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APPLIED ISSUES

Native and exotic freshwater fishes in Spanish river basins

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SUMMARY

1. The degree to which fish faunas have been invaded by exotic species is quantified on the basis of river basins.
2. Nineteen exotic species are now established in Spanish fresh waters. *Alburnus alburnus* (L., 1758) is reported here for the first time.
3. The native/total fish ratio varies from 0.71 in Galicia, the best preserved fish fauna, to 0.41 in Douro, the most modified fish assemblage. The national average ratio (0.63) is similar to that reported for Portugal (0.65), but higher than that in Italy (0.56) and much lower than that in Greece (0.88).
4. Exotic fishes have sometimes become successfully established over wide areas in a short time.

Introduction

Biological invasions have caused considerable disruption to native ecosystems around the world (see review by Drake *et al.*, 1989). Aquatic systems that have been disturbed by human activities appear to be particularly vulnerable (Mooney & Drake, 1989). Introduction of fish has usually been accompanied by the decline or extinction of native species (Brown, 1989). For this and other reasons many native fish faunas are presently threatened and efforts towards their conservation are common in developed countries (Minckley & Deacon, 1991; Moyle & Yoshiyama, 1994; Warren & Burr, 1994).

River authorities in the United States, Australia and New Zealand have expended considerable time and money to control or eradicate nuisance invaders (Lassuy, 1994). In the United States, Karr, Toth & Dudley (1985), Moyle & Williams (1990), and others have provided examples where the degradation of freshwater fish faunas has been evaluated. In southern Europe the situation is deteriorating, but evaluation of changes is not an easy task because very few data on fish abundance are available.

Sixty-nine fish species have been documented to occur in Spanish fresh waters (Blanco & González, 1992, and present report). Eighteen species are diadromous (anadromous, catadromous or amphidromous) and fifty-one have permanent inland populations. The number of exotic species has increased in recent decades; currently, nineteen exotic species are established. The origin and reasons for stocking the aliens are reviewed by Elvira (in press a). The resulting disruption is marked by the fact that indigenous species usually show restricted distributions within the Spanish rivers, while some aliens have quickly occupied extensive areas (Doadrio, Elvira & Bernat, 1991).

Introduction of exotic freshwater fishes into Spanish rivers is probably one of the main negative factors affecting the survival of the native (mostly endemic) species (Elvira, 1990; Blanco & González, 1992; Elvira, in press a, b). Few studies have been performed on interactions between exotic and native fishes, but, for example, Rincón *et al.* (1990) described the negative impact of introduced pike (*Esox lucius* L. 1758).

The current state of the main Spanish river basins is quantified here by means of the native/total fish ratio. In addition, we describe recent changes (from 1952 to 1992) and briefly review some similar cases in other south European countries (Portugal, Italy and Greece), where studies by river drainages are still unavailable.

Material and Methods

Distributions of exotic fishes were analysed in the ten largest river drainages of Spain (Doadrio *et al.*, 1991): North, Galicia, Douro, Tagus, Guadiana, Guadalquivir, South, Levant, Ebro and Eastern Pyrenees (Fig. 1). The biogeographic identity of these geographical units has been discussed in detail by Almaça (1978), Doadrio (1988) and Hernando & Soriguer (1992).

Data on fish distributions are derived from Doadrio (1988), Doadrio *et al.* (1991), Hernando & Soriguer (1992) and our own unpublished studies. These are presented here in a new synthesis according to river basins. The former references and those recorded by Anonymous (1952) were used to infer the status of the fish fauna 40 years ago.

The ratio of number of native species/total number of species currently recorded (called the 'zoogeographic integrity coefficient' by Bianco, 1990a), was calculated as an index of the degree to which fish faunas have been invaded by introduced species. This index ranges from '1' which is equivalent to pristine conditions, to '0' showing the highest degree of alteration.

Results

Nineteen exotic species have become established in Spain (Table 1). These include the eighteen species previously reported by Elvira (in press a). In addition, *Alburnus alburnus* is recorded for the first time in the river Noguera Ribagorzana (River Ebro basin), where it was collected in June 1992. Thus, 37.2% of the total freshwater fishes (fifty-one species, excluding the diadromous species) are exotic.

The native species ratios for the ten selected river drainages are shown in Table 1 and Fig. 1. The average

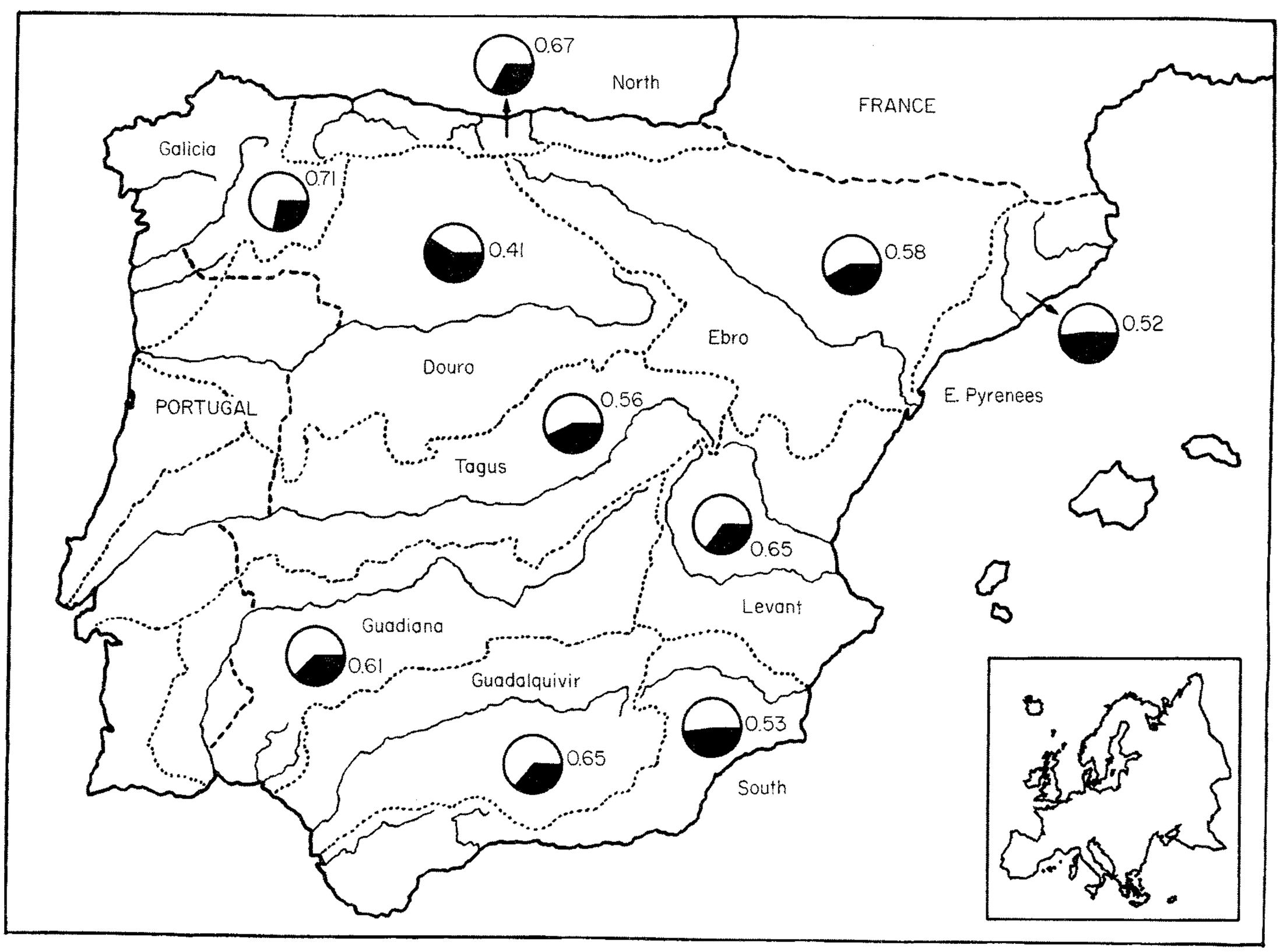

Fig. 1 Spanish river drainages selected for this study. Pie diagrams represent relative frequencies of native (open sectors) and exotic (solid sectors) fishes. Figures correspond to the zoogeographic integrity coefficient.

Table 1 Spanish freshwater fish species, including their native (N) or exotic (E) status in the different selected drainages. NO, North; GA, Galicia. DO, Douro; TA, Tagus; GN, Guadiana; GL, Guadalquivir; SO, South; LE, Levant; EB, Ebro; PY, Eastern Pyrenees, together with values for the zoogeographic integrity coefficient

	Spain	NO	GA	DO	TA	GN	GL	SO	LE	EB	PY
Zoogeographic integrity coefficient		0.67	0.71	0.41	0.56	0.61	0.65	0.53	0.65	0.58	0.52
Petromyzontidae											
Lampetra planeri (Bloch, 1784)	N	N									
Cyprinidae											
Alburnus alburnus (L., 1758)	E									E	
Anaecypris hispanica (Steindachner, 1866)	N					N	N				
Barbus bocagei Steindachner, 1865	N			N	N						
Barbus comiza Steindachner, 1865	N				N	N	N				
Barbus graellsii Steindachner, 1866	N	N								N	N
Barbus guiraonis Steindachner, 1866	N								N		
Barbus haasi Mertens, 1924	N								N	N	N
Barbus meridionalis Risso, 1826	N										N
Barbus microcephalus Almaça, 1967	N				N	N					
Barbus sclateri Günther, 1868	N					N	N	N	N		
Carassius auratus (L., 1758)	E	E		E	E	E	E	E	E	E	E
Chondrostoma polylepis Steindachner, 1865	N		N	N	N	N	N	N	E		
Chondrostoma toxostoma (Vallot, 1837)	N	N							N	N	N
Cyprinus carpio L., 1758	E			E	E	E	E	E	E	E	E
Gobio gobio (L., 1758)	E	E		E	E	E	E	E	E	E	E
Iberocypris palaciosi Doadrio, 1980	N						N				
Leuciscus carolitertii Doadrio, 1987	N		N	N						N	
Leuciscus cephalus (L., 1758)	N									N	N
Leuciscus pyrenaicus Günther, 1868	N				N	N	N	N	N		
Phoxinus phoxinus (L., 1758)	N	N		E						N	N
Rutilus arcasii (Steindachner, 1866)	N		N	N	N				N	N	N
Rutilus lemmingii (Steindachner, 1866)	N			N	N	N	N				
Rutilus rutilus (L., 1758)	E									E	E
Scardinius erythrophthalmus (L., 1758)	E									E	E
Tinca tinca (L., 1758)	N			N	N	N	N		N	N	N
Tropidophoxinellus alburnoides (Steindachner, 1866)	N			N	N	N	N				
Cobitidae											
Cobitis calderoni Bacescu, 1961	N			N	N					N	
Cobitis paludica (De Buen, 1930)	N			E	N	N	N		N	N	
Homalopteridae											
Barbatula barbatula (L., 1758)	N	N								N	
Ictaluridae											
Ameiurus melas (Rafinesque, 1820)	E			E	E					E	E
Siluridae											
Silurus glanis L., 1758	E									E	
Esocidae											
Esox lucius L., 1758	E			E	E	E	E	E	E	E	E
Salmonidae											
Hucho hucho (L., 1758)	E			E							
Oncorhynchus mykiss (Walbaum, 1792)	E	E	E	E	E	E	E	E	E	E	E
Salmo trutta L., 1758	N	N	N	N	N	N	N	N	N	N	N
Salvelinus fontinalis (Mitchill, 1814)	E			E	E					E	
Cyprinodontidae											
Aphanius iberus (Valenciennes, 1846)	N					N	N	N	N	N	N
Fundulus heteroclitus (L., 1766)	E					E	E				
Valencia hispanica (Valenciennes, 1846)	N								N	N	
Poeciliidae											
Gambusia holbrooki (Agassiz, 1859)	E			E	E	E	E	E	E	E	E
Atherinidae											
Atherina boyeri Risso, 1810	N				N	N	N	N	N	N	N

Table 1 (cont'd)

Zoogeographic integrity coefficient	Spain	NO 0.67	GA 0.71	DO 0.41	TA 0.56	GN 0.61	GL 0.65	SO 0.53	LE 0.65	EB 0.58	PY 0.52
Gasterosteidae											
Gasterosteus aculeatus L., 1758	N	N	N			N			N	N	N
Syngnathidae											
Syngnathus abaster Risso, 1810	N					N	N	N	N	N	N
Cottidae											
Cottus gobio L., 1758	N	N								N	
Percidae											
Perca fluviatilis L., 1758	E									E	E
Stizostedion lucioperca (L., 1758)	E										E
Centrarchidae											
Lepomis gibbosus (L., 1758)	E			E	E	E					E
Micropterus salmoides (Lacépède, 1802)	E	E	E	E	E	E	E	E	E	E	E
Cichlidae											
Cichlasoma facetum (Jenyns, 1842)	E					E					
Blenniidae											
Blennius fluviatilis Asso, 1801	N					N	N	N	N	N	N

for all ten drainages is 0.59 (SD = 0.088).

In the North basin (eight native, four exotic; ratio = 0.67), aliens are present as scattered populations and disruption of the native communities is still low. The Galicia basin (five native, two exotic; ratio = 0.71) is the best preserved area of all, because the only two introduced species are still very local. In contrast, the Douro basin (nine native, thirteen exotic; ratio = 0.41), recently studied by Lobón-Cerviá, Elvira & Rincón (1989) has the lowest ratio; rapid dispersal of aliens has been described in this basin. Furthermore, some exotic species (*Cyprinus carpio, Gobio gobio, Esox lucius, Gambusia holbrooki* and *Micropterus salmoides*) have widespread distributions in the basin. Fish predators such as *Esox lucius* and *Micropterus salmoides* probably present the greatest threat to the native fish fauna. The situation in the Tagus basin (thirteen native, ten exotic; ratio = 0.56) is similar to that in the Douro basin; consequently the same threats are present. Moreover, species such as *Ameiurus melas* and *Lepomis gibbosus* are locally abundant.

Southern basins show a similar level of invasion. In the Guadiana (sixteen native, ten exotic; ratio = 0.61), *Cyprinus carpio, Gobio gobio, Esox lucius, Gambusia holbrooki, Lepomis gibbosus* and *Micropterus salmoides* are widespread species. Nevertheless, the abundance of *Esox lucius*, mainly in the large reservoirs, poses the largest threat to the local fish fauna. In the Guadalquivir (fifteen native, eight exotic; ratio = 0.65), as well as the degradation caused by exotic fishes of wide distribution, the introduced *Fundulus heteroclitus* may be a direct competitor of the endemic *Aphanius iberus*. In the South basin (eight native, seven exotic; ratio = 0.53), *Gambusia hol-brooki* and *Micropterus salmoides* are the only common and widespread exotic species.

The Mediterranean basins are also highly colonized by aliens. Nevertheless, the Levant basin (fifteen native, eight exotic; ratio = 0.65) is still a well preserved region, where occurrence of *Esox lucius, Gambusia holbrooki* and *Micropterus salmoides* is the main risk factor for native fishes, including the local endemic *Valencia hispanica*. In the Ebro basin (nineteen native, fourteen exotic; ratio = 0.58), with the greatest richness of fish species in any Spanish basin, invaders such as *Cyprinus carpio, Gobio gobio, Esox lucius, Gambusia holbrooki* and *Micropterus salmoides* show wide distributions, while *Rutilus rutilus, Scardinius erythrophthalmus, Ameiurus melas, Silurus glanis* and *Perca fluviatilis* are locally common in the lower sections of the River Ebro. In the Eastern Pyrenees basin (fourteen native, French areas of the northern Pyrenees, *Rutilus rutilus, Scardinius erythrophthalmus, Perca fluviatilis* and *Stizostedion lucioperca*, are now established and can be locally abundant.

Many of the aliens have a local distribution, often restricted to small areas in only one (*Alburnus alburnus, Silurus glanis, Hucho hucho, Stizostedion lucioperca* and *Cichlasoma facetum*) or two (*Rutilus rutilus, Scardinius erythrophthalmus, Fundulus heteroclitus* and *Perca fluviatilis*) neighbouring basins. Unfortunately, however, at least seven species show a wide distribution pattern in Spain: *Cyprinus carpio, Esox lucius* and *Gambusia*

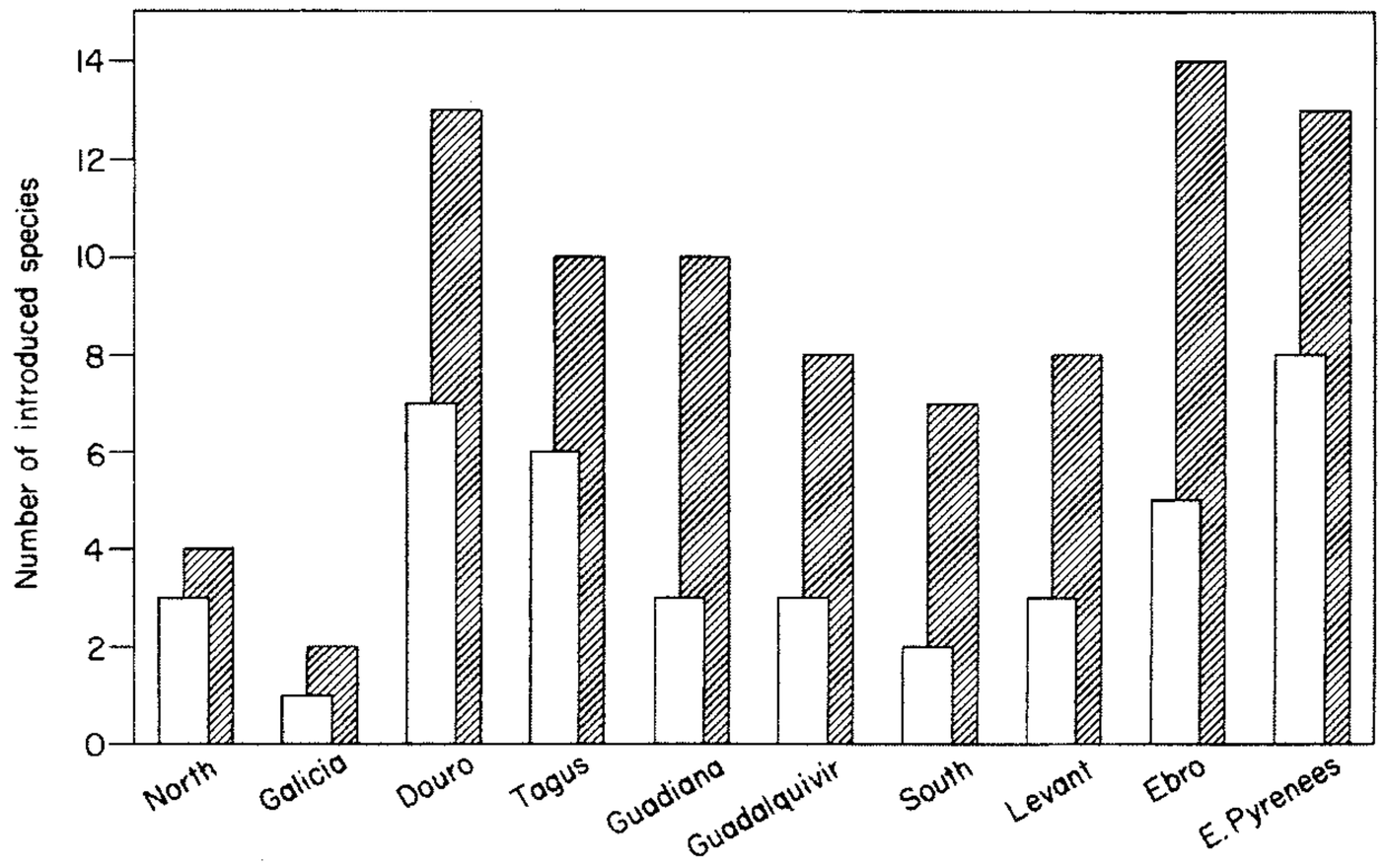

Fig. 2 Change in numbers of introduced species within the ten river basins over a 40-year interval (white bars, 1952; hatched bars, 1992).

holbrooki (eight basins), *Carassius auratus* and *Gobio gobio* (nine) and *Oncorhynchus mykiss* and *Micropterus salmoides* (ten; Table 1).

Only three native species have been transferred to other basins ('transfaunation' after Bianco, 1990b). These are *Chondrostoma polylepis*, *Phoxinus phoxinus* and *Cobitis paludica*. Each one has only been introduced into a single river basin (Table 1).

Fig. 2 illustrates the tendency for rapid spread of aliens within the river basins. From one to nine new species have become established in the various drainages (median increase = 4.8, SD = 2.44) over the last 40 years (1952–92).

Discussion

The freshwater fish assemblages currently found in Spain are far from pristine. number Aliens make up from 30 to 60% of the total fish community for the ten selected drainages. Some of the widespread exotic species are certainly a potential threat to the survival of the native fishes (Rincón *et al.* 1990; Elvira, 1990, in press a, b).

Additional negative factors affecting the native fish fauna are habitat destruction, due to water extraction, construction of dams and channelling of river courses, together with pollution of the waters (Elvira, in press b). Many exotic species have been presented with new areas to colonize as a result of conversion of lotic river sections by reservoirs; this applies to limnophylic species such as *Carassius auratus*, *Cyprinus carpio*, *Ameiurus melas*, *Silurus glanis*, *Esox lucius*, *Gambusia holbrooki*, *Perca fluviatilis*, *Stizostedion lucioperca*, *Lepomis gibbosus* and *Micropterus salmoides*. Thus, in many cases introduced species have been more successful in disturbed habitats.

The current zoogeographic integrity coefficient for Spanish river basins is 0.63 (thirty-two native species, fifty-one species in total). This is similar to that in Portugal (0.65; calculated from data in Alexandrino & Valente, 1990, slightly modified), where only ten exotic species have been introduced (Almaça, 1983; Alexandrino & Valente, 1990).

Data from Italy (0.56), the closest Mediterranean peninsula, show a higher level of disruption (Bianco, 1990b). The zoogeographic integrity coefficient from central Italy ranges from 0.37 to 0.77 (Bianco, 1990a). Transfaunation seems to be an important additional factor in Italy, where seventeen species have been translocated (Bianco, 1990b). This potential threat has generally not been realized in Spain, where, only three species have been locally stocked in other basins than those originally included in their distribution areas.

Degradation of the pristine freshwater fish fauna in Greece, caused by introduction of exotic species, seems to be still at a low level (Economidis, 1991), with only eleven aliens coexisting with seventy-eight native species. The zoogeographic integrity coefficient of 0.88 is the highest reported for a south European country.

According to Banarescu (1992), the southern Euro-Mediterranean subregion is an area with a high degree of endemism. Unfortunately, the diversity of native freshwater fish communities is presently threatened by the introduction of exotic species. Knowledge of the disruption caused by exotic species should be the

basis for preventing further introductions and to devise methods for controlling invaders that are already established.

Preservation of the native fish fauna and the eventual establishment of sanctuaries to protect endemic species ought to be priorities at the national level and for EC authorities and other international institutions interested in the conservation of river ecosystems.

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