Chapter 10

Biodiversity and Conservation of Temporary Ponds — Assessment of the Conservation Status of "Veiga de Ponteliñares", NW Spain (Natura 2000 Network), Using Freshwater Invertebrates

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http://dx.doi.org/10.5772/59104

1. Introduction

Freshwater biodiversity provides a broad variety of valuable goods and services for human societies, some of them irreplaceable [1]. Globally, the biodiversity of freshwater ecosystems is rapidly deteriorating as a result of human activities [2]. It is possible that in future decades human pressure on water resources will further endanger aquatic biodiversity present in these systems [3]. The need to protect these ecosystems and many others led to the creation of the Natura 2000 network in Europe. This network is the most important conservation and management tool in the European Union. It was established under the Habitats Directive (92/43/EEC) and the Birds Directive (79/409/EEC), and its main objective is to ensure the long-term conservation of the most important European species and habitats in a sustainable way with human activities. It is formed by Special Areas of Conservation (SAC), which are protected areas established with the purpose of conservation of habitat types and/or species included in the Habitats and Birds directives. In Spain, there are 1,448 SAC covering a total of 23.17% of the territory. Only 11.65% of the Autonomous Community of Galicia (North-western Spain) is protected (59 SAC), in spite of having a great variety of freshwater ecosystems.

Wetlands are sites of high biodiversity and productivity [4], but these ecosystems have undergone a serious decline worldwide [5,6]. Among stagnant water bodies, ponds constitute essential freshwater ecosystems for biodiversity conservation. Due to their heterogeneity and the varied network of habitats they provide, they often support higher diversity than more permanent and large freshwater habitats and act as stepping stones for the dispersal of species [7]. Among these freshwater ecosystems are temporary ponds, which are endangered due to their small size and shallowness [8]. Small changes in hydrological regimes can greatly impact the ecological regime of temporary ponds [9] and it is expected that the reduction in rainfall brought about by climate change will affect their hydrology [10]. Temporary ponds have been neglected for years and are affected by human activities, such as agriculture, urbanization, etc. The inclusion of the Mediterranean temporary ponds (code 3170*) as a priority habitat for conservation in the Habitats Directive (EEC, 1992) highlights the importance of these ecosystems and the necessity to conserve them.

Temporary ponds support a great diversity of freshwater fauna, including invertebrates. Under this assumption, the purpose of this chapter was to analyze the importance of the invertebrate fauna in maintaining the ecological balance of temporary ponds and assess the effectiveness of protecting areas in the conservation of their biological values. So, we wonder if SAC are efficient in wildlife conservation and whether the freshwater invertebrates are good indicators of the environmental quality of temporary ponds. To do this, we studied the invertebrate fauna in different ponds within the SAC "Veiga de Ponteliñares" (North-Western Spain).

2. Definition and characteristics of temporary ponds

According to the Ramsar Convention, temporary ponds are usually small (< 10 ha) and shallow wetlands which are characterized by alternating of flooded and dry phases, and whose hydrology is largely autonomous (Figure 1). They occupy depressions, often endorheic, which are flooded for a sufficiently long period to allow the development of hydromorphic soils and wetland-dependent aquatic or amphibious vegetation and fauna communities. However, equally importantly, temporary ponds dry out for long enough periods to prevent the development of the more widespread plant and animal communities characteristic of more permanent wetlands.

Temporary ponds are habitats with a predictable annual dry phase of 3-8 months, usually during summer and autumn [11]. According to [12], temporary ponds can be classified as intermittent (with a seasonal cyclic pattern of dryness and flooding) or episodic (unpredictably flooded). These habitats must undergo a periodic cycling of flooding and drought for a correct functioning [13]. They are usually located in shallow areas with impermeable ground and present a small catchment area [9]. Water volume depends on the balance between inputs (precipitation, surface runoff, melting snow and inflows of groundwater) and outputs (evapotranspiratiom, infiltration and overflow) [14]. One of the main characteristics of temporary ponds is their isolation. If they were connected to more permanent habitats, this would probably cause the colonization of species typical of permanent habitats and the disappearance of those typical of temporary habitats due to competition and predation.

Figure 1. Temporary pond in the SAC Serra do Careón (NW Spain).

Extreme fluctuations affect the physical and chemical characteristics of the water. Nutrients such as nitrate or phosphate appear usually in low concentrations, but vary throughout the different hydrological stages of the pond. The same happens with pH, dissolved oxygen or salinity. The latter present higher values in the last part of the wet phase because the ion concentration increases when the pond is drying. In general, dissolved oxygen concentration is low and organisms have developed several adaptations to survive, for example, swimming near to the water surface or having more haemoglobin [9]. Mineralization is low with electric conductivity reaching values of 0.05-0.3 mS/cm in the maximum flooding period [15].

These environments occur in many parts of the world, but are well represented in arid, semi-arid and Mediterranean areas. Mediterranean temporary ponds constitute one type of temporary ponds and are considered a priority habitat type in Europe (code 3170*). According to the *Interpretation Manual of European Union Habitats* (EUR27, July 2007) these are very shallow temporary ponds (a few centimetres deep) which exist only in winter or late spring with a flora mainly composed of Mediterranean therophytic and geophytic species belonging to the alliances *Isoetion*, *Nanocyperion flavescentis*, *Preslion cervinae*, *Agrostion salmanticae*, *Heleochloion* and *Lythrion tribracteati*.

3. Biodiversity of temporary ponds

Temporary ponds constitute an important habitat for the breeding, feeding and migration of amphibians, reptiles, invertebrates, birds and mammals [16]. Because of their relatively isolated status in comparison to permanent water bodies, their unpredictable date of flooding and their small size and shallow conditions, biodiversity in these ponds is high [9]. In addition, several studies have probed the importance of temporary ponds for rare and endangered invertebrate species [8,17,18].

According to [19], hydroperiod is one of the main factors affecting the composition and structure of aquatic assemblages. As a result, temporary ponds support biological communities different to those that inhabit permanent habitats. Organisms living in temporary waters have to adapt to temporary drought conditions to survive, sometimes being exclusive to these ecosystems [20]. They develop morphological adaptations, life cycles and dispersion mechanisms which make them survive in dry seasons. Based on the four groups proposed by [21], aquatic organisms have two strategies to survive drought: to pass the dry phase via resistant life stages or to actively migrate when water disappears. For example the aquatic beetle *Berosus signaticollis* (Charpentier) remains embedded in the sediment to complete its life cycle [19], the crustacean *Tanymastix stagnalis* Daday resists the drought with resting eggs [22] or the damselfly *Lestes dryas* Kirby and the dragonfly *Sympetrum sanguineum* (Muller) complete their life cycles before the drying season [23].

Invertebrates of temporary ponds usually exhibit traits of r-selected species, especially great dispersal ability, rapid growth, short life-span, small size, and opportunistic/generalistic feeding [12]. Insects and crustaceans constitute the larger invertebrate groups in these ponds [19]. Among aquatic invertebrates, several groups or species can be considered typical of temporary ponds, like the large branchiopods *Lepidurus apus* (L.) and the genus *Triops*; cladocerans in the genus *Daphnia*; the fairy shrimp *Tanymastix stagnalis*; odonates in the genera *Lestes* or *Sympetrum*; hemipterans in the genera *Gerris*, *Notonecta*, *Sigara* or *Hesperocorixa*; aquatic beetles in the genera *Agabus*, *Graptodytes*, *Berosus*, *Helophorus* or *Hydroporus*, among others [15,24,25].

Temporary ponds are especially favorable habitats for amphibians (*Bufo*, *Hyla*, *Rana or Triturus*) to feed and breed (Figure 2). Larvae can feed on the abundant phyto and zooplankton, and aquatic vegetation is ideal for egg laying. Many of these ponds are fishless, thus reducing predation pressure that has a great impact on larvae [26]. Reproductive success depends on the hydroperiod length, because if the pond dries out too soon the offspring can die [9]. In addition, temporary freshwater bodies are very important not only for waterfowl and migratory birds but also for other bird species that inhabit temporary ponds and their surroundings [13].

These ponds also support rich and diverse plant communities, especially in the Mediterranean region, hosting rare and endangered species [9]. Species composition depends on the flooding length, the type of substrate and water depth. In general these species are able to produce seeds in a short period of time to complete their life cycles [13]. We can typically find species of the

Figure 2. Frogs in a temporary pond in A Serra da Capela (NW Spain).

genera *Isoetes*, *Callitriche*, *Ranunculus*, *Eryngium* or *Juncus*. Regarding phytoplankton, a great number of different species belonging to Dinophyceae, Clorophyceae, Euglenophyceae, Zygnematophyceae or Cryptophyceae are usually found in these habitats. Phytoplankton and periphyton constitute the basis of the food webs in temporary ponds [27].

4. Threats

Temporary ponds constitute endangered habitats due to their shallowness and temporality, and probably in future decades their situation will get worse. In general stagnant water bodies have been considered for a long time as unproductive areas inhabited by disease-transmitting insects. Besides, the need for new farmlands has caused the reduction of these habitats [28]. The lack of information on the natural values of temporary ponds and appropriate management measures results in their deterioration or even disappearance. For example, in Spain it was estimated that in the late twentieth century more than 60% of wetlands have disappeared [29].

According to [13], threats to temporary ponds, especially Mediterranean ones, are mainly related to invasive species, pollution, changes in the hydrological functioning and climate change. These threats can be resumed as follows:

- Invasive species: allochthonous flora and fauna species can displace autochthonous ones. The introduction of invasive species of fishes, crabs or reptiles that predate crustaceans, insects and amphibians can produce the disappearance of the latter ones which are not used to inhabit ponds with this type of predators.
- Pollution: fertilizers and pesticides affect the water chemistry of the ponds. Many species are sensitive to pesticides and disappear in polluted habitats. On the other hand, fertilizers cause the eutrophication of the water, which can modify flora and fauna assemblages.
- Changes in the hydrological functioning: these changes are all related to human activities, such as urbanization, over-exploitation of aquifers, draining for new farmlands or dredging for watering cattle.
- Climate change effects: temporary ponds depend on flooding and drought phases for a correct functioning of the habitat. Changes in rainfall and temperature due to climate change can greatly affect these ecosystems. Global warming is also transforming permanent water bodies into temporary ones.

In relation to the latter, in the twenty-first century ponds will have to face global challenges [30]. The expected reduction of humid years and of rainfall globally may lead to a decrease in the probability of survival of populations of characteristic pond species [31]. Thus, changes in the hydrology will be a key factor to investigate. In this sense, long-term monitoring can provide particularly rich information, especially in the context of global change, and many protected areas have now set up systems to monitor their biodiversity [30].

5. Case study

5.1. Introduction

As mentioned before, hydroperiod is the main stressor in temporary habitats. Due to the instability of the system, temporary ponds are very diverse ecosystems. Information about the relative biodiversity value of different water body types is a vital pre-requisite for many strategic conservation goals [32], including sustainable catchment management as required by the EC Water Framework Directive (2000/60/EC). In this sense, the composition and abundance of benthic invertebrates is one of the most important criteria to be considered. So, the knowledge about the aquatic invertebrates inhabiting the different temporary pond types is essential for developing management strategies.

The use of different groups as indicators for monitoring population trends in other groups of aquatic invertebrates and for identifying high biodiversity areas at a regional scale has been suggested. For example, aquatic Coleoptera are generally considered a suitable group to assess the environmental and conservation value of wetland sites and habitats [33-36,28,37]. Aquatic Hemiptera are also considered potential bioindicators of water quality [38], so they can be used in terms of regional or global conservation planning of freshwater biodiversity [39].

In Spain, studies focused on temporary ponds have been mainly carried out in the Mediterranean region [e.g. 19,40-45]. In Galicia (NW Spain) several studies in stagnant waters have been carried out during the last years [e. g. 25]. We can conclude that the Mediterranean area of this region has a great biodiversity of aquatic organisms, but there are no studies dealing with the biology and ecology of temporary ponds.

The main objectives of this study were (a) to analyze the composition and structure of the invertebrate fauna assemblages in three temporary ponds using data obtained in studies carried out in two periods of time; and (b) to assess the effectiveness of the SAC on the conservation of their biological values by studying the change in these assemblages.

5.2. Study area

The study was carried out in "A Veiga de Ponteliñares", located in the Autonomous Region of Galicia (North-western Spain) (Figure 3). Although this area is protected under the Natura 2000 network as a SAC and is included in the Biosphere Reserve Área de Allariz, it is one of the smallest protected areas in Galicia, with a surface of 130 Ha. It is formed by alluvial water meadows with temporary flooding along the banks of the Limia River. These meadows represent a small part of what it was in this area until the middle of the 20th century, when these fields were dried including the Antela Lake. This shallow lake, which it was considered the biggest in the Iberian Peninsula, was 6 km long from northeast to southeast and 4 km wide, with a depth of 3 m in the rainy season and less than 1 m in the dry season. The Limia River valley is a highly humanized area with many crops, blasting companies and poultry and pig farms.

The SAC is included in the Mediterranean Region. The climate of the study area is warm temperate, with a mild temperature [46]. Dry summers cause the ponds to dry out, for between two and four months, depending on the year.

Three temporary ponds were sampled in the study area: Veiga da Pencha, A Telleira and A Veiga (Figures 4-6). Table 1 shows the pond codes, which are used in the paper, and the location in UTM coordinates. These ponds are Mediterranean temporary ponds, which is a priority habitat for conservation (code 3170) included in the Annex I of the Habitats Directive and are classified as intermittent waters according to [12].

Pond	Code	UTM X	UTM Y
A Veiga	AV	29T 595.518	4.655.117
Telleira	TE	29T 595.966	4.655.513
Veiga da Pencha	VP	29T 594.548	4.654.969

Table 1. Names of the studied ponds with their codes and UTM coordinates.

Veiga da Pencha (VP) is a temporary pond (15 m maximum width x 100 m maximum length) formed at the end of a stream that was probably connected to the Limia River before the construction of a road on the river side. It is not independent of the stream until late spring

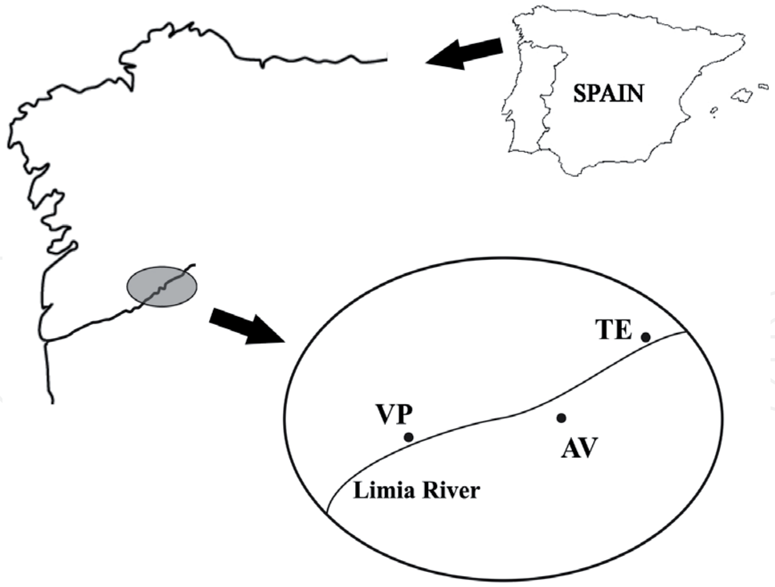


Figure 3. Map indicating the location of the studied ponds within the catchment of the Limia River. VP: Veiga da Pencha; AV: A Veiga; TE: A Telleira.

and dries completely at the end of the summer. The pond is surrounded by willows and birches.

Figure 4. A Veiga da Pencha pond.

A Telleira (TE) is the smallest sampled pond (4 m width x 7 m length). It is located at the end of a temporary stream connected to the Limia River. The pond is formed due to the temporality of the stream. The size of the pond decreases during the dry season but maintains its water volume longer than the other ponds probably due to a freatic contact with the Limia River.

Figure 5. A Telleira pond.

A Veiga (AV) is located in the southern limit of the SAC. It is an irregular and elongated (10 m maximum width x 52 m length) temporary pond. The extremes of the pond dry out rapidly at the end of the rainy season and the central part of the pond dries at the end of the summer.

The studied ponds have important riparian vegetation that consists mainly of grasses and autochthonous deciduous trees, as well as a significant macrophyte cover. The riparian vegetation is mainly composed of *Alnus glutinosa* (L.) Gaertn, *Erica* sp., *Eryngium viviparum* J. Gay, *Fraxinus excelsior* L., *Quercus robur* L. and *Salix atrocinerea* Brot. The main macrophyte species are *Agrostis* sp., *Callitriche palustris* L., *Cyperus* sp., *Damasonium* sp., *Ranunculus peltatus* Schrank and *Scirpus lacustris* (L.) Palla.

Figure 6. A Veiga pond.

5.3. Material and methods

5.3.1. Sampling

The three ponds were sampled in two periods, 2001-2002 (before being included in the Natura 2000 network) and 2007-2011 (after being included in the Natura 2000 network). During 2001 and 2002 samples were taken seasonally, and during the period 2007-2011 surveys were carried out in spring and summer of every year. In total, 24 samples were processed. Fauna was collected using an entomological net (500 µm mesh, 30 cm diameter and 60 cm deep) across a 10m transect running parallel to the margin. This semi-quantitative method allows for direct comparisons across sites or time because sampling effort can be assumed equivalent. The material was preserved in 99% ethanol, and sorted out and identified at the laboratory. After being studied, the specimens were conserved in 70% ethanol and deposited in the scientific collection of the Aquatic Entomology Laboratory at Vigo University.

5.3.2. Data analysis

The structure of the assemblage was assessed using different diversity indices: Richness (S); Rarefied richness (ES); Abundance (N) and the Shannon-Wiener diversity index (H'). Rarefied richness is the expected number of taxa for a given number of randomly sampled individuals and facilitates comparison of areas in which densities may differ [48]. It calculates the number of expected species from each sample if all samples were reduced to a standard size of n individuals. The values of this index were calculated for 200 individuals ES (200). The Shannon-Wiener index measures the average degree of uncertainty in predicting to which species will belong an individual randomly chosen from a collection [49]. It assumes that all the individuals are randomly selected and that all species are represented in the sample. The greater the index value, the greater the diversity in the habitat. According to [49], the usual range for this index is 1.5-3.5.

Similarity relationships among invertebrate assemblages in all samples were determined by the Bray-Curtis coefficient and graphically presented using non-metric Multi-Dimensional Scaling (NMDS) mapped in two dimensions. Then, we grouped the samples according to two factors: Pond (A Veiga, Telleira and Veiga da Pencha), and the two periods (2001-2002 and 2007-2011). An analysis of similarity (ANOSIM) was used to test whether the established groups based on biotic data differed significantly.

To investigate the groups' consistency the SIMilarity PERcentages-species contributions (SIMPER) analysis was used to obtain differences between all pairs of groups and the contribution of each species for the groups. SIMPER examines the contribution of each species to the average Bray-Curtis dissimilarity between groups of samples and also determines the contribution to similarity within a group [47]. Statistical analyses were carried out with PRIMER version 6.

5.4. Results

5.4.1. Diversity indices

Table 2 shows the minimum, maximum and mean (including standard deviation) diversity indices (total abundance, richness, rarefied richness and Shannon-Wiener diversity) for each sample.

	TE			AV			VP		
	Minimum	Maximum	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum	Mean ± SD
S	13	35	23.4 ± 8.02	10	61	31.75 ± 18.59	21	77	41 ± 20.38
ES (200)	10.58	22.47	15.78 ± 5	10	25	18.93 ± 5.62	16,77	34,26	24.04 ± 5.36
N	246	5469	1512 ± 2258	68	18149	3185 ± 6381	110	16349	3405 ± 5290
H'(log^2)	1.43	3.15	2.46 ± 0.71	1,86	4	2.97 ± 0.74	2,19	4,58	3.41 ± 0.74

Table 2. Minimum, maximum and mean values of the different diversity indices.

The total abundance was of 70,512 specimens. The most abundant were insects (34,600) and crustaceans (32,582). Among insects Coleoptera was the most abundant group (15,497 specimens), followed by Diptera (7,760), Hemiptera (3,681) and Odonata (3,119). The most abundant crustaceans were Cladocera (23,712), Copepoda (5,599) and Ostracoda (2,501).

The greatest abundances were observed in AV in April 2007, with 18,149 specimens collected, and in VP in the same sampling (16,349 specimens). On the contrary, the lowest values were obtained in AV in December 2001 with only 68 individuals captured and in VP in May 2002 (110 specimens). Mean abundance was significantly higher in VP (3,405 specimens) and AV (3,185) than in TE (1,512).

Regarding species, the most abundant were the water beetles *Graptodytes flavipes* (Olivier) (5,216 specimens), *Anacaena lutescens* (Stephens) (1,580), *Haliplus lineatocollis* (Marsham) (1,114) and *Hydrochus angustatus* Germar (1,027). Several species were represented by only one specimen, among which we highlight the crustacean *Lepidurus apus*, the beetle *Helophorus bameuli* Angus and the dragonfly *Boyeria irene* (Fonscolombe).

In total, 169 invertebrate taxa were collected in the three studied ponds (Table 3). The most representative group were insects (145 taxa), followed by gastropods (6 taxa) and crustaceans (5 taxa). Among insects, we highlight Coleoptera (94 species), Hemiptera (20 species) and Odonata (14 species). The other faunal groups recorded were Cnidaria, Bivalvia, Hirudinea, Oligochaeta, Arachnida and Collembola.

Taxa	**TE**	**AV**	**VP**
Cnidaria			
Hydridae			
Hydra sp.		X	
Bivalvia			
Sphaeriidae		X	X
Pisidium sp.		X	X
Gastropoda			
Ancylidae		X	X
Lymnaeidae			X
Myxas sp.		X	X
Radix sp.			X
Physidae	X		
Planorbidae		X	X
Hirudinea			
Erpobdellidae		X	X
Glossiphonidae			X
Haemopidae			
Haemopis sanguisuga (L., 1758)			X
Hirudinidae		X	X
Oligochaeta			
Enchytraeidae		X	
Lumbricidae		X	
Lumbriculidae		X	X
Naididae		X	

Taxa	TE	AV	VP
Crustacea			
Asellidae	X	X	X
Cladocera		X	X
Copepoda		X	X
Ostracoda		X	X
Triopsidae			
Lepidurus apus (L., 1758)			X
Arachnida			
Hydracarina	X	X	X
Collembola		X	X
Insecta			
Coleoptera			
Gyrinidae			
Gyrinus substriatus Stephens, 1829	X	X	X
Haliplidae			
Haliplus guttatus Aubé, 1836			X
Haliplus heydeni Wehncke, 1875	X	X	X
Haliplus lineatocollis (Marsham, 1802)	X	X	X
Haliplus sp.		X	X
Peltodytes rotundatus (Aubé, 1836)		X	
Noteridae			
Noterus laevis Sturm, 1834	X	X	X
Dytiscidae			
Agabus bipustulatus (L., 1767)	X	X	X
Agabus brunneus (Fabricius, 1798)			X
Agabus didymus (Olivier, 1795)	X		X
Agabus labiatus (Brahm, 1791)		X	
Agabus paludosus (Fabricius, 1801)			X
Agabus sp.		X	X
Bidessus goudotii (Laporte, 1835)	X	X	X
Colymbetes fuscus (L., 1758)	X	X	X
Cybister lateralimarginalis (De Geer, 1774)			X
Dytiscus marginalis L., 1758	X		X
Dytiscus pisanus Laporte, 1835		X	
Dytiscus semisulcatus O.F. Müller, 1776		X	X
Dytiscus sp.			X
Graptodytes bilineatus (Sturm, 1835)			X
Graptodytes castilianus Fery, 1995	X	X	X
Graptodytes flavipes (Olivier, 1795)	X	X	X
Graptodytes fractus (Sharp, 1882)			X
Graptodytes ignotus (Mulsant & Rey, 1861)	X		X

Taxa	**TE**	**AV**	**VP**
Graptodytes varius (Aubé, 1838)			X
Hydroporus gyllenhalii Schiødte, 1841	X	X	X
Hydroporus planus (Fabricius, 1781)			X
Hydroporus pubescens (Gyllenhal, 1808)		X	X
Hydroporus sp.		X	X
Hydroporus vagepictus Fairmaire & Laboulbène, 1854	X	X	X
Hydroporus vespertinus Fery & Hendrich, 1988		X	X
Hydrovatus clypealis Sharp, 1876		X	X
Hygrotus inaequalis (Fabricius, 1776)	X	X	X
Hyphydrus aubei Ganglbauer, 1892		X	
Ilybius meridionalis Aubé, 1837			X
Ilybius montanus (Stephens, 1828)	X		X
Laccophilus hyalinus (De Geer, 1774)	X	X	
Laccophilus minutus (L., 1758)	X	X	X
Laccophilus sp.			X
Liopterus atriceps Sharp, 1882	X	X	X
Metaporus meridionalis (Aubé, 1838)			X
Rhantus hispanicus Sharp, 1882		X	X
Rhantus suturalis (McLeay, 1825)			X
Stictonectes lepidus (Olivier, 1795)	X		
Hydrophilidae			
Anacaena globulus (Paykull, 1798)			X
Anacaena limbata (Fabricius, 1792)	X		X
Anacaena lutescens (Stephens, 1829)	X	X	X
Anacaena sp.			X
Berosus affinis Brullé, 1835	X		X
Berosus signaticollis (Charpentier, 1825)	X	X	X
Berosus sp.	X	X	X
Enochrus fuscipennis (Thomson, 1884)	X		X
Enochrus nigritus (Sharp, 1872)	X	X	X
Enochrus sp.		X	X
Helochares punctatus Sharp, 1869	X	X	X
Hydrobius convexus Brullé, 1835			X
Hydrobius fuscipes (L., 1758)	X	X	X
Hydrobius sp.		X	X
Hydrophilus pistaceus Laporte, 1840			X
Laccobius ytenensis Sharp, 1910	X		
Limnoxenus niger (Gmelin, 1790)	X	X	X
Paracymus scutellaris (Rosenhauer, 1856)	X		X
Hydrochidae			
Hydrochus angustatus Germar, 1824	X	X	X

Taxa	TE	AV	VP
Hydrochus flavipennis Küster, 1852	X	X	X
Hydrochus nitidicollis Mulsant, 1844	X	X	X
Helophoridae			
Helophorus alternans Gené, 1836		X	X
Helophorus bameuli Angus, 1987		X	
Helophorus flavipes Fabricius, 1792		X	X
Helophorus maritimus Rey, 1885		X	
Helophorus minutus Fabricius, 1775		X	X
Helophorus seidlitzii Kuwert, 1885			X
Helophorus sp.	X		X
Hydraenidae			
Aulacochthebius exaratus (Mulsant, 1844)		X	X
Hydraena brachymera D'Orchymont, 1936	X	X	
Hydraena sp.		X	X
Hydraena marcosae Aguilera,Hernando & Ribera, 1997	X		X
Hydraena rugosa Mulsant, 1844	X	X	X
Hydraena testacea Curtis, 1830	X	X	X
Hydrena exasperata D'Orchymont, 1935	X	X	
Limnebius gerhardti Heyden, 1870	X	X	
Limnebius lusitanus Balfour-Browne, 1979		X	X
Limnebius sp.			X
Limnebius truncatellus (Thunberg, 1794)		X	
Ochthebius sp.	X	X	X
Ochthebius viridis fallaciosus Ganglbauer, 1901			X
Dryopidae			
Dryops luridus (Erichson, 1847)	X	X	X
Dryops sp.		X	X
Dryops striatellus (Fairmaire & Brisout, 1859)		X	
Elmidae			
Oulimnius rivularis (Rosenhauer, 1856)	X		X
Oulimnius sp.		X	X
Scirtidae			
Helodes sp.			X
Hydrocyphon sp.		X	X
Diptera			
Ceratopogonidae		X	X
Chironomidae	X	X	X
Culicidae			
Anopheles sp.	X	X	X
Culex sp.		X	X
Dixidae			

Taxa	TE	AV	VP
Dixella sp.		X	X
Dolichopodidae			X
Empididae		X	X
Limoniidae		X	
Rhagionidae		X	
Sciomyzidae			X
Tabanidae		X	X
Ephemeroptera			
Baetidae		X	X
Siphlonuridae			
Siphlonurus sp.		X	X
Hemiptera			
Corixidae			
Corixa iberica Jansson, 1981		X	X
Hesperocorixa moesta (Fieber, 1848)		X	X
Hesperocorixa sahlbergi (Fieber, 1848)	X	X	X
Hesperocorixa sp.		X	
Sigara janssoni Lucas, 1983	X	X	X
Sigara limitata (Fieber, 1848)			X
Sigara scotti (Douglas & Scott, 1868)			X
Sigara sp.			X
Gerridae			
Gerris gibbifer Schummel, 1832			X
Gerris lacustris (L., 1758)			X
Gerris sp.		X	X
Gerris thoracicus Schummel, 1832		X	X
Hydrometridae			
Hydrometra stagnorum (L., 1758)			X
Naucoridae			
Naucoris maculatus Fabricius, 1798	X	X	X
Nepidae			
Nepa cinerea L., 1758	X	X	X
Ranatra linearis (L., 1758)		X	X
Notonectidae			
Notonecta glauca Poisson, 1758			X
Notonecta meridionalis Poisson, 1926		X	X
Notonecta obliqua Thunberg, 1787			X
Notonecta sp.		X	X
Pleidae			
Plea minutissima Leach, 1817	X	X	X
Vellidae			X

Taxa	TE	AV	VP
Lepidoptera			
Crambidae			
Elophila sp.			X
Odonata			
Aeshnidae			X
Boyeria irene (Fonscolombe, 1838)	X		
Coenagrionidae	X	X	X
Pyrrhosoma nymphula (Sulzer, 1776)		X	
Cordulegasteridae			
Cordulegaster sp.			X
Cordullidae		X	X
Lestidae			
Lestes barbarus (Fabricius, 1798)	X	X	
Lestes dryas Kirby, 1890			X
Lestes sp.		X	X
Lestes viridis (Vander Linden, 1825)		X	
Libellulidae		X	X
Sympetrum sanguineum (Muller, 1764)			X
Sympetrum vulgatum (L., 1758)	X	X	X
Platycnemididae			
Platycnemis sp.			X
Plecoptera			
Nemouridae			X
Trichoptera			
Limnephilidae		X	X
Limnephilus sp.			X

Table 3. List of the identified taxa. The crosses indicate the presence of the taxa in the ponds.

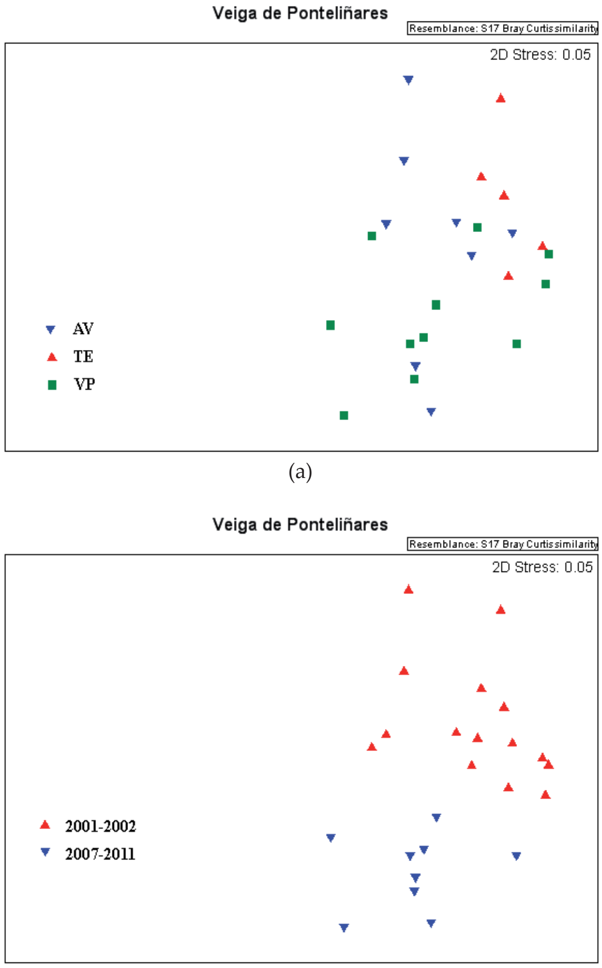
The greatest richness values were observed in VP in April 2007 (77 taxa recorded) and in July 2008 (64 taxa). On the other hand, the lowest values were observed in AV in December 2001 (10 taxa) and in TE in September 2002 (13 taxa). The mean richness value was 41 in VP, 31.75 in AV and 23.4 in TE, showing a similar pattern to that observed for the abundance. Considering the accumulated values, the richest pond was VP with 142 taxa, followed by AV (110 taxa) and TE (59 taxa).

In this study, the highest values of rarefied richness correspond to VP in July 2007 (34.26) and July 2008 (31.16). The lowest values were observed in AV in December 2001 (10) and in TE in the same sample (10.58). The mean rarefied richness was 24.04 in VP, 18.93 in AV and 15.78 in TE.

The Shannon-Wiener diversity index ($H'(\log^2)$) revealed that, in general, the studied ponds presented high diversity values. The highest values were observed in VP in July 2007 (4.58) and in July 2008 (4.27), and the lowest values were recorded in TE in December 2001 (1.43) and in AV in April 2007 (1.86). Among ponds, the mean values were 3.41 (VP), 2.97 (AV) and 2.46 (TE).

5.4.2. Assemblage composition

The NMDS ordination shows the spatial distribution of the samples and the grouping according to faunal similarity. The stress obtained with the ordination was 0.05, which ensures good consistency of results. NMDS allowed us to group the species according to two factors: Pond and Period (Figure 7). In the latter we can see a clear separation into two groups: 2001-2002 and 2007-2011. According to the ANOSIM, the assemblage composition of invertebrates shows significant differences in faunal composition related to the two periods (R=0.572; p=0.001). Regarding Pond factor, this analysis shows significant differences between TE and the two other ponds (TE-AV: R=0.225; p=0.003; TE-VP: R=0.250; p=0.002), but does not show significant differences between AV and VP (R=0.063; p=0.17).



(a)

(b)

Figure 7. Results of the NMDS analysis: (a) Pond factor, and (b) Period factor. In graph (a) AV is represented with blue triangles, TE with red triangles and VP with green squares. In graph (b) the period 2001-2002 is represented with red triangles and period 2007-2011 with blue ones.

The contribution of the taxa to each group (ponds and periods) according to the SIMPER analysis is given in the Table 4. Regarding ponds, the dissimilarity between groups ranged from 84.26% (AV-VP) to 91.55% (TE-AV) and between periods, the dissimilarity was 95.55%. The faunal groups that most contributed to group similarity were insects and crustaceans, for both pond factor and period factor. Among insects, the taxa that most contributed were the beetles *Graptodytes flavipes*, *Hydroporus vagepictus* Fairmaire & Laboulbène, *Haliplus lineatocollis*, *Hydrochus angustatus* and the dipterans *Culex* sp. and Chironomidae. The most contributive crustaceans were Cladocera, Copepoda and Ostracoda, especially important for 2007-2011 group characterization.

Factor	Number of samples	Most contributive taxa	Contribution to the group characterization
AV	8	*Hydroporus vagepictus*, *Culex* sp., *Hydrovatus clypealis*, *Hydroporus vespertinus*	57.95% (*Hydroporus vagepictus* contributed with 31.01%)
TE	5	*Graptodytes flavipes*, *Haliplus lineatocollis*, *Hydraena marcosae*, *Hydraena testacea*	83.22% (*Graptodytes flavipes* contributed with 48.76%)
VP	11	*Graptodytes flavipes*, *Hydrochus angustatus*, Chironomidae, *Anacaena lutescens*, Copepoda, Sphaeriidae	40.74% (*Graptodytes flavipes* contributed with 8.14%)
2001-2002	15	*Graptodytes flavipes*, *Hydroporus vagepictus*, *Haliplus lineatocollis*, *Hydrochus angustatus*	56.17% (*Graptodytes flavipes* contributed with 27.35%)
2007-2011	9	Cladocera, Chironomidae, Copepoda, Ostracoda	60.32% (Cladocera contributed with 20.95%)

Table 4. Results of the SIMPER analysis separated by ponds and by periods showing the most contributive taxa in each group.

5.5. Discussion

Invertebrate richness in temporary waters can be considered similar to that found in natural and artificial permanent ponds [50-52]. Other permanent systems, such as mountain peatlands [53], show lower values. Our temporary ponds had a rich invertebrate fauna with similar or higher richness than other temporary systems [54,19,55,42]. When permanent and temporary waters are compared, temporary ones are richer, probably due to the trophic state of the pond, a factor associated with water permanence [56].

In this study we found some interesting and rare species, as already highlighted in other temporary pond studies in different parts of the world, in which the importance of this habitat for rare and often endemic species has been emphasized [e. g. 57,19,58]. On the other hand, it is often assumed that there is little overlap between invertebrate species found in temporary and permanent ponds [12]. However, the results of this study show that many of the species recorded in temporary ponds can also be found in permanent ones, in agreement with other studies [59,8,60].

Despite their ephemeral nature and small size, temporary ponds have a great importance for biodiversity maintenance in particular as regards some rare invertebrate species [12]. According to [61], both common and rare species rely on a variety of pond types within each region for their continued survival. According to [19], the faunal composition of temperate temporary aquatic ecosystems includes a remarkable number of uncommon species, species associated with permanent environments and species that frequently or exclusively inhabit these environments due to their biological adaptations. Similar results were observed in our study.

The main groups observed in the studied ponds were insects and crustaceans. Many of them rely on temporary ponds for reproduction (e.g. beetles, dipterans, dragonflies) and others spend their entire life cycle in these ponds as in the case of branchiopods. According to [22], several species of this group of crustaceans are only found in this type of ponds because of the lack of predatory fish. Branchiopods found in these habitats include Notostraca (tadpole shrimps), Cladocera (water fleas), Anostraca (fairy shrimps) and Conchostraca (clam shrimps).

One interesting crustacean species was collected during the surveys, the tadpole shrimp *Lepidurus apus*. This crustacean is rare in the Iberian Peninsula and lives in small temporary waters, such as flooded roadsides and ditches widenings and backwaters, always with aquatic vegetation, and is typical of low mineralized, dystrophic and in general clear waters [22]. The *Lepidurus* genus is present in all continents except Antarctica [62]. This world-wide distribution is due to their antiquity, but possibly also to their passive transport: geographical barriers are more effective for non-passively distributed animals. From an ecological point of view notostracans, like most branchiopods, are restricted to temporary pools [63]. The ephemerality of these extreme habitats may have been selected for the development of resistant stages (dried eggs or cysts) and some unusual reproductive strategies. In this sense, [64] noted that temporary wetlands flagship taxa (e.g. anostracans) rarely co-occur together and therefore suggested that each wetland harbouring them should be given conservation priority.

Among insects, Coleoptera and Hemiptera species dominated the temporary pond assemblages. This result agrees with other studies in temporary ponds [65,19,55,61]. Adults in both groups are mobile and can leave the pond when it dries out due to their excellent dispersal capabilities [21,66]. So, the high abundance of these taxa may be explained by the arrival of dispersers, moving from dry ponds to other ponds while dispersing to more permanent habitats to survive during dry periods [21,67,66,20]. On the contrary, non-mobile invertebrates require adaptations to survive the dry period.

Regarding Coleoptera, several interesting rare species barely recorded in the Iberian Peninsula were found in the studied ponds, like *Agabus labiatus* (Brahm), *Liopterus atriceps* Sharp, *Graptodytes bilineatus* (Sturm), *G. flavipes* or *Hydroporus vagepictus*. According to [68], *G. flavipes* is a rare species, but when it occurs it is usually in high abundance, a fact also observed in our study. *H. vagepictus* is an Iberian endemic beetle which has a wide ecological range and is present in running and stagnant waters [69]. The capture of the aquatic beetle *Hydraena rugosa* Mulsant must be highlighted. This species is little cited in the Iberian Peninsula but when found it is usually collected in high abundance [70].

According to the SIMPER analysis, different beetles were the species that contributed most to the NMDS groups characterization, especially *Haliplus lineatocollis* and *Hydrochus angustatus*. *H. lineatocollis* occurs in different habitats, from temporary ponds to rivers [e. g. 19,71]. A similar pattern was observed for *H. angustatus*, present in running waters [72] and coastal lagoons [73]. This result confirms that these ponds also harbour species with a wide ecological range.

In this study, several interesting Hemiptera species scarcely recorded in the Iberian Peninsula were collected, such as *Hesperocorixa moesta* (Fieber) and *Sigara limitata* (Fieber). These insects are also common inhabitants of temporary ponds [19,55,74,42]. Two Odonata species typical of temporary habitats were recorded, *Lestes dryas* Kirby and *Sympetrum sanguineum* (Muller). These two species can complete their life cycles before the habitat dries out. [23] also found them in Irish turloughs before the drying season. Regarding Thichoptera, the only ones recorded were Limnephilidae. They are common in temporary habitats, and according to [75] they emerge before the dry period and remain inactive in vegetation until the pond refills in autumn, and the eggs may be laid.

Endemic species constitute priority species to conserve, although in many cases are common in their distribution area. In the SAC Veiga de Ponteliñares several endemisms were captured during the surveys, the water beetles *Hydroporus vagepictus*, *H. vespertinus* Fery & Hendrich, *Graptodytes castilianus* Fery, *Hydraena marcosae* Aguilera, Hernando & Ribera, *Limnebius lusitanus* Balfour-Browne, *Helophorus bameuli* Angus and *H. seidlitzii* Kuwert, and the water boatman *Sigara janssoni* Lucas. So, their presence in these temporary ponds is of particular interest as it increases their natural value.

Temporary ponds are fluctuating and unstable habitats whose faunal composition varies greatly from one year to another. In this study we have detected significant changes in their invertebrate composition. The NMDS analysis segregated the studied ponds in two groups corresponding with the two periods (2001-2002 and 2007-2011) and the ANOSIM analysis showed significant dissimilarity between the two periods (R=0.572; P=0.001). The results show that these ponds present a remarkable variability in time. Inter-annual variation may be due to variation in climate conditions, as a consequence of the wide differences in rainfall, and in the differences in the lenght of the hydroperiod observed among years. According to [76], historical events, such as very dry years, may affect the invertebrate community composition as much as site-specific abiotic differences among ponds. High variation among years has already been noted by other authors such as [44] in a study conducted in Doñana (southern Spain).

5.6. Conclusion

The use of invertebrates as monitoring tools in freshwater management programmes depends on the ability to discriminate natural (spatial and temporal) variation in community structure from alterations caused by anthropogenic disturbance [77,78]. In this sense, temporary ponds in the SAC Veiga de Ponteliñares are a good example. Despite the large inter-annual variability, these ponds can result in sustaining a rich and abundant invertebrate fauna. The high species richness recorded in this study is likely to reflect the high ecological quality of these ponds, which are located in a protected area and are minimally impaired by anthropogenic activity. In addition, the occurrence of rare and uncommon species suggests that effective conservation of aquatic biodiversity in the SAC requires a regional approach of management.

Our study emphasizes the importance of drying out of ponds for the occurrence of rare and uncommon species forasmuch several of these species were found during this study. This finding highlights the contribution of temporary ponds to regional biodiversity and their high conservation value. It is important to preserve these systems, especially in Europe, where the number of temporary ponds is probably a mere fraction of what they probably were in the past [79].

The high richness found in our study does not correspond to a single pond, but to a system of temporary ponds. According to [80] ponds located near each other allow movement and dispersal of species among them. In this kind of systems, the high connectivity and non-fragmentation area are very important factors to conserve their invertebrate biodiversity [81,82]. Some studies have claimed that for the conservation of biodiversity of temporary pond species it is more important to preserve an area with a system of temporary ponds than the preservation of isolated ponds [83-86,9,61]. In this sense, this study highlights the importance of "Veiga de Ponteliñares"in the preservation of biodiversity at a regional scale. In this SAC, there are different small ponds and the connectivity between them favours the dispersion and preservation of species and makes it a hot spot of aquatic biodiversity.

Finally, it would be interesting to expand the SAC trying to include all the ponds formed along the banks of the Limia River. Other possible management measure would be to restore the numerous ponds formed by the sand extraction which are located where once was the Antela Lake. The aquatic fauna will colonized the new habitats rapidly due to the proximity to the Limia River and the other ponds. Thus, the restoration of the Antela Lake would be fundamental for the maintenance of the biodiversity in an area full of farms and crops that polluted the aquatic ecosystems of the region causing the loss of the Galician fauna and flora. In Spain there are clear examples of the restoration of shallow lakes dried during the past century. We can highlight the cases of Cospeito and Caque (Galicia), La Nava and Pedraza (Palencia), and Cañizar (Teruel). These wetlands have been restored through the development of various projects financed by Spanish and European public administrations.

Acknowledgements

This study was financially supported by the Galician Government through different projects ("*Study of the entomological fauna of Veiga de Ponteliñares (Ourense), SAC proposed by Galicia for the Natura 2000 network*"; "*Study and assessment of the diversity of aquatic invertebrates in Galician standing waters included in the Natura 2000 network*" and "*Assessment of the effectiveness of the wetlands included in the Galician Natura 2000 network as priority conservation areas for invertebrates*").

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