atmospheric N_2 ($\delta^{15}N$). Based on laboratory standards, the measurement error was ±0.1 and ±0.2

Table 1
Main prey of focal species as based on previous literature reports in the Mediterranean Sea.

Species name	Main prey	References
Engraulis encrasicolus	Copepods, cladocerans	Costalago et al., 2012; Tudela and Palomera, 1997
Sardina pilchardus	Copepods, cladocerans, diatoms	Costalago and Palomera, 2014; Nikolioudakis et al., 2012
Sardinella aurita	Copepods, decapods larvae, fish larvae	Karachle and Stergiou, 2014; Lomiri et al., 2008
Trachurus mediterraneus	Copepods, euphasiids, fish	Bayhan et al., 2013; Yankova et al., 2008
Trachurus trachurus	Copepods, euphasiids, fish	Jardas et al., 2004; Šantić et al., 2005
Scomber scombrus	Euphasiids, decapod larvae, fish	Olaso et al., 2005
Scomber colias	Copepods, mysids, decapod larvae, fish	Castro, 1993; Keč et al., 2012
Illex coindetii	Fish, crustaceans	Martínez-Baena et al., 2016.; Rosas-Luis et al., 2014
Loligo vulgaris	Fish, crustaceans, cephalopods	Valls et al., 2015
Merluccius merluccius	Benthopelagic and pelagic fish, decapods, euphausiids	Bozzano et al., 1997; Cartes et al., 2004
Sarda sarda	Small pelagic fish	Campo et al., 2006; Navarro et al., in press