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Review

Ecological and Conservation Value of Small Standing-Water Ecosystems: A Systematic Review of Current Knowledge and Future Challenges

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Abstract: A small standing-water ecosystem (SWE) is a shallow (<20 m) lentic water body with a surface of a few hectares (≤10 ha). Compared to larger counterparts, they exhibit wider ecotones, sometimes even equaling their whole surface, which maximizes structural heterogeneity, supporting exceptionally high biodiversity, metabolic rates, and functionality. Surprisingly, no binding regulations support global strategies for SWE conservation. This work consists of a literature review performed for the period 2004–2018 to assess the ecological and conservation value of SWEs and the contribution of the Water Framework Directive (WFD) in promoting their conservation. Outcomes from this work open new perspectives on SWEs, which emerge as valuable ecosystems, and confirm their pivotal contribution to watershed biodiversity, resilience, and functionality. Results also suggest clear narrative trends and large knowledge gaps across geographical areas, biological components, and target issues. Additionally, we note that SWEs are under-represented in the frame of WFD implementation, stressing their marginality into assessing procedures. All of this calls for further studies, especially outside Europe and with a global, multi-taxon perspective. These should be devoted to quantitatively assess the roles of SWEs in maintaining global water ecosystem quality, biodiversity, and services, and to prioritize management actions for their conservation.

Keywords: lentic water bodies; small natural features; aquatic biodiversity; metabolism; eutrophication; nature conservation priorities; WFD; refuges

1. Introduction

Small standing-water ecosystems (SWEs) contribute substantially to the global functioning of catchments, modulating nutrient retention and recycling along the hydrological transport pathways [1]. Compared to larger lentic freshwater ecosystems, SWEs are characterized by a lower area/perimeter ratio that emphasizes the contribution of ecotonal zones to their metabolism and functioning, maximizing the importance of their role as biogeochemical reactors [2,3]. Accordingly, they support high metabolic rates that are often intimately coupled with naturally high levels of nutrients and trophic conditions (i.e., eutrophy, hypertrophy) [4].

SWEs are shallow (not more than 20 m deep) and small lentic water bodies ranging in area between 1 m^2 and several ha (≤10 ha), including small lakes, pools, ponds, and wetlands, both perennial and temporary, with an artificial or natural origin [5], and references therein. A further peculiar aspect is the prevalent source of water supply, which can vary from water bodies exclusively fed by atmospheric depositions (i.e., ombrotrophic), to those with prevalent surface feeding or groundwater supply (e.g., ground-water dependent ecosystems, GDE). Additionally, the potentially diversified source-water typologies are coupled with a very wide spectra of interconnection or isolation rates (in terms of both time and space) with the surface hydrological network. This translates into high structural heterogeneity that is expected to be mirrored by high rates of functional and compositional biodiversity. Hence, strong evidence indicates that—especially in heavily impacted regions—small habitat patches are essential in sustaining varied and complex communities, such as small man-made (secondary) water bodies for plants and animals (e.g., hydrophytes, Odonata species) [6–9]. In this sense, Hill et al. [10] have verified the high taxonomic richness associated to urban ponds, found to be similar to that for nonurban ponds, opening new perspectives in conserving freshwater biodiversity in highly impacted and altered landscapes. In a similar way, springs were recently confirmed by a study comparing large datasets of spring and stream diatoms to be refuges for sensitive and threatened diatom taxa [11], also likely to host least-impaired habitat relicts (LIHRe), especially in densely inhabited and heavily impacted geographic areas.

SWEs are present on almost every continent, and in all key biomes, including tropical rainforests, temperate woods, grasslands, steppe, savanna, drylands, and the arctic tundra. In Mediterranean regions, SWEs can be either perennial or seasonal with complex inter-annual dynamic phases that justify the high rates of unique floristic and biotic diversity [7,12,13]. This is especially true in lowlands with the highest human and climate-related change impacts [14,15].

However, this evidence is not translated into binding regulations and policy programs capable of generating a global protection strategy. This contrasts with outcomes from multiple studies highlighting the pivotal contribution of SWEs to the local, regional, and global biodiversity [5,13,16]. This situation mirrors what happened with spring habitats [17], and often leaves these habitats at the mercy of human tampering outside the network of protected areas and natural parks where landscape alterations have accumulated in the last centuries [18]. This is imputable to the relatively small dimensions and the high intrinsic structural and biotic complexity of SWEs, which greatly limit the possibility of establishing general conservation measures, as well as acquiring statutory quality data or naturalness values [19]. Recently, similar reflections have been advanced and discussed by Hunter et al. [8], stressing the pivotal contribution of small natural features (SNF) to the global biodiversity conservation priorities, in opposition to the role of more extensive ecosystems. From a conservation point of view, SWEs fit—in terms of dimension and structural complexity—with the definition of small natural features (SNF) [20], as, for instance, springs and temporary wetlands [15,21]. Here, we refer to SWEs as lentic freshwater representatives of SNF.

Along with this renewed interest in small ecosystems, we believe that it is urgent to reaffirm the centrality of SWEs at multiple scales for the protection and enhancement of biodiversity in general, not exclusively for the obligate aquatic fauna or flora. This is imperative considering the critical, ongoing effects of climate change on aquatic- and wet-environment dynamics worldwide.

In this context, our main objectives were to substantiate and detail the amount of literature specifically aimed at investigating the ecological value of SWEs, as well at exploring the regulatory strategies designed for SWE protection over the 2004–2018 period. Secondly, particular emphasis was placed on the last six years (2013–2018), in order 1) to compare the narrative structure of SWE papers with those focused on rivers and lakes, and 2) to highlight the latest trends in studies having SWE as topic. In fact, SWEs are generally excluded from the actual environmental legislation due to their reduced dimensions and marginality. For example, in Europe, the Water Framework Directive (WFD) sets a clear request to protect only large lakes with areas >50 ha, while the smaller ones fall in a "grey zone". For these cases, the WFD leaves Member States with the final decision to include these ecosystems in the national strategies for water body protection [22].

In light of these voluntary strategies, we explored the literature that considered SWEs within national implementation programs of the WFD to highlight the disproportionately small amount of resources invested for marginal and/or shallow water bodies compared to large, deep lentic waters.

2. Materials and Methods

Data collection included literature searches for marginal aquatic ecosystems, as well as for shallow water bodies with reduced surfaces (≤10 ha) and depth (≤20 m). These dimensional thresholds discriminate our target habitats from larger lentic aquatic ecosystems (including bays, lagoons, reservoirs, and lakes).

We focused our attention on all published records over the 2004–2018 period, up until September 30th, 2018, in the Scopus database concerning the following primary search terms: "conservation value" OR "ecological value", AND wetland OR pond OR pool OR swamp OR "shallow water body" (topic). The beginning of the period of interest corresponds to the launch of the "European Pond Conservation Network" initiative (EPCN; www.europeanponds.org; i.e., 2004). Moreover, the current ecological implications and conservation values of SWEs were investigated focusing on works published over the last six years (2013–2018; up until 30 September 2018).

These criteria generated 552 different hits (last accessed 1 January 2019). After a preliminary screening of references, relevant cross-linked references, and systematic selection, 118 papers were found to be consistent with our scope, of which 62 for the 2013–2018 period (Table S1). The papers' selection was performed following the "matrix method" approach proposed by Klopper et al. [23] that allows the generation of an evaluation matrix. This enabled the verification of the adequacy of each record selected (considering topic, habitat and dimension coherence (1–3); Table 1), and to synthesize all the main features of each paper in the analysis. We spanned our attention to five different descriptive features as follows: habitat type (4); biotic target (5); geographical location of investigated aquatic ecosystems (6); research type (7); and the target issues (8). A complete overview of the issue categories is reported in Table 1. Specifically, with reference to the research types, we split the studies into basic or applied categories (Bas, App), and—when applicable—into indexation procedures (Ind), modeling approaches (Mod), laboratory experiments (Lab), and reviews (Rev). Exclusively papers that positively meet the first three main criteria (topic, habitat, and dimension matching in agreement with the default SWE thresholds) have been considered in the analyses. On the contrary, papers with divergent topics have been discarded.

In order to compare SWE databases with studies concerning rivers and lakes, we did an additional query replacing the habitat terms (wetland OR pond OR pool OR swamp OR "shallow water body) with 'river OR stream', and 'lake OR "large water body", obtaining 514 and 182 papers, respectively. All these hits—collected in order to compare their relative importance within the field of conservation ecology—were evaluated using the evaluation matrix elaborated for previous screenings and period of investigation. Overall, 123 (57) and 46 (22) papers consistent with our topics were selected, for rivers and lakes, and for the entire period or the last six years (in brackets), respectively (Tables S2 and S3).

Table 1. List of features and categories used in the evaluation matrix performed for the inspection of selected literature, and their representativeness across target ecosystems (SWEs = small standing-water ecosystems, Rs = rivers, and Ls = Lakes), and publication periods (2004–2018 for SWEs, and 2013–2018 for SWEs, Rs, and Ls).

Feature	Cat	Explanation	SWEs		Rs	Ls
			2004–2018	2013–2018	2013–2018	2013–2018
Topic matching		If the topic of selected papers meets with the target themes	326	111	107	46
Habitat matching		If the habitat analyzed by selected papers meets with the target habitats	187	76	76	32
Habitat dimension matching		If the habitat dimensions meet with the dimensional threshold ($\leq$ 10 ha)	149	80		
Habitat type	*bog*	Bogs	3	2		
	chn	Channels (artificial hydro-system)	1			
	dit	Ditches			4	
	lak	Lakes				18
	obx	Oxbow lakes	2	2		
	pol	Pools	15	6		
	pon	Ponds	58	36		
	riv	Rivers			44	
	ric	Rice paddies	4	3		
	sla	Swallow lakes	2	1		
	sma	Small lakes	9			4
	str	Streams			12	
	swa	Swamps	1	1		
	wet	Wetlands	30	13		
Biotic target	*alg*	Algae	4	3	2	3
	amp	Amphibians	10	7		
	bac	Bacteria	2			1
	bir	Birds (including waterbirds)	4	3		2
	eco	Ecosystem	12	6	6	2
	fau	Fauna	7	4	7	
	fis	Fish	3	1	14	3
	flo	Flora, including also riparian species	23	12	7	
	mac	Macrophytes	22	9	1	8
	mam	Mammalians	1	1		
	veg	Vegetation	10	6	2	
	zoo	Zoobenthos (including invertebrates)	51	28	24	5
Geographical location	*Afr*	Africa	4	3	5	1
	Asi	Asia	12	9	11	2
	Aus	Australia	9	2	5	3
	Eur	Europe	75	42	22	15
	Glo	Global	2		1	
	NAm	North America	13	4	6	3
	SAm	South America	4	2	7	
Type of research	*App*	Applied research	85	57	46	13
	Bas	Basic research	71	41	18	10
	Ind	Indexation	10	3	4	2
	Lab	Laboratory research	2	1	1	1
	Mod	Modelling	1	1	1	1
	Rev	Review			1	
	Ali_inv	Alien invasive species controls	3	1	6	1
	CC	Climate change drivers	1	1	1	1
	Com_iss	Competition issues, including predation	3	2	1	1

Table 1. *Cont.*

Feature	Cat	Explanation	SWEs		Rs	Ls
			2004–2018	2013–2018	2013–2018	2013–2018
Target issues	*Div*	Diversity, including communities' composition and structure	100	52	50	17
	Dyn_iss	Dynamic issues	7	4	2	
	Eco_fun	Ecological functions/services, including recreational uses	13	5	5	2
	Env_det	Environmental determinants, including trophic ones	82	44	44	8
	Hum_det	Human determinants, including impairing factors, human impacts	46	19	37	5
	Met_app	Methodological approaches	7	7	4	3
	Met_int	Metabolic interactions/metabolism/food webs			2	2
	Spa_arr	Spatial arrangement, spatial patterns	87	47	47	16
	Res	Restoration programs, including problems, shortcomings and challenges	17	8	5	1

A second query was carried out that coupled the target aquatic ecosystems with the term "Water Framework Directive" in order to evaluate the level of inclusion of the three investigated habitat categories (SWEs, lotic, and lentic ecosystems) into the WFD implementation actions. For consistency with previous queries, we investigated the 2004–2018 period, considering the existence of an expected physiological time delay between the enactment of the WDF and its first-related scientific publications. These criteria generated 118, 958, and 276 different hits, respectively. Here, we focused our attention on SWE WFD-related articles.

3. Results and Discussion

The present review confirms the wide scientific interest in the ecological implications and conservation values of SWEs, rivers, and lakes worldwide, investigating preeminent ecological aspects, such as spatial patterns, and environmental and human drivers of biodiversity (Table 1; Figures 1 and 2). Globally, 287 papers consistent with the selection criteria were published between 2004 and 2018, of which nearly half (141) were published in the last six years (2013–2018). Focusing on each target habitat, SWEs and rivers exhibit comparable records (118 vs 123 papers for the entire period, 62 vs 57 for the 2013–2018 period, respectively). On the contrary, only 46 studies (22 for the 2013–2018 period) were carried out to exclusively examine lakes in this framework ("conservation" or "ecological value") (Figure 1).

3.1. Conservation and Ecological Assessment of SWEs over the Period 2004–2018

Considering the entire period under investigation (2004–2018), the target habitats of SWE studies were mainly ponds (pon; 49.2%), and wetlands (wet; 25.4%) (Table 1). On the contrary, the other habitat types taken into consideration as SWEs (bog = bogs, chn = channels, obx = oxbow lakes, pol = pools, ric = rice paddies, sla = shallow lakes, and swa = swamps) were much less investigated with rates largely smaller than 10.0%, with the exception of pol that represented 12.7% of the total number of investigated habitats. Benthic macroinvertebrates (zoo; 43.2%), vascular flora (including also not strictly aquatic plants, flo; 19.5%), and macrophytes (exclusively aquatic plants, mac; 18.6%) were the most studied biological components. In contrast, few papers have dealt with amphibians (amp; 8.5%), birds (bir; 3.4%), algae (exclusively algal taxa, alg; 3.4%), and mammalians (mam; 0.8%), or more in general with vegetation (veg; 8.5%), fauna (fau; 5.9%), or ecosystems (eco; 10.2%).

Studies were mainly carried out in Europe (Eur; 63.6%), then North America (NAm; 11.0%) and Asia (Asi; 10.2%), whereas there has been a lack of interest for these aquatic ecosystems in Australia (Aus; 7.6%), Africa (Afr; 3.4%), and South America (SAm; 3.4%). The selected SWE papers can be largely classified as applied (App; 72.0%), and basic research (Bas; 60.2%), and to a lesser extent as indexation (Ind; 8.5%), laboratory research (Exp; 1.7%) or modeling (Mod; 0.8%) activities (Table 1).

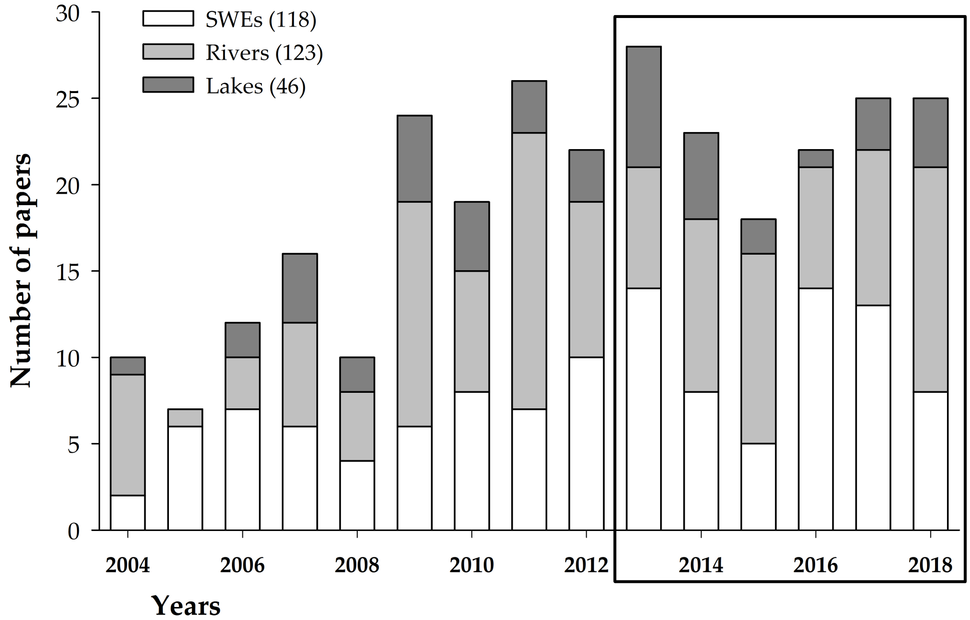

Figure 1. Temporal trend in the number of papers published per year (2004–2018) on "conservation value" OR "ecological value" in relation to habitat typology (SWEs = "wetland OR pond OR pool OR swamp OR "shallow water body""; Rivers = "river OR stream"; and Lakes = "lake OR large water body"). The black box includes the period (2013–2018) over which also rivers and lakes were included in the analysis.

Focusing on the target issues, papers have dealt largely with species diversity (Div; 84.7%) and spatial patterns (Spa_arr; 73.7%), and the study of the pivotal environmental (Env_det; 69.5%) and human (Hum_det; 39.0%) determinants. On the contrary, restoration issues (Res; 14.4%), ecological functioning including ecosystem services and recreational uses (Eco_fun; 11.0%), methodological instruments for habitat characterization (Met_app; 5.9%), and community dynamic issues (Dyn_iss; 5.9%) have been only marginally investigated. Even less attention was given to competition issues (Com_iss; 2.5%), invasive patterns by alien species (Ali_inv; 2.5%), and climate change drivers (CC; 0.8%) (Table 1).

Predominantly, the general narrative structure of the selected SWE papers focuses on ponds (as target habitat type), their diversity and the environmental determinants of species spatial patterns, mainly focusing on zoobenthos. Additionally, SWE papers have been largely carried out in Europe, and exhibit a distinct applied and/or basic research character (Table 1).

3.2. Narrative Trends in the Conservation and Ecological Assessment of SWEs over the Period 2013–2018

Generally, the basic structure of the SWE papers did not change substantially when the analysis was restricted to the most recent studies published between 2013 and 2018 (Figure 2). Ponds are the main target habitat type investigated, through applied studies conducted in Europe and aimed at analyzing the diversity and spatial patterns of zoobenthos (Figure 3).

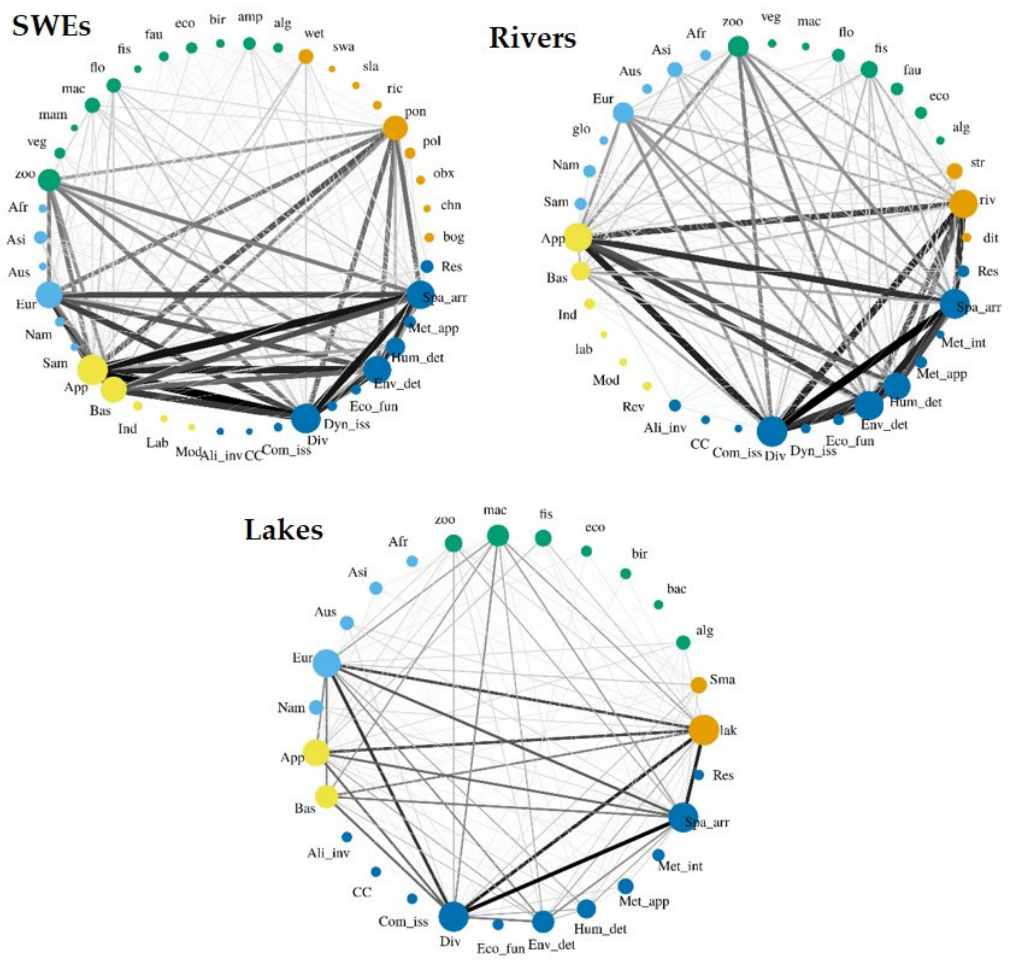

Figure 2. Representativeness and links (as reported in the legend, expressed in number of links; see Table 1) among the descriptive topics evaluated by matrix method (habitat type (**orange**; pon, ric, wet, bog, pol, swa, obx, chn, sla, dit, riv, str, sma, lak); biotic target (**green**; eco, fau, flo, veg, alg, mac, zoo, amp, bir, mam); geographical location of investigated aquatic ecosystems (**light blue**; Eur, Afr, Asi, NAm, SAm, Aus, glo); research type (**yellow**; App, Ind, Bas, Exp, lab, Mod, Rev); and the target issues (**dark blue**; Div, Env_det, Hum_det, CC, Met_app, Met_int, Dyn, Com, Spa_arr, Eco_fun, Ali_inv, Res)) for SWEs, rivers, and lakes; for definitions of the topic categories see Table 1.

However, comparing the last six years of studies (2013–2018) with the previous period (2004–2012), the narrative structure of the selected SWE papers highlighted clear trends. A substantial increase in both applied (+41.9%) and basic research (+12.6%) was recorded, as well as in papers focusing on ponds (+18.8%), and amphibians (+5.9%), and researches carried out in Europe (+8.8%) and Asia (+9.2%). Furthermore, the number of studies developing methodological approaches (+11.3%) has also been increasing. On the other hand, a loss of interest in small lakes (−16.1%), wetlands (−9.4%), and pools (−6.4%) seems to emerge in the framework context of the present review, as well as for studies focused on macrophytes (−8.7%) and indexation procedures (−7.7%), and carried out in North America (−9.6%) and Australia (−9.3%). Similarly, studies finalized to investigate the human determinants (−17.6%) of biodiversity patterns and ecological functions and services (−6.2%) are less represented in recent years (Table 1). The remaining features and categories showed minor deviations, within 5%, and were therefore considered as stable.

Rosset et al. [5,24], Fuentes-Rodríguez et al. [25], Tóth et al. [26], Briers [27], Hill and Wood [28], Bazzanti [29], Wissinger et al. [30], Harabiš [31], and Hill et al. [32] offer clear examples of the most recent SWE papers. These authors detected high rates of biodiversity and the presence of rare or threatened taxa harbored by ponds, which tend to increase significantly in presence of submerged aquatic vegetation or low human perturbation rates (near to pristine conditions). Nonetheless, ponds are habitats of exceptional value especially in moderately to highly impacted landscapes such as agricultural or urban contexts [32]. Here, ponds actively contribute to maintaining a diverse and abundant range of freshwater niches that could offer suitable refuge to a wide spectrum of species. However, this can be guaranteed only by providing robust guidance to homeowners or public opinion in such a way as to enhance the contribution of ponds to local biodiversity. Additionally, these papers also stressed the "sentinel behavior" of ponds in as much as they are particularly vulnerable both to regional and global human-mediated perturbations, including eutrophication, water acidification, and climate change.

Despite this, the studies carrying out a multi-taxon approach are scarce (14 out of 62), reducing the potentiality to capture the actual conservation value of these habitats [5,33–35]. In this context, Rodríguez-Pérez et al. [35] carried out a very interesting experiment aimed at testing the effects induced by the presence of the invasive crayfish Procambarus clarkii in a series of recreated temporary ponds on macrophytes, micro-crustaceans, and macroinvertebrates. They collected robust evidence on the dramatic consequences of this invasion on pond ecosystem structure and functioning.

A quite wide range of target biological components (amp, bir, eco, flo, mam, veg, and zoo) has been investigated by papers focused on wetlands, with a predominance of vegetation- (4; 33.3%), and ecosystemic-oriented studies (3; 25.0%) (Figure 3). Among these, the most relevant are by Brand et al. [36] and Klaus and Noss [37]. The former investigated the wetland vegetation of the Eastern Free State (South Africa), highlighting the high altitude wetland species and communities of the region—in comparison to the Cape Floristic Region. The latter focused on understanding the role played by ephemeral wetlands in supporting specialist and generalist amphibians within a longleaf pine landscape in the South-eastern United States.

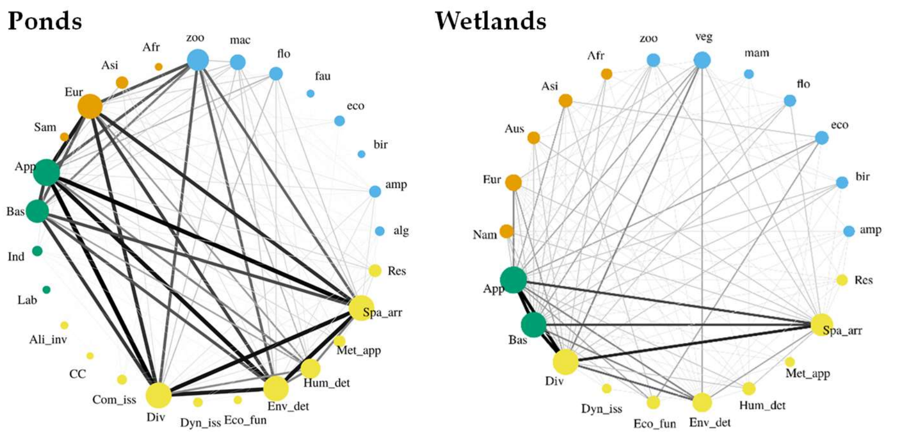

Figure 3. Representativeness and links (as reported in the legend, expressed in number of links; see Table 1) among the descriptive topics evaluated by matrix method (biotic target (**light blue**; zoo, mac, flo, fau, eco, bir, amp, alg); target issues (**yellow**; Res, Spa_arr, Met_app, Hum_det, Env_det, Eco_fun, Dyn_iss, Div, Com_iss, CC, Ali_inv); research type (**green**; Lab, Ind, Bas, App); and the geographical location of investigated aquatic ecosystems (**orange**; Nam, Eur, Aus, Asi, Afr) for ponds and wetlands; for definitions of the topic categories see Table 1.

Focusing on ecosystem functions and services, the work by Cottet et al. [38] investigated the discrepancy between social perception of wetland aesthetics and ecological value based on a photo-questionnaire submitted to lay-people or self-identified experts. The stakeholder greatly appreciated relative high water transparency levels and the diffuse presence of aquatic vegetation, verifying the feasibility of multipurpose management program of aquatic ecosystems. Additionally, Liu et al. [39] provided a framework for assessing the potential reduction in ecosystem services when wetland ecosystems are replaced by agricultural, urban or settled areas.

3.3. Comparison of Conservation and Ecological Assessment of SWEs, Rivers, and Lakes

Based on recent papers (2013–2018), a strong convergence of themes and critical issues links the three types of habitat under investigation (SWEs, rivers, and lakes) (Figure 2). They are primarily the subject of applied studies (more than 81%) aimed at investigating the diversity and spatial arrangement of zoobenthos and its environmental determinants, with an overwhelming predominance of studies conducted in Europe (>56%; Table 1). Focusing on the biotic targets, river studies differ with a preponderance of fish investigations, which represent nearly 25% of the total riverine literature analyzed (14 out of 57), whereas the lake studies show a slight predominance of macrophyte-oriented investigations (8 out of 22; corresponding to the 36.4%), two targets only marginally valued in the context of SWEs. Based on the present review, no data is available for amphibians, bacteria, and birds for rivers, and for amphibian and flora for lakes (Table 1).

River studies show a more balanced distribution among continents. On the contrary, lake studies, as well as SWE investigations, are predominantly concentrated in Europe, representing 67.7% of the total literature explored (Table 1). A single reference is available for a lake study in Africa [24], although the maximum pond/small lake area range analyzed in this work does not exceed 11 ha. On the contrary, no data is available for the same topic for South America. Only one river study has a global perspective [40], although it discusses a conceptual approach finalized to improve temporary/permanent rivers management.

Focusing on the type of research, very few studies are outside of an applied or basic approach (Table 1). Only single papers followed a modeling or manipulative (Lab) approach; only one river study presented a review perspective [40]. Based on the target issues, the least explored topics were the following: climate change determinants (CC), competition issues (Com_iss), metabolic interactions (Met_int), dynamic issues (Dyn_iss), restoration (Res), and alien invasive species (Ali_inv). Despite its relevance, this last aspect is almost completely unexplored by the selected papers. Only one paper per habitat type investigated the potential consequences of climate change on ponds [41], rivers [40], and lakes [42], in the frame of "conservation" and "ecological" topics. Specifically, Brans et al. [41] investigated urbanization-driven warming, verifying the relevant impact of this phenomenon on the water temperature of ponds in Northern Belgium, comparing urban to rural contexts. For urban ponds, higher maximum summer temperatures (+3.69 °C), and a prolongation of growing season up to 45 days were observed, hypothesizing relevant effects for biota inhabiting these systems.

Furthermore, very few papers focused on more than one biological component at the same time (23 out of 141; just over 16%). Evaluating the selected papers as a whole, this appears as the most critical limit to building a robust awareness on the pivotal contribution of habitats to support biodiversity, as well as to prepare actions useful for their preservation, especially considering the expected relevant local effects of climate change.

3.4. SWEs in the Frame of the WFD Implementation

As expected, SWEs are underrepresented in the frame of the WFD implementation: only 118 hits are selected for the period 2013–2018, compared to 958 and 276 hints obtained for rivers and lakes, respectively. Of these, only 17 papers are actually related to WFD issues. Furthermore, exclusively four articles directly deal with WFD implementation actions. Specifically, they targeted (1) the consequences of the exclusion of small water bodies (e.g., headwaters, small lakes, and ponds) from the WFD evaluation procedures at European [43], and at national (Germany) scales [44], (2) the review of the existing indicators for ponds in Spain, focusing on Mediterranean temporary wetlands [45], and (3) the validation—again for Spain—of the use of macrophyte functional groups to typify mountain lakes and ponds [46].

The remaining papers deal with the use of SWEs as biogeochemical reactors, able to ensure the achievement of good ecological status (as imposed by WFD) of related/connected larger water ecosystems (included in the WFD) at the basin scale, both in urban (as stormwater ponds) [47–49] and rural contexts [50–53]. The potential role of SWEs in controlling N and P retention was extensively explored, especially in Northern Europe (Denmark, Sweden, Norway), although more data is needed to better evaluate the effects of hydrologic pulsing on wetland metabolism and performance in the mid to long-term [50]. Generally, these studies confirmed the significant contribution of SWEs in reducing the transport of N and P: They can be good supplements to best management practices, and may, thus, be effective in counteracting local eutrophication phenomena [50,53]. However, to maximize their metabolic efficiency, complex balancing measures at farm and landscape scale must be developed taking into account a combination of wetlands and changes in crop rotations—including set-aside—to achieve required N- and P-load reduction [52].

This is a growing topic in the field of WFD implementation: It is now generally acknowledged that the catchment scale is the (unique) appropriate spatial scale of restoration intervention when long-lasting recovery of a degraded ecosystem is desired. At this scale, SWEs emerge as one of the most important components in modulating water and matter balance, especially carbon and nutrient cycles, as well as the control of pesticides and pollutants through biological purification [45,50–52]. All this brings out an interest in incorporating these habitats into legal frameworks of water management: This goal could be achieved—focusing on the EU environmental policy—responding to the growing need to involve social sciences, including managing authorities and users, in environmental policy [48]. The previously mentioned literature emphasizes these aspects, stressing the pivotal contribution offered by SWEs in controlling nutrient and pollutant mobility and accumulation, both in sediments and soils, through primary producer dynamics.

4. Conclusions

Little more than a decade has passed since the fundamental work by Oertli et al. [54] on the growing interest in pond conservation issues, a topic launched in 2004 and implemented thanks to the development of the EPCN. Since then, SWEs have emerged as one of the most explored freshwater ecosystem types, especially in human-altered contexts—in the framework of "conservation and ecological value" topics. This stresses the pivotal importance of collaborative and international initiatives in supporting biodiversity conservation and reaffirms the key role of SWEs as biodiversity and metabolic hotspots, regardless of their small size [5,10,12,15,55]. SWEs display a disproportionate perimeter/area ratio compared to larger inland water bodies, a status that further emphasizes their impairment risk, mirroring the critical global conservation status of SWEs, mainly due to habitat loss, land use change, and eutrophication [32,56]. However, at the same time, this "high riparian morphological complexity" supports the intense terrestrial–aquatic interactions able to guarantee the exceptional primary production rates of SWEs [2]. The increasing incidence of river intermittency will lead to an increasing relevance of "remnant pools", due to the progressive contraction of surficial flow in lotic aquatic habitats [57]. In a few decades, this will further expand the role of SWEs in supporting biodiversity and functions as these new SNF exhibit individual features with specific behaviors [58].

Findings from this review open new perspectives for improving current knowledge on SWEs, by both highlighting and consolidating the available evidence on their pivotal contribution to supporting biodiversity and ecosystem functions worldwide, but also stressing the narrative trends and gaps across geographical areas, biological components, and target issues. There is a clear need to stimulate studies on a global perspective by systematizing the information available outside Europe, as well as on multi-taxon investigations with respect to the main ecosystem determinants. Fish and primary producers (including algae and macrophytes) are inadequately investigated, whereas very few data are available for bacteria diversity. All these gaps could be filled utilizing molecular genetic techniques, coupled with traditional morphological approaches; in this sense, it becomes possible to overcome the limits of inaccurate determinations and/or reach a specific level for most of the systematic groups [59].

Additionally, we need to better link the key contribution of SWEs in improving the environmental quality of waters (including running waters) to their capability to harbor a prevalent share of aquatic biodiversity, especially considering the future dramatic drying scenarios. An improved comprehension of the efficiency of SWEs in removing nutrients and pesticides from the water is necessary to prompt stakeholders and public administrators to consider SWEs as an integral part of the production system. Only in this way, it is possible to give central importance to the issue of SWEs, asking for legislative adjustments. The latter might accelerate the achievements of WFD goals, enhancing the preservation of aquatic wildlife, as postulated by SNF prioritization in the frame of the global strategies for biodiversity conservation.

Nevertheless, the lack of papers concerning the public perception of SWEs and the method of communication between researchers and policymakers represents a possible barrier to the promotion of the effective management of SWEs. This goal will require a great dissemination effort, as well as commitment to increase the awareness of the relevance of SWEs.

Supplementary Materials: The following are available online at http://www.mdpi.com/2073-4441/11/3/402/s1, Table S1: Evaluation matrix of SWE papers included in the review and obtained using the following primary search terms in Scopus database (over the 2004–2018 period; up until September 30th, 2018): "conservation value" OR "ecological value", AND wetland OR pond OR pool OR swamp OR "shallow water body" (topic) (for abbreviations of the feature' categories see Table 1); six additional papers—here highlighted in bold—were selected using the primary search terms 'lake OR "large water body", Table S2: Evaluation matrix of the river' papers included in the review and obtained using the following primary search terms in Scopus database (over the 2013–2018 period; up until September 30th, 2018): "conservation value" OR "ecological value", AND 'river OR stream' (for abbreviations of the feature' categories see Table 1), Table S3: Evaluation matrix of the lake' papers included in the review and obtained using the following primary search terms in Scopus database (over the 2013–2018 period; up until September 30th, 2018): "conservation value" OR "ecological value", AND 'lake OR "large water body" (for abbreviations of the feature' categories see Table 1).

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References

1. Sharpley, A.N.; Bergström, L.; Aronsson, H.; Bechmann, M.; Bolster, C.H.; Börling, K.; Djodjic, F.; Jarvie, H.P.; Schoumans, O.F.; Stamm, C.; et al. Future agriculture with minimized phosphorus losses to waters: Research needs and direction. *Ambio* **2015**, *44*, 163–179. [CrossRef] [PubMed]
2. Wetzel, R.G. Land water interfaces: Metabolic and limnological regulators. *Verh. Int. Ver. Limnol.* **1990**, *24*, 6–24. [CrossRef]
3. Schiemer, F.; Zalewski, M.; Thorpe, J.E. Land/Inland water ecotones: Intermediate habitats critical for conservation and management. *Hydrobiologia* **1995**, *303*, 259–264. [CrossRef]
4. Søndergaard, M.; Jeppesen, E.; Jensen, J.P. Pond or lake: Does it make any difference? *Arch. Hydrobiol.* **2005**, *162*, 143–165. [CrossRef]
5. Rosset, V.; Angelibert, S.; Arthaud, F.; Bornette, G.; Robin, J.; Wezel, A.; Vallod, D.; Oertli, B. Is eutrophication really a major impairment for small waterbody biodiversity? *J. Appl. Ecol.* **2014**, *51*, 415–425. [CrossRef]
6. Bolpagni, R.; Bartoli, M.; Viaroli, P. Species and functional plant diversity in a heavily impacted riverscape: Implications for threatened hydro-hygrophilous flora conservation. *Limnologica* **2013**, *43*, 230–238. [CrossRef]
7. Williams, P.; Whitfield, M.; Biggs, J.; Bray, S.; Fox, G.; Nicolet, P.; Sear, D. Comparative biodiversity of rivers, streams, ditches and ponds in an agricultural landscape in Southern England. *Biol. Conserv.* **2003**, *115*, 329–341. [CrossRef]
8. Hunter, M.L., Jr.; Acuña, V.; Bauer, D.M.; Bell, K.P.; Calhoun, A.J.K.; Felipe-Lucia, M.R.; Fitzsimons, J.A.; González, E.; Kinnison, M.; Lindenmayer, D.; et al. Conserving small natural features with large ecological roles: A synthetic overview. *Biol. Conserv.* **2017**, *211*, 88–95. [CrossRef]
9. Maynou, X.; Martín, R.; Aranda, D. The role of small secondary biotopes in a highly fragmented landscape as habitat and connectivity providers for dragonflies (Insecta: Odonata). *J. Insect Conserv.* **2017**, *21*, 517–530. [CrossRef]

10. Hill, M.J.; Biggs, J.; Thornhill, I.; Briers, R.A.; Gledhill, D.G.; White, J.C.; Wood, P.J.; Hassall, C. Urban ponds as an aquatic biodiversity resource in modified landscapes. *Glob. Chang. Biol.* **2017**, *23*, 986–999. [CrossRef] [PubMed]
11. Taxböck, L.; Linder, H.P.; Cantonati, M. To what extent are Swiss springs refugial habitats for sensitive and endangered diatom taxa? *Water* **2017**, *9*, 967. [CrossRef]
12. Bagella, S.; Podani, J. A large-scale assessment of *Isoetes histrix* s.l. swards in the Mediterranean basin. *Plant Sociol.* **2017**, *54*, 129–136.
13. Boix, D.; Caria, M.C.; Gascón, S.; Mariani, M.A.; Sala, J.; Ruhí, A.; Compte, J.; Bagella, S. Contrasting intra-annual patterns of six biotic groups with different dispersal mode and ability in Mediterranean temporary ponds. *Mar. Freshw. Res.* **2017**, *68*, 1044–1060. [CrossRef]
14. Bolpagni, R.; Piotti, A. Hydro-hygrophilous vegetation diversity and distribution patterns in riverine wetlands in an agricultural landscape: A case study from the Oglio River (Po Plain, Northern Italy). *Phytocoenologia* **2015**, *45*, 69–84. [CrossRef] [PubMed]
15. Bolpagni, R.; Piotti, A. The importance of being natural in a human-altered riverscape: Role of wetland type in supporting habitat heterogeneity and the functional diversity of vegetation. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2016**, *26*, 1168–1183. [CrossRef]
16. Calhoun, A.J.K.; Mushet, D.M.; Bell, K.P.; Boix, D.; Fitzsimons, J.A.; Isselin-Nondedeu, F. Temporary wetlands: Challenges and solutions to conserving a 'disappearing' ecosystem. *Biol. Conserv.* **2017**, *211*, 3–11. [CrossRef]
17. Cantonati, M.; Segadelli, S.; Tran, H.; Ogata, K.; Gerecke, R.; Sanders, D.; Rott, E.; Gargini, A.; Celico, F.; Filippini, M. Petrying Springs: A global review on ambient Limestone-Precipitating Springs (LPS): Hydrogeological setting, ecology and conservation. *Sci. Total Environ.* **2016**, *568*, 624–637. [CrossRef] [PubMed]
18. Feld, C.K.; Birk, S.; Eme, D.; Gerisch, M.; Hering, D.; Kernan, M.; Maileht, K.; Mischke, U.; Ott, I.; Pletterbauer, F.; et al. Disentangling the effects of land use and geo-climatic factors on diversity in European freshwater ecosystems. *Ecol. Ind.* **2016**, *60*, 71–83. [CrossRef]
19. McGoff, E.; Dunn, F.; Cachazo, L.M.; Williams, P.; Biggs, J.; Nicolet, P.; Ewald, N.C. Finding clean water habitats in urban landscapes: Professional researcher vs citizen science approaches. *Sci. Total Environ.* **2017**, *581–582*, 105–116. [CrossRef] [PubMed]
20. Hunter, M.L., Jr. Conserving small natural features with large ecological roles: An introduction and definition. *Biol. Conserv.* **2017**, *211*, 1–2. [CrossRef]
21. Davis, J.A.; Kerezsy, A.; Nicol, S. Springs: Conserving perennial water is critical in arid landscapes. *Biol. Conserv.* **2017**, *211*, 30–35. [CrossRef]
22. Indermuehle, N.; Oertli, B.; Biggs, J.; Cereghino, R.; Grillas, P.; Hull, A.; Nicolet, P.; Scher, O. Pond conservation in Europe: The European Pond Conservation Network (EPCN). *Verh. Int. Verein. Limnol.* **2008**, *30*, 446–448. [CrossRef]
23. Klopper, R.; Lubbe, S.; Rugbeer, H. The matrix method of literature review. *Alternation* **2007**, *14*, 262–276.
24. Rosset, V.; Simaika, J.P.; Arthaud, F.; Bornette, G.; Vallod, D.; Samways, M.J.; Oertli, B. Comparative assessment of scoring methods to evaluate the conservation value of pond and small lake biodiversity. *Aquat. Conserv. Mar. Freshw. Ecosys.* **2013**, *23*, 23–36. [CrossRef]
25. Fuentes-Rodríguez, F.; Juan, M.; Gallego, I.; Lusi, M.; Fenoy, E.; León, D.; Peñalver, P.; Toja, J.; Casas, J.J. Diversity in Mediterranean farm ponds: Trade-offs and synergies between irrigation modernisation and biodiversity conservation. *Freshw. Biol.* **2013**, *58*, 63–78. [CrossRef]
26. Tóth, A.; Horváth, Z.; Vad, C.F.; Zsuga, K.; Nagy, S.A.; Boros, E. Zooplankton of the european soda pans: Fauna and conservation of a unique habitat type. *Int. Rev. Hydrobiol.* **2014**, *99*, 255–276. [CrossRef]
27. Briers, R.A. Invertebrate communities and environmental conditions in a series of urban drainage ponds in eastern Scotland: Implications for biodiversity and conservation value of SUDS. *Clean Soil Air Water* **2014**, *42*, 193–200. [CrossRef]
28. Hill, M.J.; Wood, P.J. The macroinvertebrate biodiversity and conservation value of garden and field ponds along a rural-urban gradient. *Fund. Appl. Limnol.* **2014**, *185*, 107–119. [CrossRef]
29. Bazzanti, M. Pond macroinvertebrates of the Presidential Estate of Castelporziano (Rome): A review of ecological aspects and selecting indicator taxa for conservation. *Rend. Lincei* **2015**, *26*, 337–343. [CrossRef]

30. Wissinger, S.A.; Oertli, B.; Rosset, V. Invertebrate communities of alpine ponds. In *Invertebrates in Freshwater Wetlands: An International Perspective on Their Ecology*; Batzer, D., Boix, D., Eds.; Springer: Basel, Switzerland, 2016; pp. 55–103, ISBN 978-3-319-24978-0.
31. Harabiš, F.; Tichanek, F.; Tropek, R. Dragonflies of freshwater pools in lignite spoil heaps: Restoration management, habitat structure and conservation value. *Ecol. Eng.* **2013**, *55*, 51–61. [CrossRef]
32. Hill, M.J.; Ryves, D.B.; White, J.C.; Wood, P.J. Macroinvertebrate diversity in urban and rural ponds: Implications for freshwater biodiversity conservation. *Biol. Conserv.* **2016**, *201*, 50–59. [CrossRef]
33. Ilg, C.; Oertli, B. Effectiveness of amphibians as biodiversity surrogates in pond conservation. *Conserv. Biol.* **2017**, *31*, 437–445. [CrossRef] [PubMed]
34. Manenti, R.; Zanetti, N.; Pennati, R.; Scarì, G. Factors driving semi-aquatic predator occurrence in traditional cattle drinking pools: Conservation issues. *J. Limnol.* **2017**, *76*, 34–40. [CrossRef]
35. Rodríguez-Pérez, H.; Hilaire, S.; Mesléard, F. Temporary pond ecosystem functioning shifts mediated by the exotic red swamp crayfish (Procambarus clarkii): A mesocosm study. *Hydrobiologia* **2016**, *767*, 333–345. [CrossRef]
36. Brand, R.F.; du Preez, P.J.; Brown, L.R. High altitude montane wetland vegetation classification of the Eastern Free State, South Africa. *S. Afr. J. Bot.* **2013**, *88*, 223–236. [CrossRef]
37. Klaus, J.M.; Noss, R.F. Specialist and generalist amphibians respond to wetland restoration treatments. *J. Wildl. Manag.* **2016**, *80*, 1106–1119. [CrossRef]
38. Cottet, M.; Piégay, H.; Bornette, G. Does human perception of wetland aesthetics and healthiness relate to ecological functioning? *J. Environ. Manag.* **2013**, *128*, 1012–1022. [CrossRef] [PubMed]
39. Liu, X.; Jiang, M.; Dong, G.; Zhang, Z.; Wang, X. Ecosystem Service Comparison before and after Marshland Conversion to Paddy Field in the Sanjiang Plain, Northeast China. *Wetlands* **2017**, *37*, 593–600. [CrossRef]
40. Acuña, V.; Hunter, M.; Ruhi, A. Managing temporary streams and rivers as unique rather than second-class ecosystems. *Biol. Conserv.* **2017**, *211*, 12–19. [CrossRef]
41. Brans, K.I.; Engelen, J.M.T.; Souffreau, C.; De Meester, L. Urban hot-tubs: Local urbanization has profound effects on average and extreme temperatures in ponds. *Landsc. Urban Plan.* **2018**, *176*, 22–29. [CrossRef]
42. Edwards, B.A.; Meg Southee, F.; McDermid, J.L. Using climate and a minimum set of local characteristics to predict the future distributions of freshwater fish in Ontario, Canada, at the lake-scale. *Glob. Ecol. Conserv.* **2016**, *8*, 71–84. [CrossRef]
43. Kristensen, P.; Globevnik, L. Small Water Bodies: Importance, Threats and Knowledge Gaps. *Biol. Environ.* **2014**, *114B*, 281–287.
44. Möckel, S. Small Water Bodies and the Incomplete Implementation of the Water Framework Directive in Germany. *JEEPL* **2013**, *10*, 262–275. [CrossRef]
45. Van den Broeck, M.; Waterkeyn, A.; Rhazi, L.; Grillas, P.; Brendonck, L. Assessing the ecological integrity of endorheic wetlands, with focus on Mediterranean temporary ponds. *Ecol. Indic.* **2015**, *54*, 1–11. [CrossRef]
46. Núñez, G.; Fernández-Aláez, C.; Fernández-Aláez, M.; Trigal, C. Proposal of a typology of Spanish mountain lakes and ponds using the composition of functional groups of macrophytes. *Limnetica* **2015**, *34*, 507–526.
47. Saulnier-Talbot, E.; Lavoie, I. Uncharted waters: The rise of human-made aquatic environments in the age of the "Anthropocene". *Anthropocene* **2018**, *23*, 29–42. [CrossRef]
48. Ignar, S.; Grygoruk, M. Wetlands and Water Framework Directive: Protection, Management and Climate Change. In *Wetlands and Water Framework Directive*; Ignar, S., Grygoruk, M., Eds.; Springer: Basel, Switzerland, 2015; pp. 1–7, ISBN 978-3-319-13764-3.
49. Sønderup, M.J.; Egemose, S.; Hansen, A.S.; Grudinina, A.; Madsen, M.H.; Flindt, M.R. Factors affecting retention of nutrients and organic matter in stormwater ponds. *Ecohydrology* **2018**, *9*, 796–806. [CrossRef]
50. Land, M.; Granéli, W.; Grimvall, A.; Hoffmann, C.C.; Mitsch, W.J.; Tonderski, K.S.; Verhoeven, J.T.A. How effective are created or restored freshwater wetlands for nitrogen and phosphorus removal? A systematic review. *Environ. Evid.* **2016**, *5*, 5. [CrossRef]
51. Arheimer, B.; Pers, B.C. Lessons learned? Effects of nutrient reductions from constructing wetlands in 1996–2006 across Sweden. *Ecol. Eng.* **2017**, *103*, 404–414. [CrossRef]
52. Hashemi, F.; Olesen, J.E.; Børgesen, C.D.; Tornbjerg, H.; Thodsen, H.; Dalgaard, T. Potential benefits of farm scale measures versus landscape measures for reducing nitrate loads in a Danish catchment. *Sci. Total Environ.* **2018**, *637*, 318–335. [CrossRef] [PubMed]

53. Blankenberg, A.-G.B.; Haarstad Ketil, K.; Paruch, A.M. Agricultural runoff in Norway: The problem, the regulations, and the role of wetlands. In *The Role of Natural and Constructed Wetlands in Nutrient Cycling and Retention on the Landscape*; Vymazal, J., Ed.; Springer: Basel, Switzerland, 2015; pp. 137–147, ISBN 978-3-319-08176-2.
54. Oertli, B.; Céréghino, R.; Hull, A.; Miracle, R. Pond conservation: From science to practice. *Hydrobiologia* **2009**, *634*, 1–9. [CrossRef]
55. Serrano, L.; Reina, M.; Quintana, X.D.; Romo, S.; Olmo, C.; Soria, J.; Blanco, S.; Fernández-Aláez, C.; Fernández-Aláez, M.; Caria, M.C.; et al. A new tool for the assessment of severe anthropogenic eutrophication in small shallow water bodies. *Ecol. Indic.* **2017**, *76*, 324–334. [CrossRef]
56. Bagella, S.; Gascón, S.; Filigheddu, R.; Cogoni, A.; Boix, D. Mediterranean Temporary Ponds: New challenges from a neglected habitat. *Hydrobiologia* **2016**, *782*, 1–10. [CrossRef]
57. Stanley, E.H.; Fisher, S.G.; Grimm, N.B. Ecosystem expansion and contraction in streams. *Bioscience* **1997**, *47*, 427–435. [CrossRef]
58. von Schiller, D.; Acuña, V.; Graeber, D.; Martí, E.; Ribot, M.; Sabater, S.; Timoner, X.; Tockner, K. Contraction, fragmentation and expansion dynamics determine nutrient availability in a Mediterranean forest stream. *Aquat. Sci.* **2011**, *73*, 485–497. [CrossRef]
59. Harper, L.R.; Buxton, A.S.; Rees, H.C.; Bruce, K.; Brys, R.; Halfmaerten, D.; Read, D.S.; Watson, H.V.; Sayer, C.D.; Jones, E.P.; et al. Prospects and challenges of environmental DNA (eDNA) monitoring in freshwater ponds. *Hydrobiologia* **2018**. [CrossRef]