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Effects of weir construction on fish population structure in the River Erro (North of Spain)

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In 1996, a compound gauging weir was built in Villaveta Township (Navarra, North of Spain) in the river Erro (Ebro River Basin). Before and after its construction, fish and physical and chemical variables were examined to determine weir's impact on the reach. Fish captured by electrofishing were measured (total length), and population density and length distribution of the species were estimated. Species diversity (Shannon's diversity index), dominance (Simpson's dominance index) and evenness were also calculated. The results revealed an increase in fish population density, especially in smaller specimens, but a decrease in the larger fishes. Substrate and shelter alterations could explain the observed variations in the fish community. In order to improve the consolidation of well-developed fish populations, the placement of great boulders and the restoration of the riparian vegetation are suggested.

Keywords : compound gauging weir, habitat modification, abundance, assemblage structure.

Introduction

The construction of water retention structure can create serious modifications to riverine habitats and, as a consequence, affect fish populations (Schlosser & Ebel 1989, Jurajda 1995) and other biota in rivers (Jacobsen 1998, Pardo et al. 1998). River channelisation and the destruction of riparian and submerged vegetation are some of the main reasons for the decline of some fish populations (Lusk 1996). Moreover, these structures constitute an obstacle to fish migration (Lucas & Frear 1997) and, as a result, affect population structure.

The main problem regarding the analysis of effects of human modifications of river systems is the absence of data from the affected reach prior to the alteration (Bain et al. 2000). The usual alternative is the comparison of the already altered section with other similar non-modified areas (Englund & Malmqvist 1996, Fjellheim & Raddum 1996, Pilcher et al. 2004).

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The aim of the present study was to compare the habitat character and size structure of the fish populations in the River Erro before and after the construction of a compound gauging weir (Fig. 1). to identify the most important changes in the fish fauna, to identify the probable reasons for these alterations, and to propose possible solutions for the optimal development of fish populations in the river.

Material and methods

A tributary of the River Irati, the River Erro is characteristic of the western Pyrenean Valleys, flowing for 48.5 km north to south, through the Erro River Valley (Navarra, Spain) and draining an area of approximately 214 km^2 (Fig.1). River discharge is greatest from November to April, with winter maximums related to oceanic rains. These progressively decrease in importance during spring when melt-water replaces them.

The studied area is an iberian cyprinid zone (García de Jalón & González del Tánago 1983) situated approximately 2.6 km away from the river confluence with the River Irati, where river slope was 0.29%, ele-

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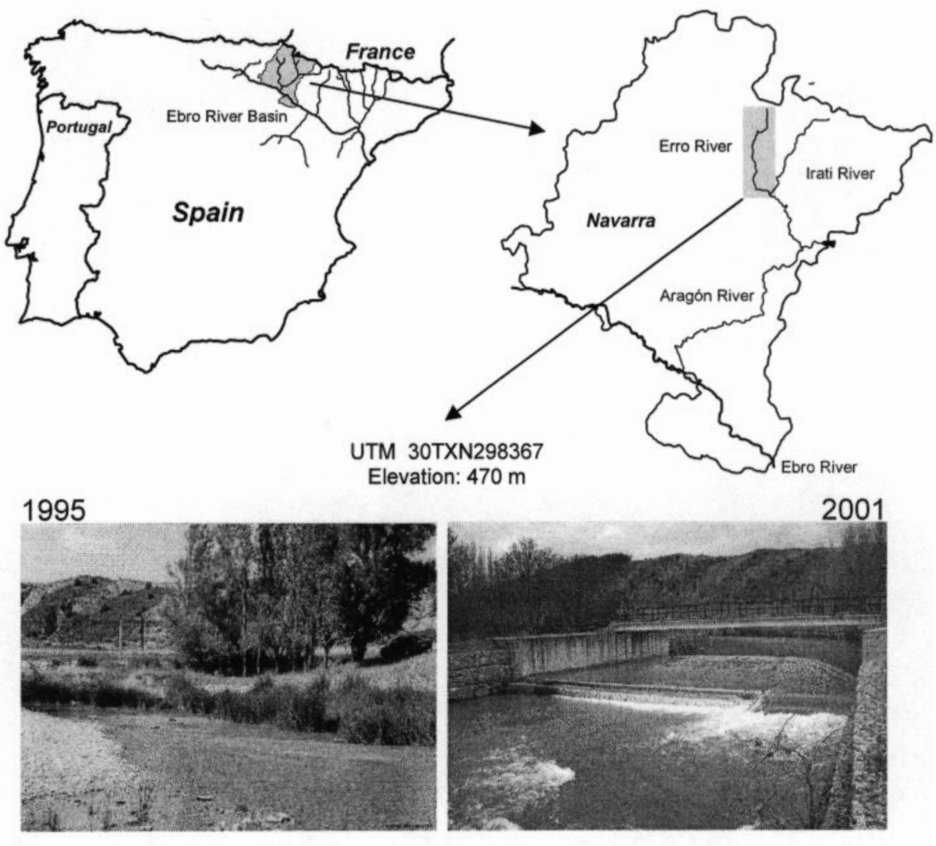

Fig. 1. Map of the Ebro River Basin and Navarra in the Iberian Peninsula (left) and the River Erro in Navarra (right). The pictures show the studied reach before (1995, left) and after (2001, right) the construction of the compound gauging weir.

vation 470 m.a.s.l. and the flooding width was about 375 m prior to weir construction.

The riparian vegetation of the sampling site was dominated by deciduous species (*Salix sp., Populus nigra* L.), with reed (*Scirpus* sp.) and bulrush (*Typha* sp.) constituting the emergent vegetation. During the construction of the compound gauging weir in 1996, the riparian and aquatic vegetation were removed.

Sampling was undertaken in the downstream reach of the compound gauging weir before (July 1995) and just after (August 1997) weir construction, and then in August 2001. The compound gauging weir consists of a 5 m long low flow section and a 16 m long high flow section.

Fish were captured by three-run depletion electrofishing between two stop nets (Lobón-Cerviá 1991). Fish collected on each run were processed separately. All the specimens were identified, measured (total length (TL) to the nearest mm) and released into the river. The same work-team and electrofishing gear were used in all surveys.

Nine habitat variables were measured along four transects using the transect-point method (Simonson et al. 1993) : water physical and chemicals (temperature (°C), conductivity ($\mu S \cdot cm^{-1}$), dissolved Oxygen ($mg \cdot l^{-1}$) and pH), water current velocities ($m \cdot s^{-1}$) at 0.6 depth, river width (m) and depths (cm), with substrate type and vegetation estimated visually.

Fish population estimates were made according to Lelek (1974), because of its simplicity and high precision (Lobón-Cerviá 1991). Fish densities for each species (number of specimens per 100 m^2) and for each body length interval were also estimated. Subsequently, species diversity (Shannon's diversity index $H'=-\sum p_i \log_2 p_i$), dominance (Simpson's dominance index $D= \sum p_i^2$) and evenness ($E=H'/\log_2 S$) were calculated, where pi is the proportion of species «i» at a given site and S is the number of species (Margalef 1980). Al-

Table 1. Habitat characteristics, physical and chemical variables measured in the sampling reach in 1995, 1997 and 2001. Substrate classes described by Platts *et al.* (1983). (-) Absent, (+) low, (++) moderate, (+++) very abundant.

Physical & chemical variables	1995	1997	2001	Substrate classes	1995	1997	2001
Water temperature (°C)	21.9	21.4	23.4	Fines (<2 mm)	-	-	-
Conductivity (µS·cm^{-1})	435	475	403	Gravel (8-64 mm)	-	+	+
Oxygen (mg·l^{-1})	9.9	9.95	9.43	Cobbles (64-256 mm)	+	++	++
pH	7.96	8.33	8.23	Boulders (>256 mm)	-	++	++
Length (m)	90	31	28	Bedrock	+++	+++	+++
Width (m)	11.03	17.73	21.45	Pools	-	+	+
Depth (cm)	22.0	15.5	21.17	Riparian vegetation	+	-	-
Area (m^2)	993	550	601	Emergent vegetation	+++	-	+
Average velocity (m·s^{-1})	0.36	0.15	0.17				

though fish species reach different sizes and have different growth rates, the densities of all the species were pooled and compared in order to check whether a certain length class was favoured by the new habitat features.

Results

Physical and chemical variables of the water did not vary significantly during the study. Habitat features, however, experienced remarkable modification, most notably the destruction of riparian and emergent vegetation and the diversification of the substrate. Other changes implied the creation of shallow backwaters with low flow (Table I).

The fish assemblage was composed of three endemic Iberian species (*Barbus graellsii* Steind., *Chondrostoma miegii* Steind. and *Cobitis calderoni* Bacescu) and four other native species (*Salmo trutta* L., *Phoxinus phoxinus* (L.), *Barbatula barbatula* (L.) and *Gobio gobio* (L.)).

Estimated total fish densities in 1997 and 2001 were respectively four and five times the density obtained in 1995 (Table II). Diversity decreased in 1997 (H'= 1.83) in relation to 1995 (H'= 2.00) and increased again in 2001 (H'= 2.04). Something similar happened with the evenness index (E_{95}= 0.71; E_{97}= 0.65 ; E_{01}= 0.79), and conversely with the dominance index (D_{95}= 0.29 ; D_{97}= 0.34; D_{01}= 0.28).

Overall, a decline in fish size was observed (Fig. 2A). Young *S. trutta* (<110 mm TL) decreased in number after weir construction, and larger specimens appeared (Fig. 2B).

P. phoxinus total densities increased in 1997 compared with 1995, and smaller size classes showed a notable increase in 2001 (Fig. 3).

G. gobio and *C. miegii* densities increased substantially in all size classes after the construction (Fig.3), particularly medium sizes (40-80 mm TL for *G. Gobio* and 100-150 mm TL for *C. miegii*). In 2001, densities decreased but still were notably higher than in 1995. Despite this, a remarkable increase in small sizes (<40 mm TL for *G. Gobio* and <50 mm TL for *C. miegii*) was recorded.

Table 2. Number of fish captured (C), number of specimens estimated (N) according to Lelek (1974) and density of specimens per 100 m^2 (d) for each species and altogether.

Species	1995			1997			2001		
	C	N	d	C	N	d	C	N	d
Salmo trutta	11	13	1	5	6	1	4	5	1
Phoxinus phoxinus	261	298	30	243	270	49	1424	1735	289
Barbatula barbatula	9	10	1	200	223	40	294	358	60
Chondrostoma miegii	479	547	55	1184	1318	240	988	1204	200
Barbus graellsii	191	218	22	79	88	16	244	297	49
Gobio gobio	184	210	21	906	1008	183	523	637	106
Cobitis calderoni	1	1	0	2	2	0	0	0	0
Total	1136	1298	131	2619	2915	530	3477	4235	705

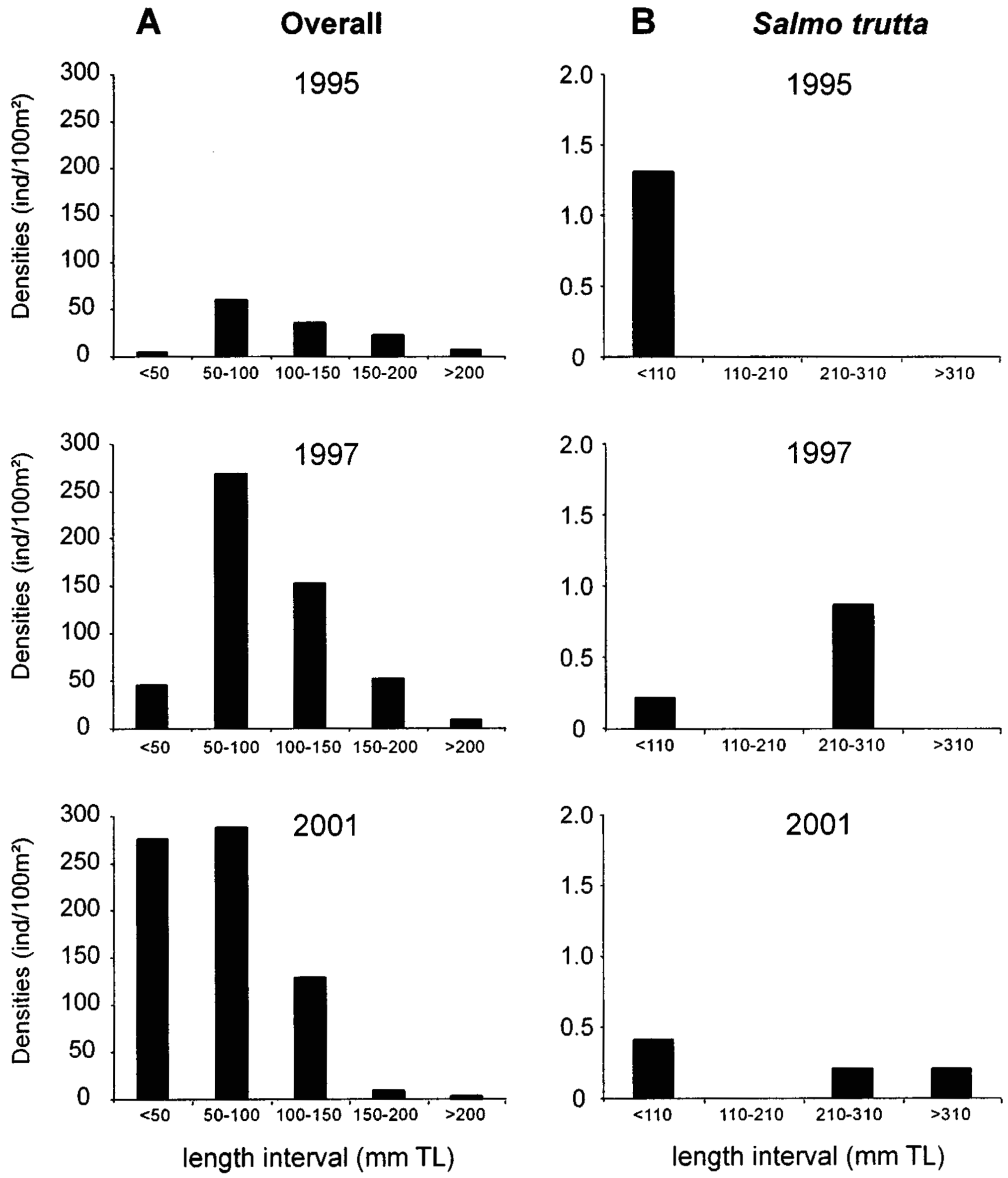

Fig. 2. Distribution of densities (N of specimens per 100 m^2) in each length interval (mm TL) for all the species as a whole (A) and *Salmo trutta* (B).

B. barbatula also underwent an important increase in 1997 (Table II) in all the size range in comparison with 1995 (Fig. 3). A new increase in total density occurred in 2001, mainly due to juveniles (<50 mm TL), in spite of the disappearance of the larger individuals.

In 1997, *B. graellsii* this species experienced a decrease in the total density, although larger barbels appeared (>350 mm TL). Nevertheless, in 2001 (Table II) its density doubled the one in 1995 and was three times the 1997 value, due mainly to a large number of smaller fish (Fig. 3). On the other hand, the density of the individuals larger than 150 mm TL decreased throughout the study (Fig. 3). One specimen of *C. calderoni* (TL= 52 mm) was captured in 1995, and two (TL= 36 mm, TL= 64 mm) in 1997 surveys, but none were caught in 2001.

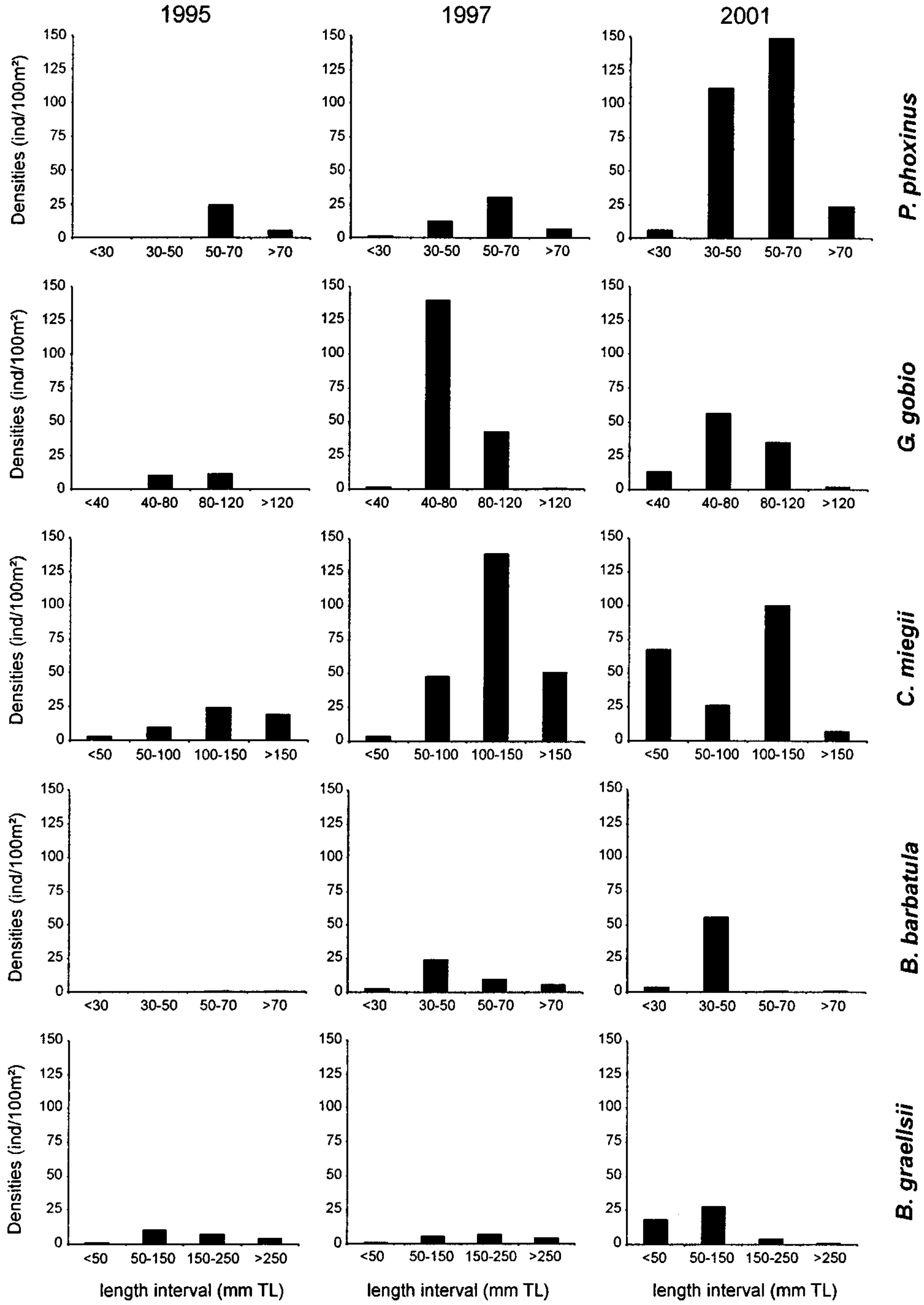

Fig. 3. Distribution of densities (N of specimens per 100 m^2) in each length interval (mm TL) for *Phoxinus phoxinus, Gobio gobio, Chondrostoma miegii, Barbatula barbatula* and *Barbus graellsii.*

Discussion

Owing to the increase of *G. gobio* and *C. miegii,* which rapidly colonised the area, H', E and D indexes changed after the construction of the compound gauging weir (1997). However, in 2001 these indexes were similar to those in 1995, as a result of the stabilisation of the affected reach.

S. trutta occurred in relatively low numbers throughout, but a shift to larger sizes was apparent (Table II, Fig. 2B). The disappearance of juveniles probably resulted from the elimination of emergent vegetation and woody debris (Langford & Hawkins 1997), which provide potential shelter and nutrient concentration area for younger trout (García de Jalón & Mayo 1996).

P. phoxinus underwent a remarkable increase throughout the studied period. The creation of shallow gravel areas with low current velocity could favour the spawning of the species in this reach (Mastrorillo et al. 1997, Mastrorillo & Dauba 1999, Miranda et al. 1999) and the establishment of small individuals (Constantinescu et al. 1984, Rabeni & Jacobson 1993).

Increase in the numbers of *G. gobio* and *B. barbatula* in 1997 may have resulted from substrate size diversification, with the appearance of cobbles, an important refuge for small benthonic fish (Mackenzie & Greenberg 1998). Another factor might be the decrease of water velocity and depth, which favours the establishment of these species (Eklov et al. 1994, Zweimüller 1995, Mastrorillo & Dauba 1999). Their generalistic nature and colonising capacity (Prenda et al. 1997) enabled the quick establishment of their populations after the construction. In 2001, the former species did not evolve in the same way. The competition and establishment of other fish species could explain the decrease of medium-sized *G. gobio* individuals (40-80 mm TL). And there is a notable increase in smaller *B. barbatula* (30-50 mm TL), probably due to the new features of the habitat fulfill species requirements (Mastrorillo et al. 1996), but with a decline in larger (>50 mm TL), perhaps due to the reasons mentioned for intermediate *G. gobio.*

C. miegii population responded in a similar manner as *G. gobio,* and possibly similar reasons could explain it. This is a lithophilous (Mann 1996) and detritivorous species, so the removal of emergent vegetation and the increase of the foraging surface might have facilitated the development of proper trophic resources.

In respect of *B. graellsii,* two different alterations were observed. On one hand, the disappearance of the largest individuals (>250 mm TL) might be explained by the elimination of suitable shelters (Linlokken 1997) and the increased shallowness (Copp & Bennetts 1996). On the other hand, the remarkable increase in the number of young-of-the-year and juveniles (<100 mm TL) may be due to the creation of optimum habitats for them.

The Iberian endemic *C. calderoni* (Doadrio et al. 1991) was captured in very low numbers in 1995, disappearing from the studied reach after the construction of the compound gauging weir, suggesting that habitat modifications pushed this vulnerable species (IUCN 2002: VU A1ace+2ce) to local extinction.

Stream canalisation and the destruction of emergent vegetation are often related to decline in fish populations (Lusk 1996). But, in the present study the weir construction had a notable increase in the species density. The creation of new shelters (calm shallow areas and small pools) and the diversification of the substrate could explain the observed increment (Shields et al. 1998, Pilcher et al. 2004).

However, fish assemblage structure has been severely altered. Considering all the species together, the impressive increase of the smaller sizes (<50 mm TL) might be because the studied stretch has become a typical breeding area for cyprinids: low depth, absence of plant cover, high exposure to the sun, low water velocity and suitable substrate, both for the development of macroinvertebrate communities and to provide shelter (Grossman et al. 1987, Schlosser & Angermeier 1990, Rabeni & Jacobson 1993, Pilcher et al. 2004). The compound gauging weir also might have a « crowding effect » on this size class.

In addition, the decrease of the largest *B. graellsii,* an endemic species of the Ebro River Basin (Doadrio et al. 1991), could be due to the elimination of suitable refuges, as mentioned above. This negative effect could be rectified with the placement of great boulders, which would create deep pools with woody debris (Linlokken 1997) and with the restoration of the native vegetation providing cover and shadow (Petts & Calow 1996).

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