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Predation of European catfish on anadromous fish species in an anthropised area

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Abstract. Increases in both food availability and intraspecific competition downstream of dams have the potential to trigger the emergence of trophic specialisation among fish predators, with considerable implications for prey species populations. The aim of this study was to assess whether the presence of a dam located on the River Garonne (France) affected the dietary preference of the European catfish *Silurus glanis* towards anadromous prey. Stable isotope analysis showed that the contribution of marine-derived carbon in the diet of the European catfish was substantial (on average 53% of the diet) and was similar between individuals caught downstream of the dam and those caught from the free running part of the river. In contrast with previous studies, a significant relationship between the size of European catfish individuals and their consumption of marine-derived nutrients was found in this study. Anadromous fish populations are in decline; therefore, this significant predation is concerning.

Additional keywords: fresh water, introduced species, marine, stable isotopes.

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Introduction

Interruptions to the longitudinal connectivity in rivers have long been recognised as a serious menace for anadromous species populations by preventing breeding adults to reach spawning grounds (Collins 1976; Wohl 2012). Dams are also suspected to reduce the survival of migrating organisms by increasing predation pressure, either by increasing prey residence time and predator density and therefore predator encounter rate or by decreasing the ability of the prey ability to escape predators (Young and Cech 1994; Baumgartner 2007; Agostinho *et al.* 2012; McLaughlin *et al.* 2013). Increases in food resource availability and intraspecific competition observed downstream of dams have the potential to trigger the emergence of trophic specialisation among consumers (Baumgartner 2007; Agostinho *et al.* 2012), which may have considerable implications for ecosystem functioning and populations dynamics (Bolnick *et al.* 2003; Bolnick and Araújo 2011).

Originating from Eastern Europe and Western Asia, the European catfish *Silurus glanis* L. 1758 has now spread to some western and southern European countries, as well as outside Eurasia, due primarily to illegal introductions for recreational angling (Cucherousset *et al.* 2018). The European catfish is a true generalist predator that can exhibit short-term individual trophic specialisation through foraging on non-aquatic birds (Cucherousset *et al.* 2012) and small mammals (Copp *et al.* 2009) thanks to the ability of some individuals to learn and use new and difficult-to-catch food sources (Vejřík *et al.* 2017). Recently, it was reported that a few specialised catfish individuals were able to adapt their behaviour to predate adult Atlantic salmon inside a fishway (Boulêtreau *et al.* 2018). In some French rivers where European catfish have established self-sustaining populations (Poulet *et al.* 2011; Guillerault *et al.* 2015), the species has been observed to aggregate downstream of dams and weirs during anadromous species runs (Fig. 1). In the River Garonne in France, stable isotope analysis (SIA) has revealed that anadromous fish significantly contribute to catfish diet (more than 50% for some individuals; Syväranta *et al.* 2009). DNA analysis of catfish faeces has also revealed that almost all the anadromous species of the River Garonne (Atlantic salmon, twait shad, thinlip grey mullet and sea lamprey) were predated by catfish (Guillerault *et al.* 2017).

The aim of this study was to determine whether the presence of a dam increased the contribution of anadromous organisms to the diet of European catfish. We hypothesised that the diet of catfish individuals caught near the dam would contain more marine-derived carbon than the diet of individuals caught in the free running part of the same river.

Materials and methods

European catfish and potential prey were caught concurrently in two stretches of the River Garonne (south-western France; for more details regarding the river, see Syväranta *et al.* 2009). The dam site is the first barrier for upstream migration of anadromous species and is located ~250 km from the sea, near the Golfech power plant (0°55′22.3″E, 44°06′37.6″N). The dam site

Fig. 1. Aggregation of European catfish observed downstream the Golfech dam on the River Garonne (photo credit: F. Santoul).

Table 1. Effects of the presence of the dam, European catfish body length and sampling date on the proportion of marine prey in European catfish diet in the River Garonne

Significant *P*-values ($\alpha = 0.05$) are in bold. TL, total length

Variable	Parameters	d.f.	Estimate	s.e.	*t*-value	*P*-value
Marine prey (%)	Site (control)	1, 63	0.023	0.034	0.69	0.491
	log(TL)	1, 62	1.194	0.253	4.72	**<0.001**
	Date	1, 61	0.0004	0.0003	1.31	0.193
	Intercept	60	−2.251	0.578	−3.89	**<0.001**

consists of two connected river channels bounded by dams (the power plant tailrace and the diversion canal), in which catfish are known to make regular nocturnal and diurnal movements based on a radio-acoustic telemetry study (Coustillas 2007). The dam site was compared with a river stretch located 20–50 km downstream of the dam (0°19′56.6″E, 44°18′50.7″N) where fish composition and density were comparable to that at the dam site (long-term electrofishing survey; see Table S1, available as Supplementary material to this paper). Because catfish are sedentary with high site fidelity (Carol *et al.* 2007; Slavík *et al.* 2007), we considered that no fish moved from one site to another during the study period.

Seventy-four catfish individuals (mean ± s.d., size 179 ± 27 cm; range 132–230 cm) were collected by local anglers with baits or lures ($n = 32$ at the dam site; $n = 32$ at the control site; no difference in body size between sites) from mid-March to the end of August 2013 (i.e. during the migration period of anadromous species and until August to integrate potential effects of seasonality and isotope turnover of fish fins). Freshwater prey were collected using baited hook or trap nets and consisted of common bream (*Abramis brama* L., 1758), bleak (*Alburnus alburnus* L., 1758), common barbel (*Barbus barbus* L., 1758) and carp (*Cyprinus carpio* L., 1758) at the dam site ($n = 5$; Table S2 in the Supplementary material). At the control site, the freshwater prey consisted of common bream (*A. brama* L., 1758), bleak (*A. alburnus* L., 1758) and chub (*Squalius cephalus* L., 1758; $n = 4$). Anadromous prey were collected using trap nets or trammel nets and consisted of sea lamprey (*Petromyzon marinus* L., 1758; $n = 3$) at the control site and allis shad (*Alosa alosa* L., 1758; $n = 2$) at the dam site. The total length (TL) of catfish was measured to the nearest centimetre and a pectoral fin clip was collected for SIA. After handling, catfish were released back into the river.

Fin samples were oven dried (60°C, 48 h) and analysed at the Cornell isotopes laboratory (Cornell University, New York, NY, USA) for SIA of carbon and nitrogen. Data were corrected using working standards (fish tissue, mink tissue and methionine s.d. < 0.2‰ for both $\delta^{13}C$ and $\delta^{15}N$) that were previously calibrated according to International Atomic Energy Agency standards. No lipid correction was performed because samples have low and homogeneous ratios (mean ± s.d., 3.1 ± 0.1). A Bayesian mixing model (the Stable Isotope Analysis in R package (SIAR); Parnell *et al.* 2010) was used to estimate the contribution of freshwater and marine prey to the diet of each individual European catfish (median of the 500 000 iterations per individual) in each site, using the commonly reported fractionation factors (±s.d.) estimated at 1 ± 1 and 3.4 ± 1.0 for $\delta^{13}C$ and $\delta^{15}N$ respectively (Inger *et al.* 2010; Cucherousset *et al.* 2012) and using the mean ± s.d. freshwater source stable isotope signature corresponding to each site ($n = 5$ at the dam site, $n = 4$ at the control site). The marine prey from both sites was pooled to produce one mean ± s.d. stable isotope value ($n = 5$). Effects of sampling site (dam site or control site), body size (TL) and sampling date on the mean contribution of marine prey to catfish diet were tested using linear models. Each model was initially fitted with log-transformed size, sampling date and sampling site as fixed predictors. The interaction terms were subsequently removed when not significant (Crawley 2012). Statistical analyses were performed using R (ver. 3.1.0, R Foundation for Statistical Computing, Vienna, Austria).

Results and discussion

We observed no significant effect of the dam on the contribution of marine prey to catfish diet ($P > 0.05$; Table 1). It may be that European catfish exhibit non-selective predation on all prey species, freshwater or anadromous, gathering downstream of the dam. Moreover, we observed no significant effect of the sampling date on the contribution of marine prey ($P > 0.05$; Table 1), confirming no bias of sampling on isotope values. The mean ± s.d. $\delta^{15}N$ of freshwater prey at the control and dam sites was 13.2 ± 1.0 and 12.7 ± 0.4‰ respectively, whereas the mean ± s.d. $\delta^{15}N$ of anadromous prey was 12.5 ± 0.5‰ (Fig. 2; Table S2). The mean ± s.d. $\delta^{13}C$ of anadromous prey was over 5‰ higher than that of freshwater prey, with values of −21.9 ± 1.3‰ for freshwater prey at the control site and −23.2 ± 1.4 and −16.7 ± 0.9‰ for anadromous prey at the control and dam sites respectively, allowing clear distinction between each type of prey (Fig. 2; Table S2). The mean ± s.d. $\delta^{15}N$ of European catfish was 15.8 ± 0.6‰ (range 14.7–17.1‰), whereas the mean ± s.d. $\delta^{13}C$ was −18.7 ± 1.7‰ (ranging from −23.3 to −16.4‰), revealing a wide dietary spectrum for catfish in the River Garonne (Fig. 2). Catfish are known to consume invertebrate prey (molluscs and crayfish), cyprinids and anadromous fish (Syväranta *et al.* 2009, 2010).

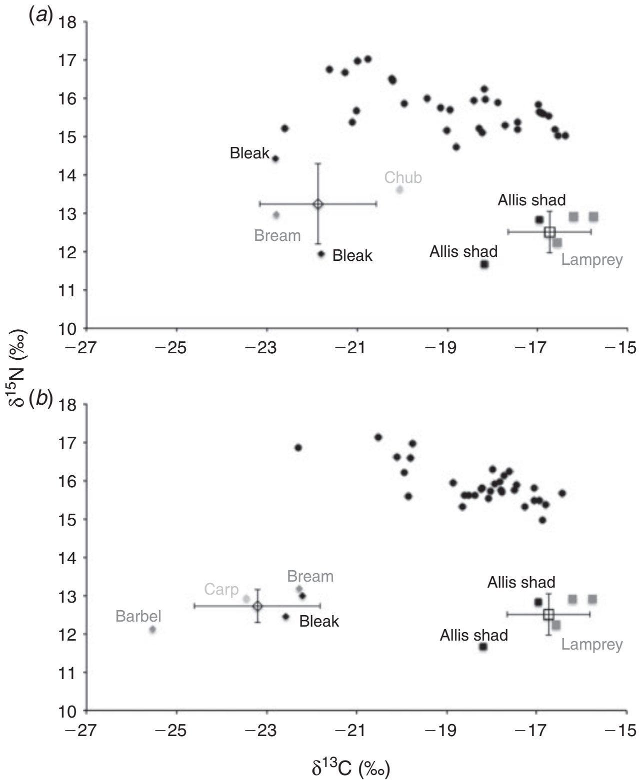

Fig. 2. Stable isotope values (δ^{13}C and δ^{15}N) of European catfish individuals (closed black circles), freshwater fish prey (closed diamonds) and marine fish prey (closed squares) at the (*a*) control and (*b*) dam sites. The large symbols for each type of prey (freshwater and marine) represent the mean ± s.d.

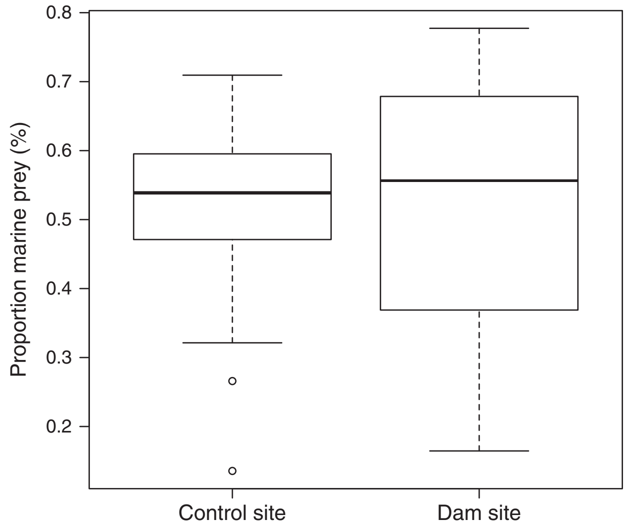

Fig. 3. Predicted proportions of marine prey in the diet of European catfish at the control and dam sites. Boxes show the interquartile range, with the median value indicated by the horizontal line. Whiskers indicate minimum and maximum values and outliers are indicated by open circles.

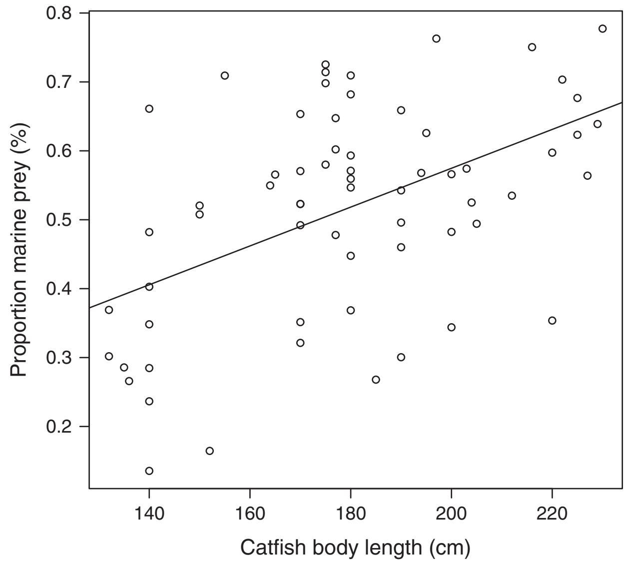

Fig. 4. Regression between the predicted proportion of marine prey in the diet of European catfish and its body size.

Some terrestrial vertebrates, primarily birds and small mammals, have also been reported to contribute to the diet of catfish (Copp *et al.* 2009; Cucherousset *et al.* 2012), as have plants (Vejřík *et al.* 2017).

The mean (±95% confidence limits) proportion of marine prey in the catfish diet (64 fish), estimated by the mixing model, was 0.52 (0.48–0.55), with minimum and maximum individual proportions that varied widely from 0.14 to 0.78 (Fig. 3). These results are in accordance with the previous calculated proportions from 21 European catfish in the River Garonne reported by Syväranta *et al.* (2009). The similar and progressive evolution of the proportion of marine prey in individual catfish diets at both sites does not show individual catfish specialisation on anadromous prey (Fig. 2). However, the contribution of marine prey to the diet increased significantly with catfish TL ($P < 0.001$; Table 1; Fig. 4; $y = 0.0028x + 0.0111$, $R^2 = 0.25$). In contrast with the results of Syväranta *et al.* (2009), the present study highlights an effect of catfish size on marine-derived nutrient consumption in the same river. This could be explained by a better sampling effort in the present study (number and size range of fish). Larger and dominant individuals presumably exploit most profitable resources (Fretwell 1972; Bernstein *et al.* 1988; Ruxton *et al.* 1999; Svanbäck and Bolnick 2007; Araújo *et al.* 2011), such as anadromous prey.

Conclusion

Contrary to our expectations, the presence of the dam did not increase either the mean proportion of marine carbon or the individual trophic specialisation of European catfish towards anadromous species. Even though the presence of the dam may not affect per capita consumption of anadromous species by catfish, it could still influence predation pressure on anadromous species due to the increase in catfish density downstream of the dam (Baumgartner 2007; Agostinho *et al.* 2012; Schmitt *et al.* 2017). Nevertheless, the high proportion of marine prey in the European catfish diet, observed at both sites in this study, is concerning, especially given the strong decline of these anadromous species.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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