

Research Article

The zebra mussel invasion in Spain and navigation rules^{*}

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Abstract

Dreissena polymorpha (zebra mussel) has been invading freshwater bodies in Europe since the beginning of the 19th century and is still doing so. The zebra mussel was introduced in the Iberian Peninsula in 2001, and since then the Ebro Hydrographic Confederation has adopted several measures to stop the invasion. The main invasion route for the zebra mussel in Spain is via recreational boating in lakes and reservoirs, so the main measure adopted has been to change the navigation rules in the Ebro basin. Restrictions on the number of navigable reservoirs and the introduction of disinfection protocols and access controls have helped to prevent the spread of the zebra mussel.

Key words: Spain, *Dreissena*, Navigation rules, Ebro River, reservoirs

Introduction

The zebra mussel *Dreissena polymorpha* (Pallas 1771) is a small bivalve native to the lakes, slow-moving rivers and low salinity areas of the Caspian and Black Sea regions. It was formerly present in the Aral Sea, but due to increasing salinities and reduced lake area it no longer exists there (Karatayev et al. 1998). In the early part of the nineteenth century, it dramatically expanded into western Europe, appearing in London in 1824, Rotterdam in 1826 and Copenhagen in 1940. The species has continued to spread in Europe, being first recorded in Italy in 1969-70 and Greece in early 1980 (Morton 1997). *Dreissena polymorpha* was first discovered in Spain in 2001, and probably reached the Ebro River via sport fishing boats.

The Ebro basin is one of nine river basins in Spain. It is large, with 347 rivers and 347 dams distributed over 85,550 km². Almost 3 million people live in this region. The first populations of zebra mussels were discovered in this basin in 2001 at Ribarroja Reservoir, located almost at the end of the Ebro River (Figure 1 and Figure 2). In the summer of 2006, the species was discovered at Sobrón Reservoir near the source of the Ebro River (Figure 3). Details of invasion history of *Dreissena polymorpha* in the Ebro River basin (coordinates and dates of records) are provided in Annex 1.

The primary pathway for the spread of the zebra mussel in this basin is probably via transport on recreational boats and associated equipment.

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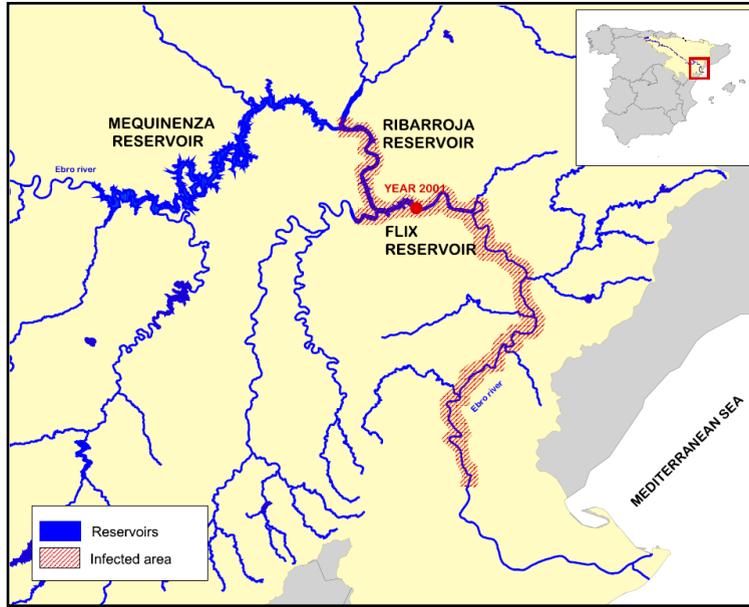


Figure 1. Location of first record of *Dreissena polymorpha* in Ribarroja Reservoir, Ebro River.



Figure 2. Metal bars from Ribarroja reservoir (Photograph by Nuclear Power Station of Ascó).

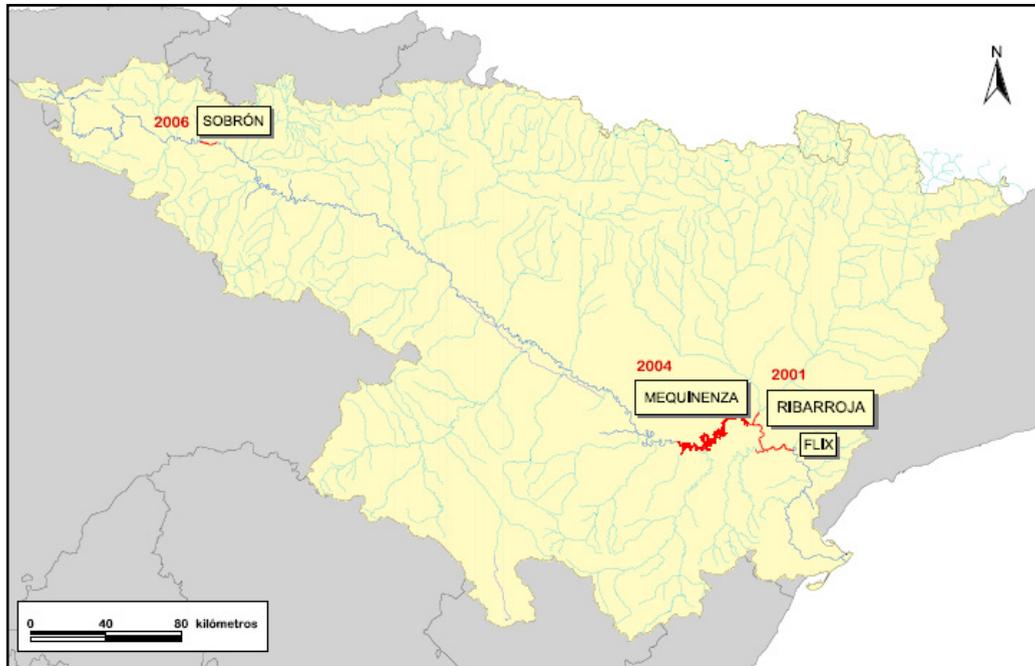


Figure 3. Distribution map of *Dreissena polymorpha* in Ebro River basin in 2001 – 2006.

The principles of intervention adopted by the Ebro Hydrographic Confederation are: prevention, control and eradication. Work has been carried out in the following main areas: a) Searching for solutions to deal with the main infection pathways: sport fishing from boats; b) Diffusion and spreading; c) Unifying efforts between the authorities and affected users; d) Trying to stop the expansion; e). Looking for solutions to deal with the problem.

Main studies

Search for possible alternatives including: manual or mechanical extraction, decreasing the water level at Ribarroja, test on survival against drought

Aided by the Spanish Army, we carried out some tests to find out how long it took a defined number of divers to eradicate a particular area invaded by zebra mussel, so that we could inform others users with similar problems. We extracted to a certain depth by vacuum and used sonar and a specific underwater camera for this zebra mussel project.

Other searches have shown that the mortality period in natural conditions is between 7 and 10

days at our latitude. Exposure time and percentage mortality are very influenced by orientation. The most favourable orientation for drying in decreasing order is: S>W>NE>N. The accumulated temperature during the mortality period oscillated between 25.00 - 33.80°C. Finally research showed that the zebra mussel in Spain colonises every kind of hard surface - even other bivalves (CHE¹-2005).

Estimated cost of the zebra mussel invasion in the Ebro basin

A cost study for the invasion in the Ebro River predicted an accumulated cost of around 40 million euros over the next 20 years, in the mouth area alone. It is currently believed that this cost will be higher (CHE 2005-B).

Providing information

There is an important advertising campaign with the slogan: “Remember: although you may not see them, they may still be there. Act at all times as if they were present”. The information is given to different water users in the river. Boating knowledge of invasive species plays an

¹ Ebro Hydrographic Confederation

important role in the prevention of the spread of the zebra mussel. This invasion is a problem for everybody, as is the solution.

The objective is to inform and educate the public about the ecological and economic impacts of zebra mussels, the pathways by which they spread, and what actions can be taken to prevent this.

Advice for affected users

The first time that users detect the zebra mussel in their facilities, they can ask for advice from the Ebro Hydrographic Confederation. This service needs users to act appropriately, as there is a high environmental risk from poor treatment in affected facilities.

Vulnerable reservoirs

To focus resources when planning on how to contain the spread of an invasive species, we need to predict which habitats are most at risk from invasion and therefore the most vulnerable. There is a high probability of zebra mussels being introduced into other freshwater lakes and reservoirs, so it is important to predict which reservoirs are most at risk from invasion and therefore the most vulnerable.

With the prioritisation of vulnerable freshwater bodies, the information for preparing new navigation rules is now better (CHE 2007).

Monitoring of colonies: larvae and adults

Larvae colony monitoring is going on at 48 points in rivers and at 63 reservoirs. The process is a filtration of 50 litres with a 45µm plankton net. The test sample is taken to the laboratory, concentrated by a centrifugal process, identified using polarised light (Johnson 1995) and counted in a counting chamber.

Adult monitoring is carried out at several points, with the work being carried out by local and regional governments of the Ebro basin. Every month there is a visual inspection for zebra mussels in the reservoirs.

This monitoring helps in preparing the navigation rules for the basin. It is very important to quickly know of any new water bodies which might be infected. The objective is to respond rapidly to eradicate or contain the zebra mussels immediately after detection.

Disinfection stations and access points control

Steps such as draining live wells, cleaning vegetation off boat trailers, removing attached zebra mussels from boat hulls, and not dumping bait into lakes or rivers can prevent zebra mussels and other non-native species from spreading into hitherto unaffected waters.

The number of access points present on a reservoir or lake is also important so, in many cases, access to infected reservoirs has been closed or privatised. Research in North America found that the more public access routes there were, the more boats per lake were present; and boats are a high risk in the spread of the zebra mussel (Reed-Andersen et al. 2000).

Changes in navigation rules

The introduction of species is now regulated in many countries and legislation is directed against their deliberate introduction. In the Ebro river basin, solutions are directed towards another area: accidental introduction in non-infested areas due to human activity.

Human activity has unknowingly spread the zebra mussel into many reservoirs, usually via recreational boating, fishing, and diving practices.

All of these actions have been included in the National Strategy, approved 6th September, 2007.

Navigation rules

It was believed that it was inevitable that zebra mussels would spread through navigable areas and create new populations, either by spawning or by dropping from hulls and forming clusters. Boat traffic peaks during the summer months, and this coincides with their spawning period. It is very important therefore to have a good set of navigation rules for the Ebro basin as navigation and the fight against the zebra mussel are closely linked.

In accordance with articles 23.1(b), 24(a), 51(a) and 78 of the updated text of the Water Law (REAL LEGISLATIVE DECREE 1/2001), the granting of a navigation licence in rivers and reservoirs and their regulation is the responsibility of the Hydrographic Confederations.

The main work of the Ebro Hydrographic basin is to eliminate the invasive pathways by changes in the navigation rules. Since the appearance of the zebra mussel in 2001, there



Figure 4. Technician boat cleaning.

have been changes in navigation rules to preserve the waters of the Ebro basin. The resolutions controlling the spread of the zebra mussel are: 1) RESOLUTION September 11th 2001, from the Ebro Hydrographic Confederation Presidency, classification of reservoirs in the Ebro basin for navigation purposes. (BOE² 23.10.2001); 2) RESOLUTION September 24th 2002, from the Ebro Hydrographic Confederation, navigation rules in Mequinenza reservoir, Ribarroja reservoir and Flix reservoir, the lower reaches of the Ebro river, due to the appearance of the zebra mussel (BOE 12.11.2002); 3) RESOLUTION May 15th 2007, from the Ebro Hydrographic Confederation, changes in the navigation rules due to the spread of the zebra mussel and the new reservoir classification for the Ebro basin. (BOE 19.06.2007); 4) RESOLUTION September 11th 2001, from the Ebro Hydrographic Confederation Presidency, classification of reservoirs in the Ebro basin for navigation purposes. (BOE 23.10.2001).

The navigation rules published in 2001 gave boating reservoirs different restrictions. They were divided into four types: 1) Type 0 – Not suitable for boating; 2) Type 1 – Reservoirs with boating restrictions; 3) Type 2 – Reservoirs not particularly suited to boating; 4) Type 3 – Reservoirs without restrictions.

Types 0 to 3 were further divided into reservoirs suitable for motor boats, and those for vessels without an engine, or sailing boats (see in Annex 1).

The ruling made it obligatory to apply these restrictions in all the navigable reservoirs of the

Ebro basin. In total, there were 72 boating reservoirs. For each type, there was a specific authorisation: 1) SINGLE AUTHORISATION (TYPE 1): an authorisation for a reservoir according to the type of boat. It was possible to use this permit in more than one reservoir. It could be used in other reservoirs classed as type 1 for this kind of boat; 2) RESERVOIR AUTHORISATION (TYPES 2 AND 3): an authorisation permitting boating in all reservoirs classed as types 2 and 3 for each type of boat.

RESOLUTION September 24th 2002, from the Ebro Hydrographic Confederation, navigation rules in Mequinenza reservoir, Ribarroja reservoir and Flix reservoir, the lower reaches of the Ebro river due to the appearance of the zebra mussel (BOE 12.11.2002).

The second set of navigation rules, for the Ribarroja, Flix and Mequinenza reservoirs, were published in 2002 after the appearance of the zebra mussel in Ribarroja-Flix in 2001.

The resolution established a delimited infected area: Flix reservoir and Ribarroja reservoir, and a risk area in Mequinenza reservoir.

The Ebro Hydrographic Confederation was trying to control and monitor boat traffic between infected and non-infected waters. Therefore, there were important measures about cleaning and disinfection for these infected areas.

It prepared a specific Protocol for disinfecting boats in bodies of water infected with the zebra mussel. This protocol contained specific provisions for motor boats, vessels without an engine and sporting equipment (CHE 2002) (Figure 4).

It was obligatory to inspect the vessel and equipment that had been in contact with the water to remove any individual zebra mussels and any visible remnants of vegetation.

The remains of the ballast water, live tank containers and bilge piping all had to be emptied of water, as well as the equipment that has been in contact with the water.

Secondly, the disinfection method recommended was with high pressure sprays. To provide this cleaning and disinfecting, specific disinfecting stations with the following features were built throughout the basin: 1) Pressure: 160 bar minimum; 2) Working temperature: 60°C minimum. Instantaneous heating. 3) Flow rate: 600 – 1,200 L/hr .

There are some places in which it is obligatory to spray with high pressure water: 1) in all the

² Official Government Reporter



Figure 5. Reservoir access ramp with a control chain.

vessel (hull, engine, interior, etc); 2) over all areas of the transport vehicle that has been in contact with the water; 3) on all the equipment that has been in contact with the water (life jackets, boots, fishing equipment, etc)

After a first cleaning, it is obligatory to check all the critical points (anchor, rollers, motor, etc) and apply pressurised water more times in less accessible locations which carry more risk.

Cleaning the motor is especially important as it can contain larvae. Firstly, the engine should be turned over (revved), just before stopping the boat, to increase the movement of water and temperature of the engine, thereby killing any larvae. The engine coolant circuit then has to be refilled with clean water. The engine is then removed from the water and rinsed with clean water.

The water used for cleaning the boat must not enter any water courses or sewage systems. It must be collected in containers or poured directly on filter beds.

Finally, the remainder of the sporting equipment that has been in contact with the water (helmet, oars, lifejackets, etc) must be disinfected, either by soaking, immersion or spraying with a disinfectant solution (at a concentration of 1 ml of 5% bleach per litre, about 20 drops per litre). Special care must be taken to prevent the used disinfectant solution from entering the aquatic environment, thereby preventing damage to other organisms.

In an area infected with zebra mussel larvae, the organisers of any sporting competition, such as canoeing or rowing, must have a high pressure

water jet facility available (a steam cleaner or similar) and ensure that all participating boats receive proper treatment.

Along with the publication of the rules, an inventory of all access points to infected areas was carried out. Some access points and jetties were closed and others equipped with disinfection stations (Figure 5). The rules state that it is obligatory to enter the reservoirs at fixed points equipped for the purpose.

RESOLUTION May 15th 2007, from the Ebro Hydrographic Confederation, changes to the navigation rules due to the spread of the zebra mussel and the new classification of reservoirs in the Ebro basin (BOE 19.06.2007).

In the latest rules published in June of 2007 there were modifications to boating in reservoirs and rivers. For rivers, motor boating was temporarily suspended from the source to Escatrón, but was allowed from Flix to Tortosa. Non-motor boats were allowed throughout the whole Ebro and its tributaries.

The reservoir provisions were modified in two ways: to try to prevent the zebra mussel from leaving infected areas, and to preserve the status of reservoirs without the zebra mussel.

There are 56 boating reservoirs in total and some of them have special restrictions (Annex 1).

Among the navigation rule measures published in 2007 were two new types of classifications for reservoirs: 1) Type C – Reservoirs with the proven presence of zebra mussel; 2) Type P – Reservoirs under special protection.

In both types of reservoir, it is obligatory to clean and disinfect the boat and trailer before entering and after leaving the reservoir (Figure 6).

Type C reservoirs with proven presence of zebra mussel: we don't want them to escape from here and boats need an exclusive authorisation: 1) Mequinenza Reservoir; 2) Ribarroja Reservoir; 3) Tranquera Reservoir; 4) Ullivarri Reservoir.

In other reservoirs, boating is temporarily suspended because there are no disinfection stations: 1) Sobron Reservoir; 2) Calanda Reservoir; 3) Lanuza Reservoir; 4) Bubal Reservoir; 5) Sabiñanigo Reservoir, 6) Rialb Reservoir. 7) Talam Reservoir, 8) San Lorenzo Reservoir.

Type P reservoirs we don't want zebra mussel to enter here, so they are protected reservoirs.

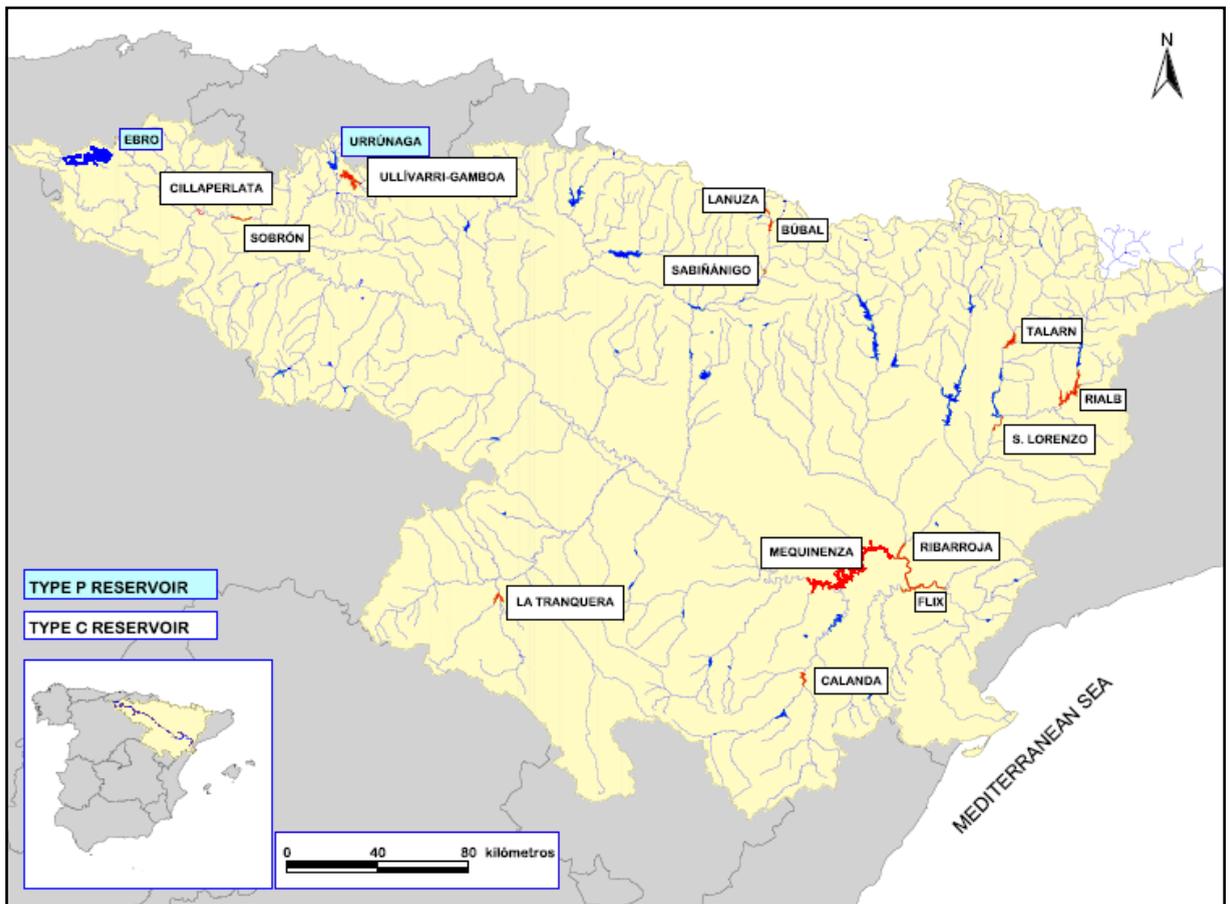


Figure 6. Distribution of Type C and Type P reservoirs in the Ebro Basin (September 2008). See also Annex 1.

There are two types: 1) Reservoirs with confined vessels (EEC³). An exclusive authorisation is required for boating in these. These are reservoirs which transfer water to other basins (Urrunaga Reservoir and Ebro Reservoir). 2) Water-supplying reservoirs. Boating is suspended indefinitely in these because these are used for human drinking water supply (Eugui Reservoir, Vadiello Reservoir, González La Casa Reservoir, Alviña Reservoir, Almochuel Reservoir, Bolaso Reservoir, Cienfuens Reservoir, Gallipúen Reservoir, González-Lacasa Reservoir, Hoz Reservoir, Irabia Reservoir, Lasarra Reservoir, Monteagudo de Las Vicarías Reservoir, Niño Jesús Reservoir, Paso Nuevo Reservoir,

Perdiguero Reservoir, Tramacastilla Reservoir, Valbornedo Reservoir).

In Type C and Type P (EEC) reservoirs, boats need an exclusive authorisation, i.e. the boat can be used only in the designated reservoir. Renouncing the authorisation means a new one can be applied for in a different reservoir. In order to apply for another, it is necessary to have the accreditation form from vessel cleaning in accordance with the Disinfection Protocol.

The rules state that if the presence of zebra mussel or its larvae are detected in any of the unaffected reservoirs, this reservoir will then immediately be classified as Type C. As a result, these reservoirs will have the same rules as the Type C reservoirs. The first measure is to temporarily suspend boating until a disinfection station is in place.

³ Confined boats reservoirs

At the moment, there are 4 reservoirs classed as Type C due to the presence of larvae: Ullivarri Reservoir, Lanuza Reservoir, Bubal Reservoir and Sabiñanigo Reservoir.

Finally, the licence plate must be checked. The licence plate is very important for checking boat traffic and to know where boats are coming from inside the Ebro basin.

Type C reservoirs have a red licence plate and Type P a yellow one, with an identifying mark for each reservoir. The rest of the reservoirs have a white plate.

Over the last year, we have been in the process of reviewing the navigation rules to incorporate new modifications to prevent the spread of the zebra mussel. Information boards have been placed at all jetties and reservoir access points. These measures are directed to stop or slow down the invasion of the zebra mussel. Extensive studies have led us to believe that it is very difficult to prevent the zebra mussel from spreading, but we can at least try to slow down this invasion of reservoirs.

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Annex 1. Classification of navigable reservoirs in the Ebro Basin and dates of first records of zebra mussel (September 2008).

Reservoir	Geographic coordinates		River (Province)	Record Date	Jet skis	Sail boats	Motor boats
	Latitude	Longitude					
Aliaga	40°41'04"N	0°40'42"W	Guadalope (Teruel)	-	2	2	0
Alloz	42°43'06"N	1°56'47"W	Salado (Navarra)	-	3	3	0
Ardisa	42°12'08"N	0°45'00"W	Gállego (Huesca-Zaragoza)	-	2	0	0
Arguis	42°18'25"N	0°25'53"W	Isuela (Huesca)	-	3	2	1
Bubal	42°41'15"N	0°17'38"W	Gallego (Huesca)	2008	Type C – Reservoirs with the proven presence of zebra mussel		
Calanda	40°54'47"N	0°12'42"W	Guadalope (Teruel)	2008	Type C – Reservoirs with the proven presence of zebra mussel		
Camarasa	41°55'46"N	0°51'33"W	Nog. Pallaresa (Lleida)	-	3	2	3
Canelles	41°59'00"N	0°37'54"E	Nog. Ribagorzana (Lleida-Huesca)	-	3	2	2
Caspe o Civán	41°08'18"N	0°00'29"W	Guadalope (Zaragoza-Teruel)	-	3	3	0
Ciurana	41°15'06"N	0°55'01"E	Ciurana (Tarragona)	-	2	2	0
Cueva Foradada	40°58'11"N	0°41'40"W	Martín (Teruel)	-	2	0	0
Ebro, El	43°00'20"N	3°58'25"W	Ebro (Cantabria-Burgos)	-	Type P – Reservoirs under special protection		
Escales	42°20'33"N	0°44'49"E	Nog. Ribagorzana (Huesca-Lleida)	-	3	3	3
Escarra	42°44'36"N	0°21'33"W	Escarra (Huesca)	-	2	0	0
Escuriza	40°56'53"N	0°35'43"W	Escuriza (Teruel)	-	2	0	0
Estanca de Alcañiz	41°03'49"N	0°11'26"W	Guadalope (Teruel)	-	3	3	3
Esterri	42°39'26"N	1°05'17"E	Nog. Pallaresa (Lleida)	-	2	0	0
Flix	41°14'46"N	0°28'27"E	Ebro (Tarragona)	2001	Type C – Reservoirs with the proven presence of zebra mussel		
Grado, El	42°12'56"N	0°13'45"E	Cinca (Huesca)	-	3	3	1
Guiamets	41°05'43"N	0°45'54"E	Asmat (Tarragona)	-	3	2	0
Javierrelatre	42°24'25"N	0°28'30"W	Gallego (Huesca)	-	2	0	0
Joaquín Costa o Barasona	42°08'39"N	0°19'34"E	Esera (Huesca)	-	3	3	3
Lanuzza	24°45'39"N	0°19'10"W	Gállego (Huesca)	2008	Type C – Reservoirs with the proven presence of zebra mussel		
Linsoles	42°35'03"N	0°29'22"E	Esera (Huesca)	-	1	0	0
Maidevera	41°34'48"N	1°45'47"W	Aranda (Zaragoza)	-	3	3	0
Mansilla	42°09'10"N	2°56'21"W	Najerilla (La Rioja)	-	3	2	1
Mediano	42°22'05"N	0°10'15"E	Cinca (Huesca)	-	3	3	3
Mequinzenza	41°17'36"N	0°02'13"E	Ebro (Zaragoza)	2004	Type C – Reservoirs with the proven presence of zebra mussel		

Annex 1 (continued)

Reservoir	Geographic coordinates		River (Province)	Record Date	Jet skis	Sail boats	Motor boats
	Latitude	Longitude					
Mezalocha	41°25'04"N	1°04'06"W	Huerta (Zaragoza)	-	2	0	0
Moneva	41°10'07"N	0°49'50"W	Aguas Vivas (Zaragoza)	-	2	0	0
Navas, Las	42°17'10"N	0°38'25"W	Astón.Navas (Huesca)	-	2	0	0
Oliana	42°08'13"N	1°18'46"E	Segre (Lleida)	-	3	1	1
Pajares	42°05'05"N	2°36'07"W	Piqueras (Rioja)	-	3	3	1
Pena	40°48'48"N	0°07'52"E	Pena (Teruel)	-	3	3	1
Peña, La	42°23'05"N	0°43'22"W	Gállego (Huesca)	-	3	2	1
Rialb	41°59'24"N	1°16'41"E	Segre (Lleida)	2008	Type C – Reservoirs with the proven presence of zebra mussel		
Ribarroja	41°21'47"N	0°18'20"E	Ebro (Zaragoza-Huesca-Lleida-Tarragona)	2001	Type C – Reservoirs with the proven presence of zebra mussel		
Sabiñánigo	42°31'17"N	0°20'38"W	Gállego (Huesca)	2008	Type C – Reservoirs with the proven presence of zebra mussel		
San Bartolome	42°13'03"N	1°09'01"W	Arba de Luesia (Zaragoza)	-	3	2	0
San Lorenzo de Mongay	41°51'29"N	0°50'23"E	Segre (Lleida)	2008	Type C – Reservoirs with the proven presence of zebra mussel		
Santa Ana	41°54'15"N	0°36'01"E	Nog. Ribagorzana (Huesca-Lleida)	-	3	3	1
Santolea	40°45'20"N	0°19'31"W	Guadalope (Teruel)	-	3	3	1
Sobrón	42°45'45"N	3°09'32"W	Ebro (Alava-Burgos)	2006	Type C – Reservoirs with the proven presence of zebra mussel		
Sotonera, La	42°06'52"N	0°40'53"W	Astón y Sotón (Huesca)	-	3	3	1
Sta.Mª de Belsue	42°18'31"N	0°20'50"W	Flumen (Huesca)	-	2	0	0
Tabescán	42°38'24"N	1°15'11"E	Nog- de Cardós (Lleida)	-	2	0	0
Talarn, Tremp o San Antonio	42°12'25"N	0°57'35"E	Nog. Pallaresa (Lleida)	2008	Type C – Reservoirs with the proven presence of zebra mussel		
Terradets	42°04'12"N	0°53'20"E	Nog. Pallaresa (Lleida)	-	3	2	3
Torcas, Las	41°17'03"N	1°05'49"E	Huerta (Zaragoza)	-	2	0	1
Torrassa, La	42°35'34"N	1°08'04"E	Nog. Pallaresa (Lleida)	-	3	2	0
Tranquera, La	41°15'16"N	1°47'54"W	Piedra (Zaragoza)	2006	Type C – Reservoirs with the proven presence of zebra mussel		
Ullivarri-Gamboa	42°55'47"N	2°34'18"W	Zadorra (Alava)	2008	Type C – Reservoirs with the proven presence of zebra mussel		
Urrúnaga	24°57'52"N	3°39'09"W	Sta. Engracia (Alava-Vizcaya)	-	Type P – Reservoirs under special protection		
Utchesa	41°29'46"N	0°30'45"E	Canal Serós (Lleida)	-	3	2	2
Val, El	41°52'52"N	1°48'19"W	Val. Queiles (Zaragoza)	-	3	3	0
Yesa	42°36'13"N	1°05'35"W	Aragón (Navarra-Zaragoza)	-	3	3	3