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SHORT COMMUNICATION

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Inter-population plasticity in dietary traits of invasive bleak *Alburnus alburnus* (Linnaeus, 1758) in Iberian fresh waters

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1 | INTRODUCTION

The potentially disruptive effect of fish invasions is of particular concern to conservation in Iberian fresh waters, where endemism (>50% of native fish species) is high (Reyjol et al., 2007), and non-native fishes (>30%) are on the increase (Leunda, 2010).

In its native area, bleak *Alburnus alburnus* (L., 1758) inhabit lakes or still waters in medium-large rivers and feed chiefly on zooplankton (Freyhof & Kottelat, 2008). In the Iberian Peninsula, this species was introduced mainly in reservoirs during the 1990s as a “forage fish” for non-native piscivorous fishes such as *Esox lucius* (L., 1758), *Micropterus salmoides* (Lacépède, 1802) and *Sander lucioperca* (L., 1758) (Vinyoles et al., 2007). Since its introduction, the bleak has displayed a strong invasive character and is potentially an aggressive competitor for the native fish fauna (Leunda, 2010). Information on this species in the Iberian Peninsula is limited to spatial distribution (Vinyoles et al., 2007), size structure (Almeida, Stefanoudis, Fletcher, Rangel, & da Silva, 2014), and growth rates (Masó, Latorre, Almeida, Tarkan, & Vila-Gispert, 2016).

Dietary traits of non-native fishes can show wide plasticity under contrasting local conditions (Almeida, Almodóvar, Nicola, & Elvira, 2009; Godard, Almeida, Zięba, & Copp, 2013); analyses thereof can assist environmental managers in designing monitoring programmes for the assessment of risk invasion (e.g. Almeida & Grossman, 2014).

Consequently, the aim of the present study was to assess the inter-population plasticity in dietary traits of *A. alburnus* under variable local conditions in Iberian fresh waters. For this purpose, bleak populations were compared across selected Iberian streams showing similar environmental conditions at the regional scale. Specifically, the diet composition was analysed and four dietary parameters were examined: ingested mass, prey richness, trophic diversity and trophic niche breadth.

2 | MATERIALS AND METHODS

2.1 | Study area

Bleak populations were sampled in four small Catalonian north-south water courses (i.e., streams <100 km river length) at <250 meters above sea level: Muga, Fluvià, Cardener and Foix. These streams are geographically in close proximity (lat. 41°19′–42°16′N, maximum distance ≈120 km) and possess similar limnology and geomorphology at the regional scale, i.e., bed shape, wetted width, flow, substratum composition, riparian vegetation, fish assemblages, and level of human disturbances (see details in Catalan Water Agency, 2015). The studied streams show a typical Mediterranean hydrological regime (i.e., autumn-winter floods and summer droughts). Bleak were introduced in the four streams around the year 2000, thus their populations are at the same “invasive stage”, i.e., well established and spreading in these habitats (Vinyoles et al., 2007).

2.2 | Field sampling and laboratory procedures

Bleak were collected from late May to early June 2012, before the spawning period and thereby avoiding any foraging effect of the “reproductive stage”. Fish collection was carried out by trained personnel along a 10 km stretch in the middle reach of each stream by electrofishing (2000 W DC generator at 200–250 V, 2–3 A), following a zigzag and upstream direction. A representative sample of *A. alburnus* was collected across the broadest possible body size range from each stream. After capture, bleak were immediately immersed in an overdose solution of anaesthetic (MS-222) and stored on ice. Sample sizes (*n*) were 84, 88, 83 and 81 from the Muga, Fluvià, Cardener and Foix streams, respectively. All field procedures complied with the animal use and care regulations of Spain and Europe.

TABLE 1 Diet composition of bleak *Alburnus alburnus* in studied streams (*n* = examined guts with content)

Stream	Muga (82)		Fluvià (86)		Cardener (80)		Foix (78)	
Food category	Oc.	Mass	Oc.	Mass	Oc.	Mass	Oc.	Mass
Algae and plant debris	54	11	17	10	18	2	4	25
Planktonic Crustacea (Cladocera and Copepoda)	5	1	25	4	6	<1	5	1
Ephemeroptera and Plecoptera nymphs	20	2	6	4	18	1	2	3
Odonata nymphs	20	5	1	1	3	<1	1	<1
Diptera larvae	93	34	61	16	94	22	87	33
Trichoptera larvae	27	2	2	4	5	<1	9	19
Other benthic invertebrates	12	3	10	1	12	57	4	1
Nektonic insects	20	2	10	1	2	<1	9	<1
Flying insects	88	40	45	59	24	17	19	17

Percentages of occurrences (Oc., %) and ingested masses (Mass, %) are presented. Sampling period: May–June 2012.

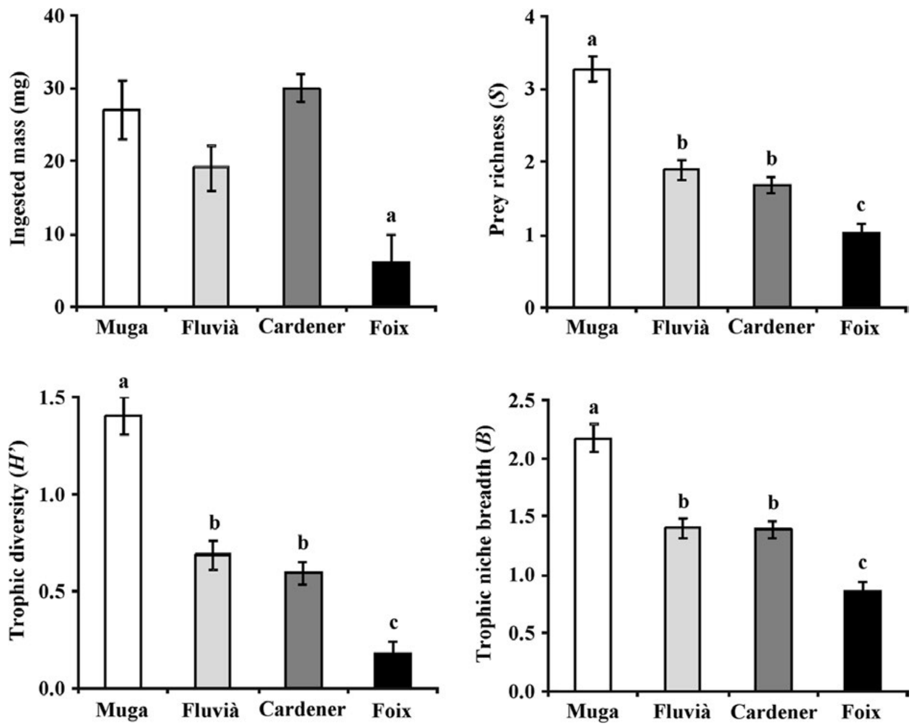

FIGURE 1 Comparison of four dietary parameters for bleak *Alburnus alburnus* among studied streams. Results are adjusted means ± SE, after ANCOVA (covariate: TL). Sample size (*n*) = 326. Sampling period: May–June 2012. Letters above columns indicate significant differences in bleak populations, after Tukey HSD tests (*p*-value ≤ 0.05)

On arrival at the laboratory, fish were measured for total length (TL, ±1 mm) and dissected to examine the sex. Eviscerated weight (eW, ±0.1 g) was recorded to avoid the effect of gonad and gut masses. Only the anterior one-third of the intestinal tract was preserved in 4% formalin for subsequent examination to avoid any severely digested food remains. Food items were identified to the lowest possible taxonomic level using a dissecting microscope (40×) and weighed using an electronic balance (wet weight to within 0.1 mg).

2.3 | Data analyses

Percentage of occurrence (omitting empty guts) and percentage of ingested mass (relative to the total ingested mass in all examined fractions of intestinal tracts) were calculated for each food category. Four dietary parameters were calculated for each fish: ingested mass (mg), prey richness (*S*), trophic diversity (Shannon index, *H′*), and trophic niche breadth (Levin index, *B*). Fulton's condition factor (*K*) was also calculated.

Preliminary analyses found no difference between sexes, thus this categorical factor was not included in subsequent data analyses. Analysis of covariance (ANCOVA) was used to reveal significant differences between populations for the four dietary parameters. The effect of body size was tested by using total length (TL) as the covariate, as this was a better predictor for dietary parameters than either eW or *K*. ANCOVAS were followed by a *post hoc* Tukey-Kramer honestly significant difference (HSD) test. Data were transformed by using ln (x + 1). Data normality of distributions and homogeneity of variances were verified through Shapiro-Wilks and Levene's tests, respectively.

Statistical analyses were performed with SPSS v.19 (SYSTAT Software Inc., Chicago, IL, USA). The significance level was set at p-value ≤.05.

3 | RESULTS

Bleak size ranged from 43 to 144 mm TL, and bleak mass from 0.7 to 45.3 g eW. Diptera larvae and flying insects (e.g. just emerged Ephemeroptera) were the most common prey in the studied populations (Table 1). In terms of ingested mass, flying insects were most important in the Muga and Fluvià streams. In the Cardener stream, other benthic invertebrates (e.g. Coleoptera larvae or Gastropoda) and Diptera larvae reached the greatest percentages of ingested mass. Diptera larvae and plant material were the most important food mass in the Foix stream (Table 1).

Significant differences were found among the bleak populations in terms of ingested mass ($F_{3,321}$ = 4.78, p < .01), prey richness ($F_{3,321}$ = 35.46, p < .001), trophic diversity ($F_{3,321}$ = 32.46, p < .001) and trophic niche breadth ($F_{3,321}$ = 25.69, p < .001). Specifically, the least value of ingested mass was found in the Foix stream (<10 mg, Fig. 1). The remaining parameters had the same pattern, with bleak from the Muga stream reaching the highest mean, followed by the Fluvià and Cardener streams, and then the Foix population (Fig. 1).

4 | DISCUSSION

Ecological responses, such as dietary traits, are expected to show wide plasticity in non-native species when invading new habitats (Agrawal, 2001; Almeida, Almodóvar, Nicola, Elvira, & Grossman, 2012; Godard et al., 2013). Accordingly, dietary traits were highly variable among the studied streams, indicating wide inter-population plasticity in bleak foraging strategies dependent on local conditions. Similarly for other biological attributes (i.e., growth and reproduction), Masó et al. (2016) suggested that this great plasticity helps to successfully invade novel Mediterranean freshwater ecosystems.

The bleak is an open-water feeder in its native area, where this species inhabits mainly lentic habitats and consequently, the diet is chiefly based on zooplankton (Herzig, 1994; Vašek & Kubečka, 2004; Vinni, Horppila, Olin, Ruuhijärvi, & Nyberg, 2000). Conversely, bleak fed mostly on benthic invertebrates and flying insects in the studied Iberian streams, where these two prey types were readily available during the sampling period (D. Latorre, personal observation). Therefore, bleak could shift their foraging strategy to better thrive in stronger flowing waters, where zooplankton is a more limited trophic resource. Moreover, fish communities are less complex in the Iberian Peninsula than in the rest of Europe (Reyjol et al., 2007) and endemic species are specialised to narrow trophic niches (Sánchez-Hernández, Vieira-Lanero, Servia, & Cobo, 2011). Thus, strong invasive competitors such as the bleak usually displace native species from their ecological resources. For example, direct observations of bleak have shown how this fish can clearly disturb the foraging behaviour of the endemic cyprinid *Parachondrostoma miegii* (Steindachner, 1866) (Almeida & Grossman, 2012).

In the Foix stream the large proportion of ingested plant mass might indicate that some bleak were heading towards a higher consumption of plant material. Furthermore, the ingested mass and overall food diversity in the stream had the lowest values for the population as a whole. Environmental conditions (e.g. lack of suitable substrata) may thus restrict the prey supply in particular habitat patches of the Foix stream. This could increase their algae intake, despite this food category having less energy content as suggested by Chappaz, Brun, and Olivari (1987), who reported a relationship between the high presence of algal debris in the bleak diet of some individuals and their lesser growth/fecundity levels. Similarly, Masó et al. (2016) found the bleak population in the Foix stream to be in poor health with regard to growth rate, body condition and late sexual maturity.

The overall dietary diversity in terms of prey richness, trophic diversity and trophic niche breadth was clearly highest in the Muga stream. In this respect, bleak can display a more generalist strategy where the variety in prey items is greater (Chappaz et al., 1987), which may be what is occurring in the Muga stream. Local conditions of structural habitat heterogeneity are especially high in the Muga stream, as observed by Zamora, Saavedra, and Moreno-Amicht (1996), which surely increases food diversity for fish assemblages. These conditions of great habitat complexity are probably the reason for the greatest diversity in dietary traits of bleak from the Muga stream.

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