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1 **An invasive species, *Carassius gibelio*, alters the native fish community through trophic niche competition**

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31 **Abstract**

32 Carbon and nitrogen stable isotope analyses were used to determine isotopic niche width of the invasive fish
33 species *Carassius gibelio* to help assess the niche overlap and potential impact of this species on the native fish
34 fauna in the Karamenderes River, northwest Turkey. *C. gibelio* had the highest niche area of the coexisting
35 species. The greatest overlap of isotopic niche was between *C. gibelio* and *Mugil cephalus* in the river mouth.
36 The freshwater species displayed similar patterns when taking into consideration their relative abundance and
37 isotopic overlap. While *C. gibelio* is likely to outcompete some species at some localities, the species was found
38 co-occurring with others by maximum tolerable overlap degree and apparently utilised vacant niche space at
39 some stations. Overall our results indicate that *C. gibelio* has extensive niche overlap with the native fish species
40 making it a strong competitor, and because of its high abundance and high niche width this invasive species
41 represents a serious threat to the native fish fauna, particularly in the river mouth.

42 **Key words:** Feeding ecology, fish, stable isotopes, invasive

43

44 **Introduction**

45 Niche width of a species is affected by several abiotic and biotic factors such as resource density and diversity,
46 population density, competitors and predators (Fox 1981; Bearhop et al. 2004; Olsson et al. 2009). The relation
47 between niche widths and abundance of species was formalized by early ecologists as a spatial model of the
48 niche concept (Hutchinson 1957; Levins 1968; MacArthur 1968). Although a negative correlation between
49 species abundance and niche width of a species in a community has been discussed by some authors (Seagle
50 and Mccracken 1986), the general consensus is for a positive correlation between the abundance and the niche
51 width of species which is explained by an increase in the variety of resources consumed and increased
52 tolerance to environmental conditions (Rocha et al. 2018). Successful invaders tend to have wider niches with
53 high abundance and higher plasticity in resource use than non-invasive species (Correia 2002), thus increasing
54 their competitive capabilities (Blossey and Nötzold 1995; Tilman 1999). There are several hypotheses about
55 the wide niche area of a species. For example; expansion of niche width has been explained as a result of
56 decreased interspecific competition in order to maintain energy requirements (Robinson and Wilson 1994;
57 Svanbäck and Persson 2004). As a superior competitor, an invasive species can compete for particular
58 resources used by native species and cause competitive exclusion of that native species (Britton et al. 2018). On
59 the other hand, co-existence of an invasive species with other species might be explained by availability of
60 sufficient resources for all species and resource partitioning. In that respect, the degree of virtual and actual
61 niche width of species (Colwell and Futuyma 1971), The maximum tolerable overlap among species in a
62 community (Pianka 1974), is a useful tool to understand competition and the potential impact of an invasive
63 species. Successful invaders may also occupy previously vacant niche space (Karlson et al. 2015). Therefore,
64 the abundance of invasive fish species and degree of niche overlap with the native populations is a good
65 indicator of possible impacts on a fish community. The impact of an invasive species with the abundance and
66 overlap degree were documented recently for some fish species (Sakai et al. 2001; Ayala et al. 2007; Carey and
67 Wahl 2010). However, revealing the quantitative ecological impacts of invasive species is challenging due to

68 the complexity of ecological interactions (Miranda and Perissinotto 2012), and there are still gaps in the
69 empirical examples of the impact of an invasive species in terms of community dynamics.

70 The Gibel carp, *Carasius gibelio* (Bloch 1782), with its rapid dispersion and high establishment success in both
71 lentic and lotic inland waters is considered a nuisance species in Turkey and Europe (Özcan, 2007; Özüluğ,
72 Meriç, & Freyhof, 2004). The community-based impact of this species has only been reported to a limited
73 extent (Crivelli 1995; Gaygusuz et al. 2007; Specziár and Rezsü 2009; Tarkan et al. 2012; Yalçın Özdilek and
74 Jones 2014). Therefore studies of the spatio-temporal variation of niche width together with the niche overlap
75 with native species along a river will improve understanding of community dynamics and potential impact for
76 this invasive species.

77 Stable isotope analysis (SIA) offers an effective tool for understanding trophic niche widths of fish
78 (Layman et al. 2007b; Schmidt et al. 2007; Syväranta and Jones 2008; Fink et al. 2012; Syväranta et al. 2013),
79 the dietary overlap of species in a fish guild (DeNiro and Epstein 1978; Bootsma et al. 1996) and also the impact
80 of invasive species (Vander Zanden et al. 1999; Simon et al. 2004; Yuille et al. 2015; Britton et al. 2018). We
81 therefore used trophic (isotopic) niche width to understand the impact of invasive *C. gibelio* and the extent of
82 dietary overlap with native species in the Karamenderes River in northwest Turkey. To explain the impact of
83 this invasive species we tested the hypotheses that invasive *C. gibelio* have wider isotopic niche than co-existing
84 species. *C. gibelio* may outcompete some co-existing species or may be found together by maximum tolerable
85 overlap degree of co-existing species. In addition, invasive *C. gibelio* may occupy vacant niche space by having
86 minor dietary overlap with co-existing species.

87 **Materials and Methods**

88 **Study area and sampling**

89 The Karamenderes River, which rises in the Ağrı and Kaz Mountains and flows into the Çanakkale strait
90 near the ancient city of Troy, is located in northwest Turkey (Fig. 1). The river is about 110 km long with
91 discharge from 60-70 m³ to 1530 m³ per second throughout the year and is one of the biggest rivers in the Biga
92 Peninsula (Sarı et al. 1999; Baba et al. 2007) . The river flow is regulated by two reservoirs at Bayramiç and
93 Pınarbaşı. The first record of invasive *C. gibelio* from this river was in a 2007 survey at Pınarbaşı station (Yalçın
94 Özdilek 2008) after field studies performed in the Biga Peninsula in 2000 and 2001 (Sarı et al. 2006). The
95 Karamenderes river has regional endemic species such as *Salmo cf. coruhensis*, *Squalius cii* (Richardson, 1857),
96 *Alburnus cf. attalus*, *Barbus oligolepis* Battalgil, 1941, *Cobitis fahirae* Erk'akan, Atalay-Ekmekçi-Nalbant,
97 1998. *Cyprinus carpio* has been introduced to reservoirs by aquaculture activities. Another introduced species
98 *Gambusia holbrooki* Girard, 1859 had not been recorded from this river before this field study. *Gobio*
99 *kovatschevi* Chichkoff, 1937 is also a regional endemic and is listed by the IUCN (International Union of
100 Conservation of Nature) as vulnerable (Freyhof and Kottelat 2008). *Anguilla anguilla* (L., 1758) has a wide
101 distribution, but the population of this species is decreasing and it is listed by the IUCN as critically endangered
102 (Jacoby and Gollock 2014).

103 Materials for the study were collected at five locations, Ahmetçeli (Ahm), Sarmısaklı (Srm), Kalafat
104 (Klf), Kumkale Köprü (Kkop), Kumkale açık (Kka), from upstream to downstream along the river in Summer

105 2012, Fall 2012, and Spring 2013 (Figure 1). Along the river each station has different characteristics such as
106 depth (30 cm to 5 meters) and width (5 m to 30 m). Therefore, the fish sampling was performed using backpack
107 electrofishing (SAMUS 725G) accompanied by cast net (10 -16 mm), gill net (18-45 mm), and fyke net to cover
108 all habitat types. The water temperature, (T, °C), dissolved oxygen (DO, mgL⁻¹) and electrical conductivity (C,
109 μScm⁻¹) were measured by WTW ® 340i multimeter in the field. The relative abundance (%N) of each species
110 was calculated as numerical percentage of all specimens collected (Table 1). The sum of relative abundances of
111 all species was assumed to be one hundred for each sampling station. Fork length of each *C. gibelio* individual
112 was recorded and dorsal muscle tissue samples of all fish specimens were taken for stable isotope analysis
113 (SIA).

114 **Figure 1**

115 **Stable isotope analyses**

116 For isotopic analysis, muscle samples of all fish specimens were dried at 60°C for 24 hours and
117 homogenized with a microdismembrator-U (2 min at 1500 rpm) into a fine powder. Stable isotope analyses were
118 conducted using a FlashEA 1112 elemental analyser (Thermo Fisher Scientific Corporation, Waltham, MA,
119 U.S.A.) coupled to a Thermo Finnigan DELTA^{plus} at the University of Jyväskylä, Finland. Prior to analysis,
120 0.500–0.600 mg of homogenized powder from each sample was weighed into tin capsules. Standard delta
121 notations ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) were used for stable carbon and nitrogen isotope ratios relative to the international
122 standards for carbon (Vienna PeeDee Belemnite) and nitrogen (atmospheric nitrogen). Pike (*Esox lucius* L.)
123 white muscle tissue with known isotopic composition was used as an internal working standard inserted in each
124 run after every five samples. Standard deviation of the internal standards was less than 0.16 ‰ for $\delta^{13}\text{C}$ and 0.12
125 ‰ for $\delta^{15}\text{N}$ in each run. Lipid correction of muscle $\delta^{13}\text{C}$ values was not performed because the C:N ratios
126 (average = 3.4, range = 3.2–3.8) indicated very low lipid content (Kiljunen et al. 2006; Post et al. 2007).

127 **Data analyses and statistics**

128 The isotopic niche widths of the fish species were calculated from the $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$ data as total area
129 (TA), which means the total amount of isotopic niche area occupied, and as the standard ellipse area corrected
130 for sample size (SEAc), which is less sensitive to outliers, using the SIAR package (Stable Isotope Analysis in
131 R; Layman et al. 2007a; Parnell et al. 2010). The overlap between ellipses was calculated using the Bayesian
132 method (SEA.B) and polygons were drawn using the code that underlines the overlap function in the SIBER
133 package (Jackson et al. 2011). Bayesian-based determination of standard ellipse area of each species (SEA.B)
134 was used to compare the isotopic niche metrics of species statistically in the same package in R. The mean
135 SEAc values of all specimens in the stations with and without *C. gibelio* were compared using Student t-Test.
136 In the assessment of the degree of niche overlap between species (overlap degree), the fish species were grouped
137 as <1 and >1 units of overlap degree. The highest overlap degree of *C. gibelio* with the other species were taken
138 as the maximum tolerable overlap degree. The α value was calculated as $\alpha = 0.05/49 = 0.001$ for multiple
139 comparisons of SEA.B values of species pairs according to Bonferroni correction (Bland and Altman 1995).
140 Statistics were performed using R, version 2.1.3 (Jackson et al. 2011) and Microsoft Excel version 2010.

141 **Results**

142 A total of 106 individuals of the invasive *C. gibelio* together with individuals of other species were
143 caught with various nets along the Karamenderes River. *C. gibelio* were caught from all the stations below the
144 Bayramiç reservoir dam along the river. The mean length of *C. gibelio* with the standard deviation and some
145 habitat characteristics for each station are given in Table 1. While small specimens were caught at the upper
146 stations, larger specimens were caught from the river mouth in all three seasons. In the river mouth with the low
147 temperature and high salinity, smaller specimens were found in fall than in the other seasons (Table 1). The
148 relative abundances of *C. gibelio* and of the other species are given Table 2 as N%. *C. gibelio* had highest
149 relative abundance in the river mouth stations in Summer 2012 (Table 2).

150 **Table 1.**

151 The other fish species were categorised into three groups: (1) native freshwater fish species, which
152 were *A. anguilla*, *S. cii*, *B. oligolepis*, *A. cf. attalus*, *G. kovatschevi*, *C. fahirae*, *Rhodeus amarus* (Bloch, 1782);
153 (2) introduced species, which were *C. carpio* and *G. holbrooki*; and (3) marine-freshwater transitional fish
154 species, which were *L. aurata* (Risso, 1810), *Liza ramada* (Risso, 1827), *Chelon saliens* (Risso, 1810), *C.*
155 *labrossus* (Risso, 1827), *Mugil cephalus* L., 1758, and *Platichthys flesus* (L., 1758) (Table 2). While *C. gibelio*
156 were collected from all stations below the Bayramiç reservoir in summer, they were not sampled at the Srm
157 station in fall and were collected only from the two lower stations, Klf and KKop in spring. *C. gibelio* shared the
158 last two stations KKop and KKa with transitional fish species such as Mugilidae family members and *P. flesus*.
159 Specimens of *S. cii*, *B. oligolepis*, *R. amarus* together with *C. gibelio* were caught only from Klf and KKop
160 stations in all three seasons (Table 2). *Sparus aurata* with low abundance were recorded only from KKa station
161 in Summer 2012 (7.3%) and Spring 2013 (1.4%). Similarly, *A. anguilla* were recorded from Srm (1.5% in
162 Summer 2012), KKop (10% Spring 2013), KKa (3.3% in Summer 2012 and 12.2% in Spring 2013) stations.

163 **Table 2.**

164 *C. gibelio* exhibited wide variation in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values which encompassed the range of values of
165 nearly all the native species (Figure 2). Total isotopic niche area (TA) of *C. gibelio* varied from 2.2 to 25.7 ‰
166 and exceeded that of all the other species. The highest recorded value of TA was for *C. gibelio* in spring at the
167 KKop station, when there were no mugilids at that station. In general, the TA of *C. gibelio* increased
168 downstream, the downstream KKa site having the highest TA (Table 3).

169 **Figure 2.**

170 The indigenous freshwater fish species shared similar isotopic niche area with the three most freshwater tolerant
171 transition fish species (Figure 3). Interestingly, *C. gibelio* appears to occupy a similar isotopic niche area as
172 nearly all the other freshwater and transitional fish species. However, *C. gibelio* occupied a wider isotopic
173 overall niche area than the others, exhibited higher plasticity in isotopic niche width, and occupied a particular
174 isotopic area which was about -26‰ to -27‰ and about 14‰ to 16‰ for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values, respectively.

175 **Figure 3.**

176 *C. gibelio* had higher values of standard ellipse area than the native fish species except for Mugilidae family
177 members. We compared two ellipses for significant differences in SEA.B to test whether *C. gibelio* isotopic
178 niche area differed from that of other fish groups (Table 3). The SEA.B values for *C. gibelio* showed a much
179 larger area than the other species particularly at the river mouth stations and particularly for native freshwater
180 fish species, but also for other introduced species (Table 3). However, the SEA.B value of *C. gibelio* was not
181 significantly larger than that of the mugilids ($p>0.05$).

182 **Table 3.**

183 The corrected mean standard ellipse areas (SEAc) of all specimens for the stations with and without *C. gibelio*
184 were 25.1 ± 14.6 and 10.8 ± 5.6 respectively, and there was a significant difference between these mean values
185 ($t=2.74$; $p<0.05$). However, at the level of individual species, although SEAc values of *S. cii* (1.7 times) and *B.*
186 *oligolepis* (1.5 times) were higher in the absence of *C. gibelio*, there were no significant differences between
187 SEAc values of these native fish species, which are the dominant freshwater fish in the Karamenderes River, in
188 the presence and absence of *C. gibelio* ($p>0.05$).

189 The niche overlap degrees between species and their significance varied according to season and station (Table
190 3, Figure 3). The species which had <1 overlap degrees any time with *C. gibelio* were *P. flesus*, *G. holbrooki*,
191 and *C. fahirae*. *B. oligolepis*, *G. kovatschevi* and *L. ramada* followed having <1 overlap degrees with *C. gibelio*
192 on more than 75% of co-occurrences of these species. About 50-60% of co-occurrence of the species of *S. cii*, *A.*
193 *cf. attalus*, *R. amarus*, *C. carpio*, *L. aurata* and *M. cephalus* were <1 overlap degrees with *C. gibelio*. No
194 overlap was observed with *C. labrossus*. Moreover, there were no, or only very low, overlap degrees between *C.*
195 *gibelio* and other species at KKop and Ahm stations in Summer 2012 and Fall 2012 seasons, respectively (Table
196 3).

197 The greatest extent of isotopic niche overlap was between *C. gibelio* and *M. cephalus* at the Kka station in
198 summer and the Kkop station in fall. Despite the low abundance of *M. cephalus*, SEA.B of *C. gibelio* was not
199 larger than *M. cephalus* at these sites ($p>0.05$; Figure 4). In addition, there were high overlaps with *L. ramada*
200 at the Kac station in fall and with *B. oligolepis* at the Sar station in summer (Figure 4). At these stations the
201 SEA.B value of *C. gibelio* was also statistically lower than those of these other species (Table 3). However,
202 these species were more abundant than *C. gibelio* at those stations.

203 The relation between abundance and isotopic overlap of particularly freshwater fish species indicated that the
204 species represented similar patterns rather than station (Figure 4b). For instance, *S. cii* and *R. amarus* were more
205 abundant and had high overlap degree at various stations even under the condition of higher isotopic niche area
206 of *C. gibelio*. These species are freshwater species which had mostly smaller isotopic niche areas than that of *C.*
207 *gibelio* and the extent of overlap at different stations related to their abundance relative to *C. gibelio*.

208 **Figure 4.**

209 **Discussion**

210 The isotopic niche concept, which is widely used by ecologists, is a useful tool for indicating the potential
211 impact of invasive species. In a river ecosystem, the dynamics of the fish community is flexible and
212 environmental dependent. Even though the possible consequences of invasive fish introductions to natural
213 ecosystems is well known, the possible effects of invasive species on dynamic stream ecosystems are poorly
214 understood. This study presents some explanatory arguments on the possible impacts of invasive species on
215 native fish species in a dynamic lotic system. The most important findings of this study are that *C. gibelio* has a
216 large niche width and high niche overlap with native fish species. The hypotheses that successful invaders have
217 a large niche width (Elton 1958; Shea and Chesson 2002) is supported by our results. In addition, this invasive
218 species occupies vacant niche space particularly in unfavourable environmental conditions for freshwater fish.

219 The isotopic niche width and the isotopic niche overlap of coexisting species in the Karamenderes river showed
220 spatial and temporal variation. It is known that interspecific competition is a major factor determining the
221 trophic niche width of coexisting species (MacArthur 1972; Pianka 1974; Cody 1974). According to optimal
222 foraging theory, niche width will increase as the availability of foraging resources decreases (Mac Arthur and
223 Pianka 1966; Pianka 2011). Therefore, high niche width with the lower overlap of *C. gibelio* might be
224 explained by a decrease in the optimal prey of *C. gibelio*. These limited resource conditions promote the
225 consumption of a wide range of suboptimal prey types which are shared by all freshwater fish species
226 particularly at the river mouth stations (Klf, Kka and Kkop) in fall and spring, where the maximum tolerable
227 overlap of *C. gibelio* was 2.33, 0.16, 1.63, 0.35, 2.77 for *S. cii*, *B. oligolepis*, *A. cf. attalus*, *G. kovatschevi* and
228 *R. amarus*, respectively. We suggest that *C. gibelio* has a greater advantage in habitat use than the other
229 freshwater fish species, particularly less abundant species like *C. fahirae* and *G. kovatschevi*, and the fact that
230 these rare species were not found from some stations may reflect competitive exclusion. The importance of
231 impact by *C. gibelio* is clear when taking into consideration the vulnerability of *G. kovatschevi*.

232 The total niche area of fish communities generally increased from upstream to the river mouth except in spring.
233 The fluctuations in the total niche area in that season might be explained by low abundance of *C. gibelio* at the
234 Srm (1.8%) and KKa (4.1%) stations. The dominance of transitional fish species in that season suggests that
235 high salinity (7.44 mScm⁻¹) might have limited the abundance of *C. gibelio* in the river mouth in Spring 2013.
236 On the other hand, *C. gibelio* appeared to occupy high salinity (6730 μScm⁻¹) environmental conditions which
237 other freshwater fish species could not survive at KKa station in Summer 2012. As explained by Hubbell
238 (2001), new individuals cannot enter the community, either by birth or by immigration, unless there is a vacant
239 niche left by individuals. Environmental fluctuation at the river mouth may result in disappearance of freshwater
240 fishes because of intolerance to salinity. Then the vacant niches might be used by *C. gibelio* and transitional fish
241 species under high salinity conditions. The chemistry of a river has dynamic patches through time and space
242 with more fluctuations in the lower reaches than in the headwaters (Sabater et al. 1991). The more time-
243 dependent chemistry of the lower reaches might represent a marked advantage for survival of *C. gibelio*.

244 The variance in the population stable isotope values of species can be used as an indicator of feeding niche
245 widths (Syväranta and Jones 2008). Bearhop et al. (2004) recommended using SEAc for estimating the niche
246 width from small sample sizes (Bearhop et al. 2004; Jackson et al. 2011). However, even SEAc is still
247 susceptible to sample size effects (Syväranta et al. 2013), and we acknowledge that our sample sizes are small.
248 However, SEA.B, which provides the 95% CI of the ellipse, is used in SIBER when comparing the ellipses of

249 species. Therefore, the statistical test results give unbiased comparison of isotopic niche area of *C. gibelio*. In
250 fact, the highest TA value for *C. gibelio* actually derived from a small sample size (n=6) in KKop in Spring
251 2013. Moreover, the rather close clustering of replicate individuals from each species suggests that our
252 calculated SEAc values are unlikely to be overestimates and we are confident that the larger value for *C. gibelio*
253 than for the other species is a true reflection that this species has a wider trophic niche than the native freshwater
254 species.

255 The isotopic niche width of *C. gibelio* was relatively small compared to other fish species at Ahm and Sar
256 stations. The small niche width at these sites might be explained by less diverse resources, with species adapting
257 to the availability of the most suitable foods (Gordon and Illius 1989). On the other hand, smaller niche area
258 with a high degree of overlap with sympatric species might be explained by Pianka's maximum tolerable
259 overlap degrees of these species (Pianka 1974). In the Karamenderes river, the smaller and even zero degree of
260 overlap support Pianka's hypothesis that limited resources result in smaller degree of overlap among sympatric
261 species before competitive exclusion occurs. This would suggest that, *C. fahirae* is the most susceptible species
262 in the presence of invasive *C. gibelio*. However, elimination of these vulnerable species because of competitive
263 exclusion should take place slowly for the reasons given by Hubbell (2001) relating to density dependence.

264 There are different microhabitat characteristics along the river and depending on their adaptations different
265 kinds of fishes respond with greater or lesser foraging niche width and abundance. In general, and despite
266 having a small isotopic niche area than *C. gibelio*, *S. cii* is abundant probably due to its better adaptability to any
267 particular microhabitat throughout the river. *S. cii* has a generalist feeding strategy, may outcompete other
268 species under limited resource conditions (Yalçın Özdilek 2017) and is also widespread through the Biga
269 peninsula (Bakaç 2018). *C. gibelio* is also a generalist feeder and mostly utilises similar food items as *S. cii*
270 (Partal and Yalçın Özdilek 2017; Yalçın Özdilek 2017). It was notable that *C. gibelio* mostly covered at least
271 50% of the SEAc of *S. cii* and the two species compete for some foods. *S. cii* outnumbers *C. gibelio* only at the
272 upper station (Srm). However, *C. gibelio* did not outcompete *S. cii* at any other station or season. Therefore, the
273 competitive pressure of *C. gibelio* on at least the dominant fish species, *S. cii*, is not as large as expected. On the
274 other hand the river provides many suitable microhabitats for both fish species with their high spatial and
275 temporal dietary plasticity.

276 *C. gibelio* has a wide diet compared to native species in the Karamenderes river (Partal and Yalçın Özdilek
277 2017), so some degree of isotopic niche overlap with other freshwater fish is expected. In this study the isotopic
278 overlaps were assessed for fish of all length groups combined and there is a lack of data regarding possible
279 length-based niche overlaps between fish species. However, the degree of overlap may vary according to length
280 groups; Specziar & Rezsü (Specziar and Rezsü 2009) reported that *C. gibelio* diet overlapped only with 41–120
281 mm *Rutilus rutilus*. Studies of possible size-specific overlap will be required to understand fully the competitive
282 interactions between *C. gibelio* and the native freshwater fish species. *C. carpio* is another species which is
283 regularly introduced into the Bayramiç Dam which is a potential site for entry of *C. gibelio* to the lower sections
284 of the river system. *C. carpio* and *G. holbrooki* are not common in the river system and the abundances of these
285 species were very low (*Cc*, 6.1% in Ahm 3.4% in Klf and *Gh*, 3.4% in Klf). The high isotopic niche area *C.*
286 *gibelio* with the low degree of overlap might be explained by high competition with these introduced species.

287 *C. gibelio* has herbivore-omnivore characteristics and the trophic position of *C. gibelio* is lower than that of the
288 other dominant fish species such as *S. cii*, *B. oligolepis* and *A. cf attalus* (Yalçın Özdilek and Jones 2014).
289 Therefore, the population of *C. gibelio* might be regulated by piscivore species such as *A. anguilla* at the river
290 mouth stations. The large mean fork length of *C. gibelio* recorded at the KKa and Kkop stations might support
291 this finding being a consequence of size-dependent prey selectivity by piscivore species on small *C. gibelio*
292 species. If we can assume *C. gibelio* is a potential prey for European eel, even though no data in this study can
293 be used to support that assumption, the decreasing trend in *A. anguilla* populations (ICES 2016) might be
294 advantageous for *C. gibelio* particularly at the river mouth.

295 The introduction of *C. gibelio* is assumed to arise from escapes from reservoirs, and the Ahm station is the
296 station for entrance of *C. gibelio* to the river system. The results indicate that *C. gibelio* has not successfully
297 established at these first two stations but when moving to the lower part of the river they find the most suitable
298 conditions at Klf station where they can establish by resource partitioning with the other dominant fish species
299 such as *S. cii* and *B. oligolepis* according to the maximum tolerable niche overlaps. However, at the river mouth
300 stations, very variable environmental parameters, such as conductivity, restricts survival of the freshwater fish
301 species and the more tolerant *C. gibelio* can occupy the resulting vacant niche space, outcompeting or sharing
302 the resources with the transition fish species in terms of resource partitioning.

303 In addition to typical advantages for successful invasion, the wide isotopic niche area and competition ability of
304 *C. gibelio* was assessed in this study. Less than a decade from the first introduction into the river system (Yalçın
305 Özdilek 2008) may be too soon to see the full potential impact of this species on the native river fish community
306 in terms of any extinction of species compared to previous data (Sarı et al. 2006). However, it is clear that *C.*
307 *gibelio* has an important functional role in the community dynamics, having high dominance, high niche area
308 and some degree of niche overlap with many freshwater and transitional fish species, including new
309 introductions. We suggest that the different microhabitat characteristics of the river system should be maintained
310 and long-term monitoring studies are needed for the river management plan.

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467 **FIGURE CAPTIONS**

468 **Fig. 1** The study area showing the Karamenderes River and the sampling stations (Changed from Partal and
469 Yalçın Özdilek 2017)

470 **Fig. 2** The range of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of four species collected from Klf and Kkop for three seasons
471 combined (Cg: *C. gibelio*, Sc: *S. cii*, Bo: *B. oligolepis*, Ra: *R. amarus*)

472 **Fig. 3** Trophic niche widths and overlaps of native fish species and invasive *C. gibelio* along the Karamenderes
473 River. (Black, *C. gibelio*; red, *S. cii*; green, *B. oligolepis*; cyan, *A. cf. attalus*; darkviolet, *C. carpio*; blue, *G.*
474 *kovatschevi* ; grey, *R. amarus*; midnightblue, *G. holbrooki*; orange, *L.ramada*; slateblue, *M. cephalus*; pink, *P.*
475 *flesus*)

476 **Fig. 4** The abundance and isotopic overlap relationships of fish species at different *C. gibelio* abundances. (a)
477 These species had significantly larger SEA.B values than that of *C. gibelio*. (b) These species had significantly
478 smaller SEA.B values than that of *C. gibelio*. The circle indicates freshwater fish species which have low
479 abundance and low overlap with *C. gibelio*

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497 **TABLE CAPTIONS**

498 **Table 1.** The mean fork length with standard deviation of invasive *C. gibelio* and some habitat characteristics
499 of water along Karamenderes River (N, number of specimens used for SIA analysis; FL, fork length; G, gillnet;
500 C, cast net; F, fykenet; E, electrofishing)

501 **Table 2.** The SEAc and TA of fish species in three seasons along the Karamenderes River (N%: Percentage of
502 abundance of species, N: number of specimens used in analysis)

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504 **Table 3.** The significant values of statistical test results from comparisons of *C. gibelio* SEA.B with the other
505 fish species and the overlap degrees of each species with *C. gibelio* are indicated in parentheses. *S. cii* (*Sc*);
506 *B. oligolepis* (*Bo*); *A. cf. attalus* (*Acfa*); *C. carpio* (*Cc*); *G. kovatschevi* (*Gk*); *C. fahirae* (*Cf*); *R. amarus* (*Ra*); *G.*
507 *holbrooki* (*Gh*); *L. ramada* (*Lr*); *L. aurata* (*La*); *M.l cephalus* (*Mc*); *C. labrossus* (*Cl*) and *P. flesus* (*Pf*)

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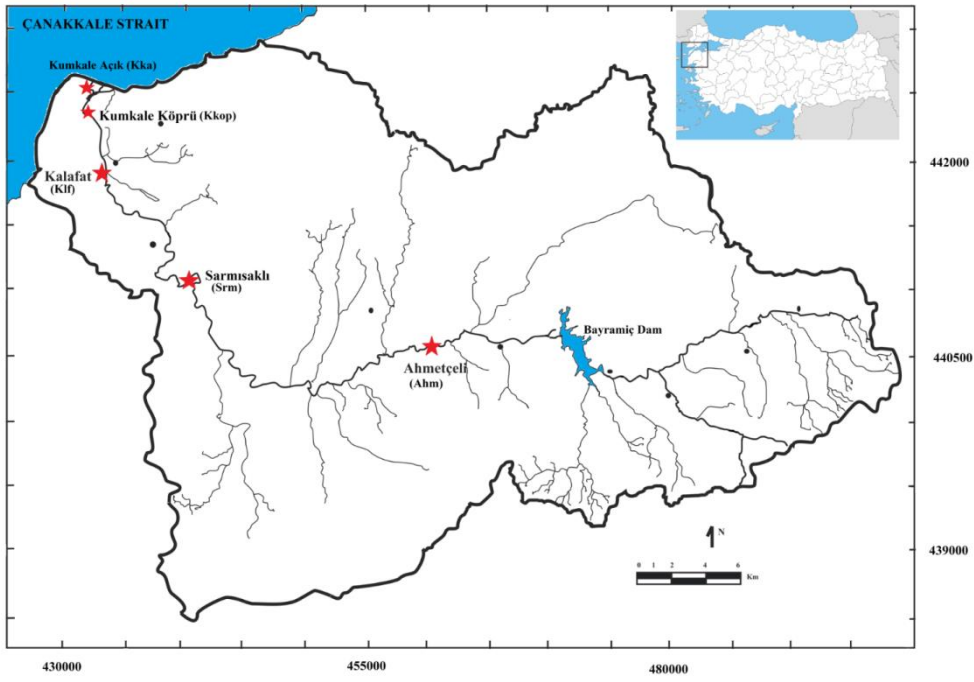
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531 **Fig. 1**

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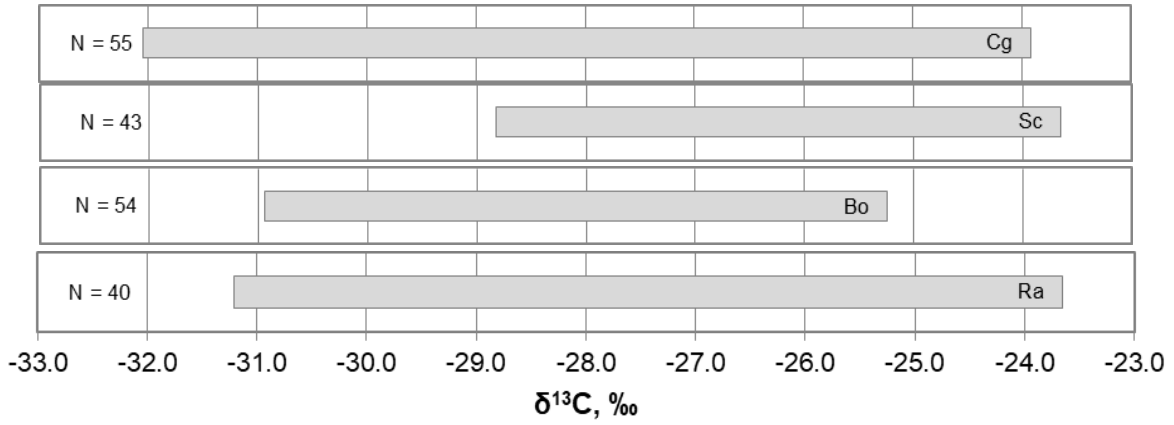
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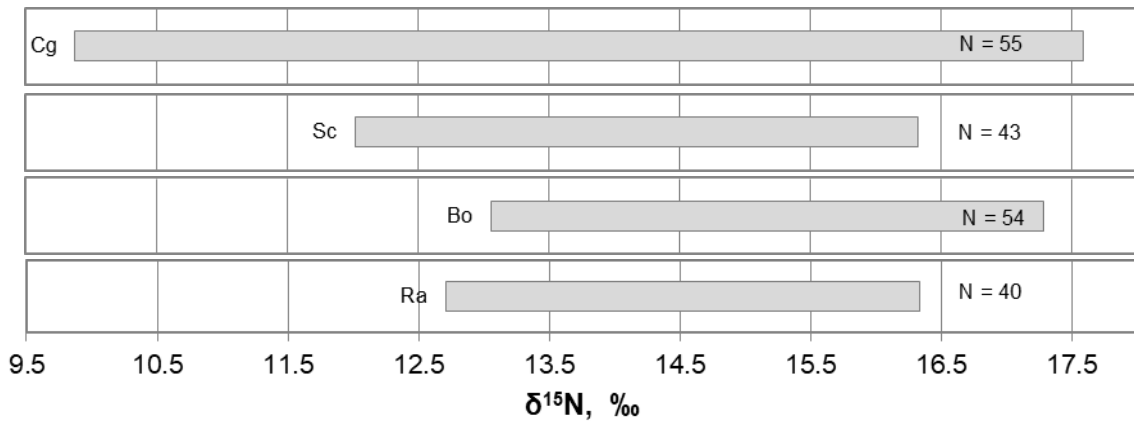
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560 **Fig. 2**

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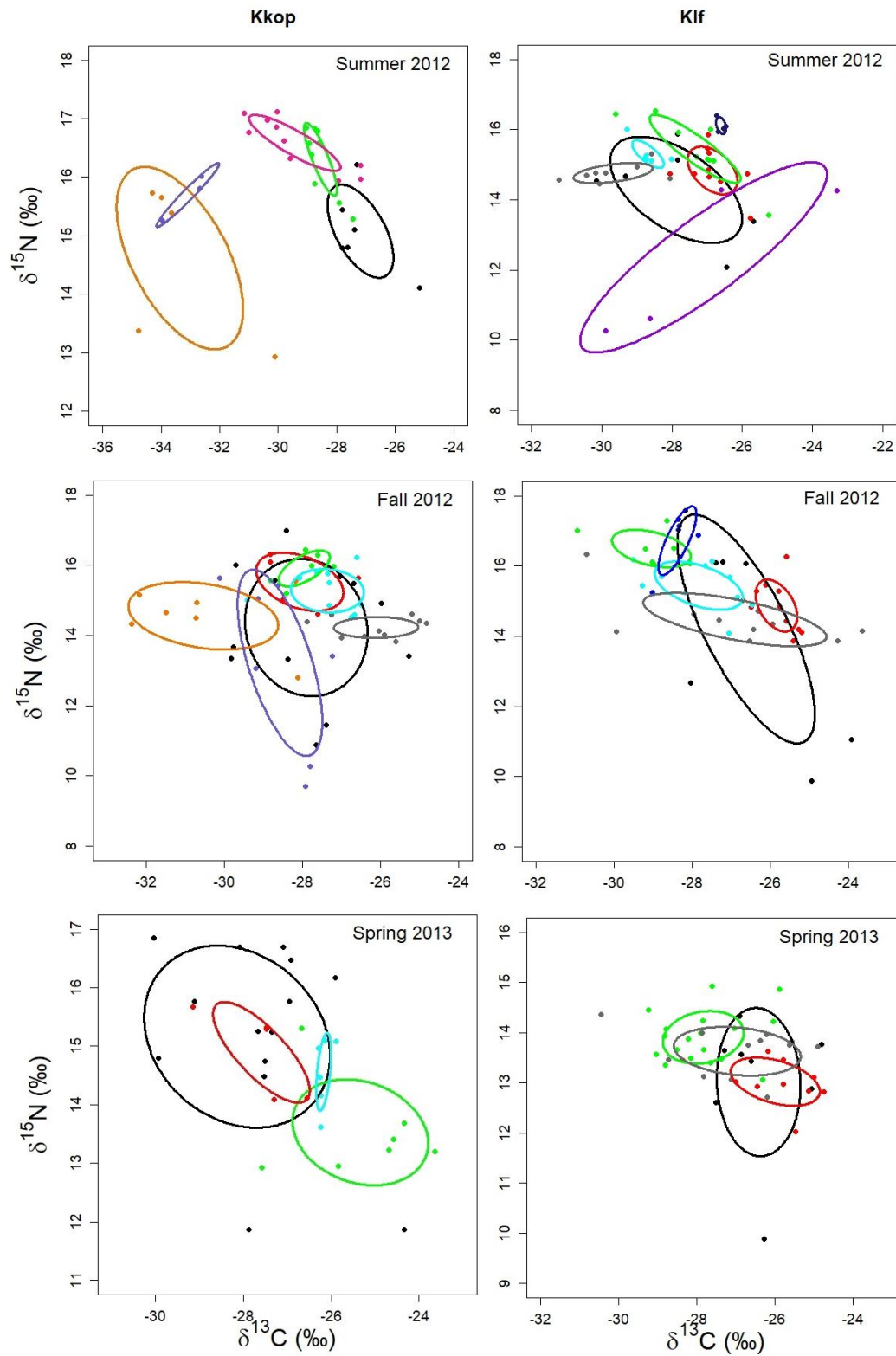
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568 **Fig. 3**

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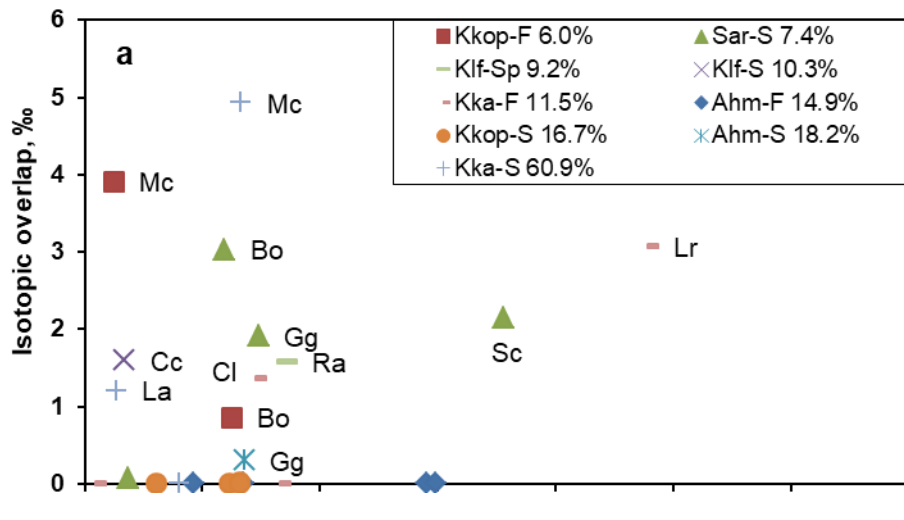
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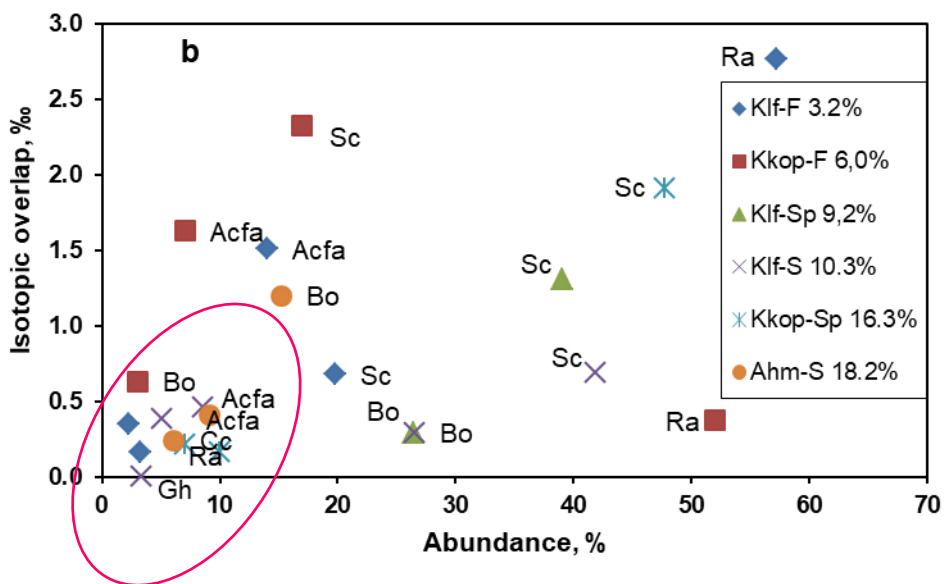
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587 **Fig. 4**

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598 **TABLES**599 **Table 1.**

Season	Stations	Gear	Mean FL	± sd	T, °C	DO, mgL ⁻¹	C, µScm ⁻¹
Summer 2012	Ahm	C	5.1	± 0.55	20.3	11.6	320
	Srm	F,G	7.6	± 1.8	25.6	6.6	458
	Klf	F,G,E	11.4	± 6.98	24.4	5.8	611
	Kkop	G	18.1	± 2.99	25.7	6.0	871
	KKa	G,F	21.4	± 3.17	25.0	7.2	6730
Fall 2012	Ahm	E	6.3	± 0.5	14.5	8.4	640
	Klf	E	9.9	± 1.74	22.4	8.6	648
	KKop	E,G	7.2	± 1.61	17.7	8.2	647
	KKa	G	17.1	± 3.18	14.0	7.8	1019
Spring 2013	Klf	E	19.0	± 3.86	21.1	8.7	502
	Kkop	E,G	24.2	± 3.86	21.7	7.4	610

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Station	Species	Summer 2012				Fall 2012				Spring 2013			
		N%	N	SEAc	TA	N%	N	SEAc	TA	N%	N	SEAc	TA
Ahm	<i>A. cf atalus</i>	9.1	6	1.3	1.4	1.4				-	7	1.7	2.0
	<i>B. oligolepis</i>	15.2	10	2.5	4.1	9.2	9	7.7	11.2	3.4	7	3.8	4.5
	<i>C. carpio</i>	6.1	4	0.4	0.2	0.7				-			
	<i>C. fahirae</i>	4.6	6	2.4	2.5	29.8	10	1.3	2.2	5.1	7	1.3	1.3
	<i>C. gibelio</i>	18.2	10	4.7	7.3	14.9	10	2.1	3.0	-			
	<i>G. kovatschevi</i>	13.6	6	2.9	3.1	13.5	10	5.8	8.1	35.7	7	1.7	2.0
	<i>R. amarus</i>	3.0				1.4				1.7	2		
	<i>S. cii</i>	30.3	9	2.7	4.3	29.1	10	1.8	3.4	54.0	16	2.8	6.6
Srm	<i>A. cf attalus</i>	-				1.4	6	0.5	0.5	5.5	1		
	<i>B. oligolepis</i>	11.9	9	6.8	11.7	12.7	9	5.2	7.3	12.7	7	3.5	4.3
	<i>C. fahirae</i>	3.7	5	0.5	0.5	1.6	7	0.8	1.0	16.4	2		
	<i>C. gibelio</i>	7.4	10	3.5	6.8	0.2				1.8	1		
	<i>G. kovatschevi</i>	14.8	10	3.2	5.2	14.3	10	3.2	5.0	-			
	<i>G. holbrooki</i>	8.2	-			-				-			
	<i>R. amarus</i>	17.0	-			34.4	10	4.1	7.6	7.3			
	<i>S. cii</i>	35.6	10	3.3	5.4	35.3	10	5.2	10.4	56.4	26	3.1	11.3
Klf	<i>A. cf attalus</i>	5.0	6	0.3	0.4	14.0	10	2.1	3.5	8.1			
	<i>B. oligolepis</i>	26.1	9	1.6	3.3	3.2	7	1.5	1.9	26.4	18	1.7	4.8
	<i>C. carpio</i>	3.4	4	9.7	8.0	0.5				-			
	<i>C. gibelio</i>	10.1	6	6.0	7.7	3.2	7	12.0	15.1	9.2	8	5.0	6.7
	<i>G. kovatschevi</i>	0.8				2.3	5	1.0	0.7	-			
	<i>G. holbrooki</i>	3.4	4	0.1	0.1	-				-			
	<i>R. amarus</i>	8.4	8	0.8	1.3	57.2	10	4.3	8.2	17.2	12	2.4	4.1
	<i>S. cii</i>	41.2	10	1.2	2.6	19.8	11	1.1	1.7	39.1	10	1.6	2.8
KKop	<i>A. cf attalus</i>	-				7.0	10	1.8	2.6	7.0	16	0.3	0.3
	<i>B. oligolepis</i>	13.2	9	0.6	0.8	3.0	6	0.8	0.9	10.0	7	1.9	1.5
	<i>C. fahirae</i>	-				-				1.2			
	<i>C. gibelio</i>	16.7	6	2.3	2.2	6.0	12	9.6	16.6	16.3	6	10.1	25.7
	<i>L. aurata</i>	0.9				12.5				1.2	1		
	<i>L. ramada</i>	6.1	5	8.8	5.9	-	7	5.6	7.4	2.3	1		
	<i>M. cephalus</i>	12.3	5	15.0	10.7	2.5	7	7.0	7.6	3.5	-		
	<i>P. flesus</i>	13.2	10	1.1	2.0	-				-			
	<i>R. amarus</i>	-				52.0	10	1.0	1.7	-			
	<i>S. cii</i>	37.7				17.0	5	2.7	2.1	47.7	5	4.3	4.7
KKa	<i>A. cf attalus</i>	-				1.0				-			
	<i>B. oligolepis</i>	-				1.0				-			
	<i>C. gibelio</i>	60.9	21	10.9	13.8	11.5	10	9.0	14.7	4.1			
	<i>C. labrosus</i>	-				14.6	4	2.9	1.8	-			
	<i>M. cephalus</i>	13.3	4	34.7	18.5	16.7	7	14.8	7.0	13.5			
	<i>L. aurata</i>	2.7				1.0	4	12.0	14.6	10.8	9	4.6	7.2
	<i>L. ramada</i>	8.0	7	4.9	15.2	47.9	6	14.5	16.6	8.1			
	<i>C. saliens</i>	-				-				14.9	11	3.2	6.1
	<i>P. flesus</i>	4.6	3			1.0				1.4			
	<i>S. cii</i>	-				5.2	6	0.9	0.7	-			

Season	Station	Native freshwater fish species						Introduced species		Transition fish species				
		<i>Sc</i>	<i>Bo</i>	<i>Cf</i>	<i>Acfa</i>	<i>Gk</i>	<i>Ra</i>	<i>Cc</i>	<i>Gh</i>	<i>Lr</i>	<i>La</i>	<i>Mc</i>	<i>Cl</i>	<i>Pf</i>
Summer - 2012	Ahm	0.07 (0.97)	0.05 (1.2)	0.07 (0.18)	0.03 (0.41)	0.18 (0.30)		0.05 (0.24)						
	Sar	0.42 (2.14)	0.86 (3.03)	0.09 (0.07)		0.40 (1.91)								
	Klf	0.01 (0.69)	0.05 (0.29)		0.01 (0.38)		0.02 (0.46)	0.80 (1.60)	0.03 (<0.01)					
	Kkop		0.10 (0.03)							0.93 (0.00)		0.54 (0.00)		0.38 (<0.01)
	Kka									0.71 (0.00)	0.89 (1.21)	1.00 (4.93)		
Fall - 2012	Ahm	0.45 (<0.01)	0.99 (0.00)	0.32 (0.00)		0.98 (<0.01)								
	Klf	<0.001 (0.68)	<0.001 (0.16)		<0.001 (1.51)	0.01 (0.35)	0.05 (2.77)							
	Kkop	0.03 (2.33)	<0.001 (0.63)		<0.001 (1.63)		<0.001 (0.37)			0.13 (0.86)		0.28 (3.91)		
	Kka	0.01 (<0.01)								0.78 (3.07)	0.69 (<0.01)	0.66 (<0.01)	0.06 (1.37)	
Spring - 2013	Klf	0.05 (1.31)	0.02 (0.29)				0.15 (1.58)							
	Kkop	0.04 (1.91)	0.01 (0.16)		<0.001 (0.21)									

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