Draft Title: The role of citizen science within WFD and SDGs, and how to incentivize the collaboration with environmental regulators

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Scope: The present work explores the state of the art and the opportunities for citizen science to achieve WFD and SDGs goals, as well as the levers for a stronger collaboration between citizen science programmes and regulatory agencies at a national and subnational basis. The present study was based on a thorough analysis of international and national scientific literature and databases. While the focus is on the current state of the art, the authors also explore current opportunities to increase the impact of freshwater citizen science and potential obstacles.

1. Introduction

The European Water Framework Directive (WFD) sets a goal to reach "good status, and to prevent deterioration" of all water bodies in the European Union and Norway through the use of River Basin Management Plans by member states. The objectives were set in 2000 when the WFD was implemented as the main law for water protection, and should be achieved in 2027. The WFD takes into consideration inland water bodies, groundwaters, as well as surface coastal and transitional waters that should reach a good chemical and ecological status by the date set by the framework. The good chemical and ecological status are assessed by biological, hydromorphological, physico-chemical properties, and chemical pollutants' concentration (Fig.1).

The WFD works on an integrated approach based on river basins to ensure that neighbouring countries cooperate to manage shared waters, and the implementing process encompasses reporting of river basin management plans every six years. Every river basin management plan includes the assessment of water bodies within the river basin, the pressures all aquatic ecosystems are undergoing, as well as relevant plans towards achieving good status. The WFD currently covers more than 146500 surface water ecosystems and 15000 groundwater bodies in the EU and Norway (WISE website). As the 2027 deadline approaches, the situation in nearly all member states is far from the prospected objective. There are currently 8 member states in which the implementation of WFD is lagging behind more or less severely, with a case (Bulgaria) in which the public consultations are yet to be held, as reported in early October 2023 (WFD website).

On an international level, freshwater is addressed by the Sustainable Development Goal (SDG) nr. 6 and sub-targets,, in particular nr. 6.3 which sets the goal to "improve water quality by reducing pollution, eliminating dumping and minimising release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally" by 2030. Additionally, sub-target 6.5 has the goal to "implement integrated water resources management at all levels, including through transboundary cooperation as appropriate" and sub-target 6.b aims to "support and strengthen the participation of local communities in improving water and sanitation management". Terrestrial ecosystems are addressed by SDG nr. 15, which aims to "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" (SDG goal 15 website) and sub-targets, covering water quality in its statement to contain biodiversity loss.

In order to track the progress towards the 6.3 SDG goal, each adhering state is required to report their advancements using SDG indicator 6.3.2 which tracks "the proportion of bodies of water with good ambient water quality, as per national and/or subnational water quality standards and based on measurements of five water quality parameters (Oxygen, Nitrate, Phosphorus, Salinity, Acidification) that inform on the most common pressures on water quality at the global level" (SDG indicator 6.3.2 website).

Globally, as of 2020, only 60% of monitored water bodies have a good water quality, with the majority of water bodies remaining unmonitored in most member states. The percentage of unmonitored water bodies increases exponentially in low income countries (SDG indicator 6.3.2 website).

Citizen Science targeted to aquatic ecosystems can be a powerful tool and opportunity to strengthen scientific and environmental literacy while supporting research and ecosystems' management. A number of studies have in fact suggested that citizen science can assist national and subnational objectives related to the WFD (Carvalho et al., 2019; European Commission Directorate-General for Environment, 2018) as well as the SDGs (Fraisl et al., 2020; Quinlivan et al., 2020a; Venkatesh & Velkennedy, 2022 Quinlivan et al., 2020b; Fritz et al., 2019; Biraghi et al., 2022; Hegarty et al., 2021). Citizen science is a fast-growing field of action and research that needs specific guidelines and standardisation methods to support environmental monitoring, allowing to create comparable results across countries and similar environmental objectives. At the same time citizen science needs to encompass a strong public participation and social implications, and in some WFD related projects the actual citizen participation has been so far limited (Rimmert et al., 2020) or challenging (van der Heijden & ten Heuvelhof, 2012).

It should be noted that citizen science can create a positive environmental impact across a range of related areas, with studies showing that citizen science has also the potential to identify pollution events (Collins et al., 2023), improving social learning around environmental issues, and can contribute to shaping attitudes and behaviours towards a more sustainable lifestyle, if the project is designed adequately to take them into consideration (Fielke et al., 2022; Jørgensen & Jørgensen, 2021; van Noordwijk et al., 2021).

The European Union Mission "Restore our Ocean and Waters" launched in September 2021 set the aims to "protect and restore the health of our ocean and waters through research and innovation, citizen engagement and blue investments, addressing the ocean and waters as one, playing a key role in achieving climate neutrality and restoring nature" (EU Mission "Ocean and Waters" website). To reach this objective, broad public mobilisation and engagement are cross-cutting actions that the EU identifies of particular relevance (EU Mission "Ocean and Waters" website). Under the Mission, a portfolio analysis of 841 EU-funded research projects was recently published (Chimini, Failer, Galgani et al., 2023). The report identifies a large but non-exhaustive list of projects that address the Mission objectives, the Green Deal targets, and enablers, among those of particular relevance is enabler 2a "mobilisation and engagement". Of the 841 projects analysed, 252 have "Citizen Engagement" as lever of change, but only 23 address sub-objective 1b of the Mission "Protect and restore marine and freshwater ecosystems and biodiversity - Focus on freshwater". Despite this limited number of projects addressing citizen science and freshwater environments, clearly, citizen engagement is gaining more and more recognition on a European and international level to act as a promoter of change.

The present policy draft is based on a comprehensive literature review, focusing on specific aspects of citizen science and water quality monitoring. It aims at exploring the state of the art in citizen science-based projects monitoring water quality, identifying challenges and opportunities and the potentials for collaboration with national Environmental Agencies and citizens to ensure longer term commitment, and at providing suggestions to overcome hurdles in upcoming research programmes and activities.

2. Methodology of research

To conduct the literature review, a set of keywords was chosen, ranging from the type of scientific data used to relevant directives, most relevant projects, terminology linked to the river ecosystem, and terminology linked to citizen science, as can be seen in the table below (Table 1). We further proceeded by mixing different types of keywords, mostly two at a time and sporadically also three at a time, usually one keyword concerning the scientific aspects with one or more keywords concerning citizen science.

Topic	Keywords
Scientific parameters	Macrobenthos; turbidity; nitrates and phosphates concentrations; geomorphology, fishes, plastic
Directives	WFD; SDG
Most relevant European projects	RiuNet; Riverfly; Flow; FreshWater Watch, Merlin
Citizen Science	Co-design; impact; behaviour; experimental design; early warning process; Environmental Agencies collaboration; stakeholder involvement

Tab 1. List of keywords used by topic.

We looked for published literature mainly on Scopus and Google Scholar, as these two search engines are very well suited to do a snowball-like search, as linked publications are listed under each paper studied.

We identified 295 papers, of which 85 were selected thematically by filtering them by subject of interest: WFD, SDG, Environmental Agencies collaboration. More specifically, we selected 17 papers linked to WFD, 13 for SDG, and 55 for other themes such as Regulatory Agencies collaboration, social and political perspective and more (Figure 1). We can also look at the geographical distribution of such publications (Figure 2).

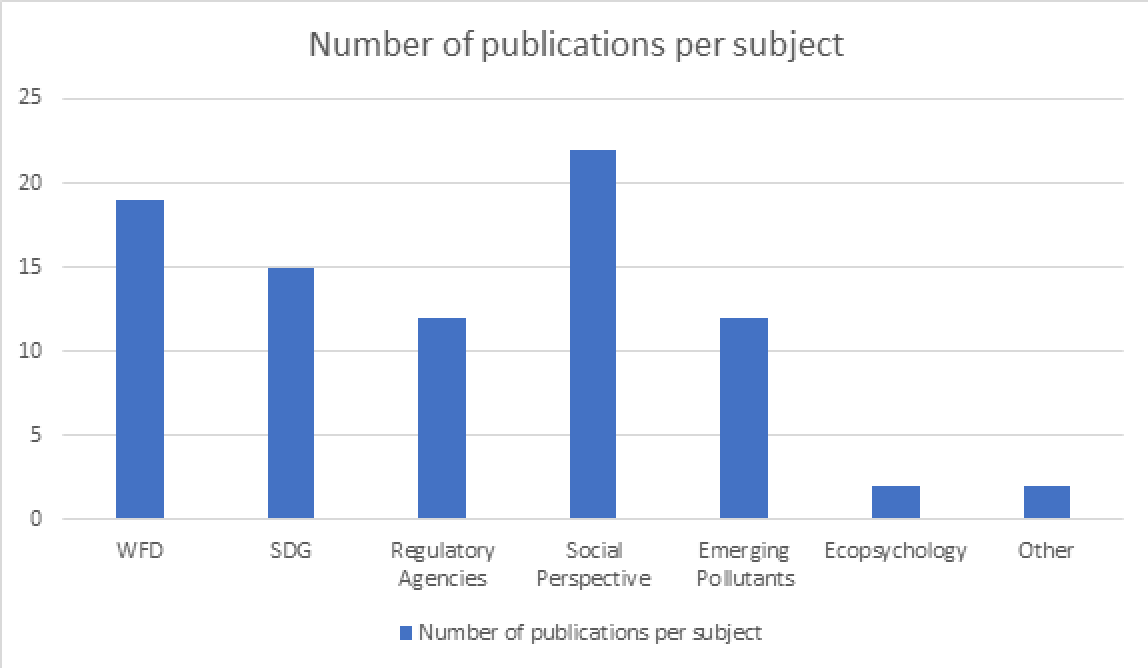

Figure1. Publications found per subject area (n =85).

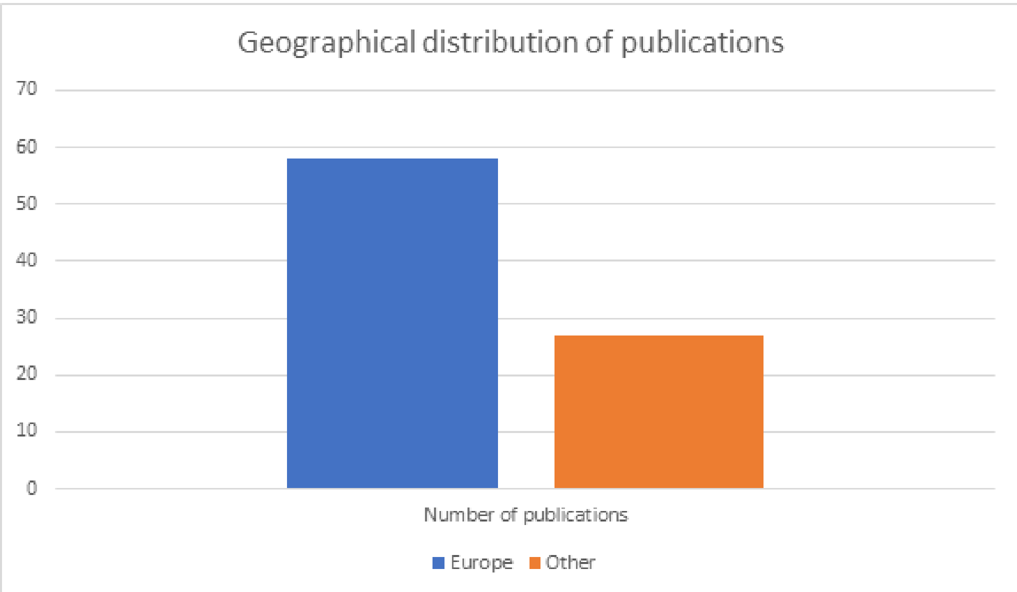

Figure 2. Geographical distribution of publications (n=85).

3. Results : State of the art

What is often debated around citizen science is the quality of the data acquired. In the past many environmental agency experts - and scientists too - did not trust citizens enough in terms of quality control and measurement bias, where monitoring design and analytical methods were not considered sufficiently robust to be representative of the conditions of the waterbody, something that has changed in recent times with a growing number of Environmental Agencies using citizen science data to integrate their own databases (de Sherbinin et al., 2021; Wyeth, 2023; Thornhill et al., 2016). In order to achieve such collaboration a lot of work has been put into the formation and training of volunteers prior to monitoring and data gathering activities. Quite often side by side measurements are performed for a fixed number of samples, comparing simultaneously acquired professional gathered data and volunteer gathered data to evaluate the precision and accuracy of the latter (von Gonner et al., 2023), while some scientists have focused on statistical comparisons between expert and citizen collected data in order to show that indeed citizen science data is good enough (Hadj-Hammou et al., 2017).

The published studies show that data gathered by citizen scientists represents an elevated accuracy, between 70% to 90% of laboratory values, and more than sufficient to complement agency monitoring (Breuer et al., 2015; deSherbinin et al., 2021; Fritz et al., 2019; Pinto et al., 2020; Quinlivan et al., 2020; Stankiewicz et al., 2023; vonGonner et al., 2023). There is an increasing number of publications that report the use of citizen scientist acquired data for hypothesis testing and complementary monitoring of water quality in European freshwater ecosystems.

We are here focusing on the type of scientific endeavours that can rely on citizens both for the gathering and the analysis of data, which is to say projects in which the in situ data collection and analysis is feasible. When monitoring freshwater ecosystems, chemical approaches to determine water quality chemical conditions and identification of macrobenthos communities are the first that come to mind. Both can be done in-situ by trained citizen scientists and are being addressed by several initiatives. Additionally, contaminants of emerging concern (CECs) like plastic and microplastics are also suitable parameters for the in situ monitoring by trained citizens and volunteers through various approaches because these compounds are relatively stable and do not need special laboratory treatment for an immediate visualisation and analysis (Raman et al., 2023).

So far most citizen science efforts on plastic and microplastics have concentrated on marine systems (Blettler et al., 2018), especially on beaches, with a minor number of initiatives focused on freshwater environments. This partly reflects the amount of scientific literature on marine plastic and microplastics compared to other environments, however, research studies are indeed expanding to include other habitats, followed along by citizen science initiatives.

The most commonly used techniques in the publications identified were, in fact, chemical analysis and macrobenthos; mixed techniques refer to the use of more than one of the listed techniques, among which macrobenthos was always present. The ‘others’ category comprises water quality analysed through the presence of underwater vegetation, the turbidity level through the use of Secchi disks, and other less commonly used techniques.

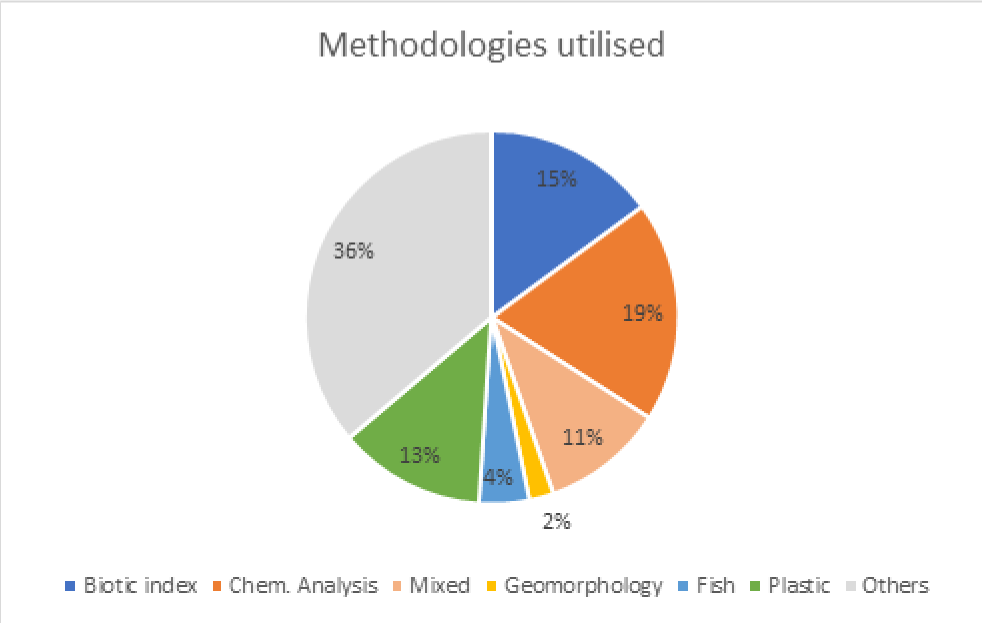

Figure 3. Type of methodologies utilised (n=47).

As quality control is a key factor in the utilisation of citizen science data, we looked for the presence of either direct comparison to professional gathered data, professional screening of the obtained data, or validated techniques of data gathering - such as the FreshWater Watch one (FWW website). We have found that while most of the projects utilising macrobenthos and chemical analysis have some forms of data validity checks, many of the publications did not (Figure 4).

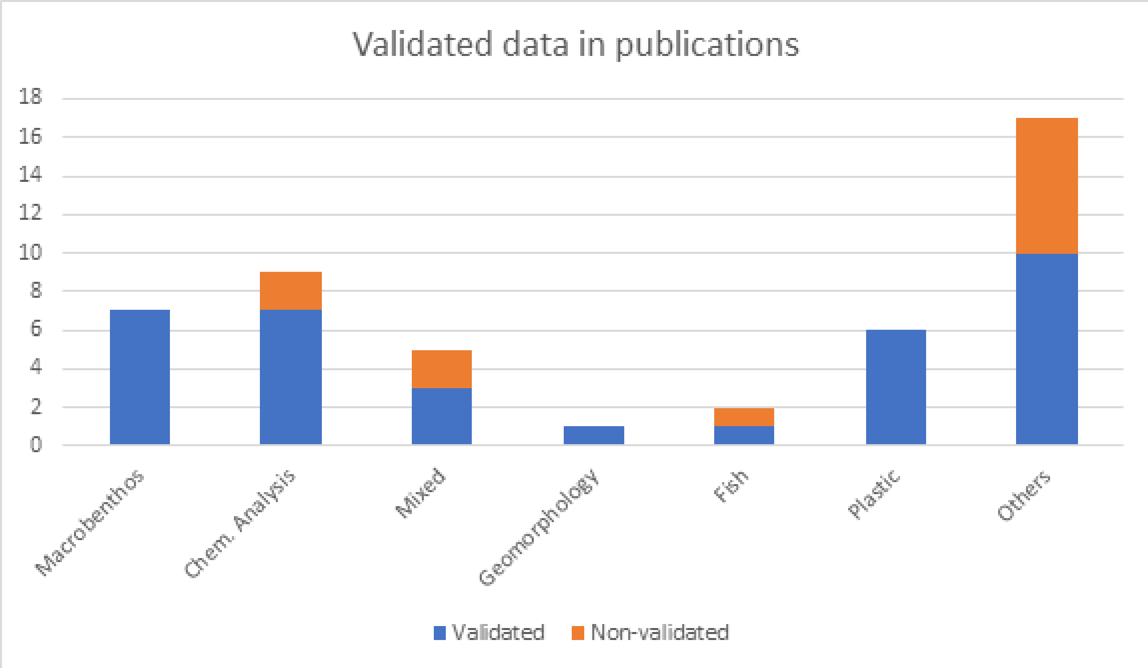

Figure 4. Number of data validated paper per category of technique used (n=47).

For the success of citizen science initiatives, besides scientific aspects of data trustworthiness and validation, it emerged from the literature that a focused integration of both hard and social sciences is often lacking (Nardi et al., 2022; Newson, 2021). The call for more interdisciplinarity arises from the fact that social sciences are usually better equipped when dealing with aspects of engagement in projects and assessment of the impact and participant motivations, by way of surveys or other methods (Ballard et al., 2017; Church et al., 2019).

It is indeed well recognized that engagement of the general public by professional scientists is often challenging, with some categories of participants being overrepresented in citizen science projects (Heywood & Besley, 2013; Altman et al., 2023; Kaplan et al., 2023), as is the case with students - both high school and university ones - and people who are already part of environmental projects or that are environmentally engaged or literate. These latter categories of participants are more easy to recruit and sensitise to the subject area of environmental citizen science projects. This results in a participation bias within most citizen science projects and the limited representation of marginalised parts of society.

Several studies have focused on the motivational drivers of participants; why they want to participate in the projects and what keeps them engaged for extended periods (Altman et al., 2023; Church et al., 2019; Kaplan et al., 2023). These studies highlight the practices that have been successful at maintaining high participant retention rates, fundamental for ensuring project sustainability as well as improving data quality, typically higher when measurements are made by participants with longer experience.

Understanding, trust and access are the three keys to ensuring higher participation and retention. Understanding, for example of the scientific process, is often lacking among the general public but can be built up over time. Establishing trust also requires time and the development of a common language and vision. Access is fundamental to avoid a participant selection bias, a common challenge in citizen science. All three keys should be considered in the phase project design (Altman et al., 2023).

Drivers for initial participation include the desire to contribute to nature conservation and the possibility to learn through social interaction or interaction with professional scientists (Kaplan et al., 2023, Moshi et al. 2022). More specifically to freshwater citizen science, positive feelings towards rivers, desire to learn about science and nature have been identified among the drivers for participation (Church et al., 2019). The beneficial physical and positive mental health effects from spending time in nature, explored in studies of e*copsychology* should also be considered (Cameron et al., 2020; Roszak et al., 1995).

In terms of retention, the creation of virtual spaces that favour interactions between participants, as well as mechanisms for feedback based on their participation in the project have been shown to improve participant retention (Torres et al., 2023; Zhou et al., 2020). Direct feedback from scientists is usually both a benefit to retention as well as an opportunity for knowledge exchange.

What emerges from the literature is the need to establish an ongoing relationship between scientists and citizen scientists over time, building trust, shared understanding and access. Projects that have the possibility to improve a current situation of a local watercourses are prime examples of opportunities to build relationships and a common shared vision. More efforts are needed from scientists to try and help the creation of a network between the participants and themselves, by facilitating interactions and feedback in both directions.

Another common observation in the literature is the idea that citizen scientist generated data is often underused for policy or regulatory purposes (Carlson & Cohen, 2018; Woods et al., 2022). This has been associated with the generally low trust associated with the limited quality control of citizen scientist generated data, which is also influenced by the often limited diffusion of projects' results as well as limited access to citizen science data, reports and publications. Ensuring open access to all data and correct metadata generated by citizen science projects could help lower this barrier. Citizen science data could be in fact a very valuable resource to monitor the progress towards the SDGs, since regulatory agencies are often limited to major water bodies and do not extend to remote areas (Ballerini and Bergh, 2021; Bishop et al., 2020). The European Union has recognized the potential of citizen-generated data to inform the environmental policy landscape and to meet societal demands for more participatory decision-making. At the same time, the EU also identifies that contributions of citizen science to environmental policies is still limited, often due to the poor understanding of the benefits of citizen science. It is also important to determine whether projects that provide policy support also receive benefits to citizen engagement (REF Eu report; Turbé et al., 2019). To this end, an overview of citizen science activities in support of environmental policies in Europe is provided in an inventory which is updated on a regular basis and with global coverage (Joint Research Centre Data Catalogue website).

Characteristics of project duration

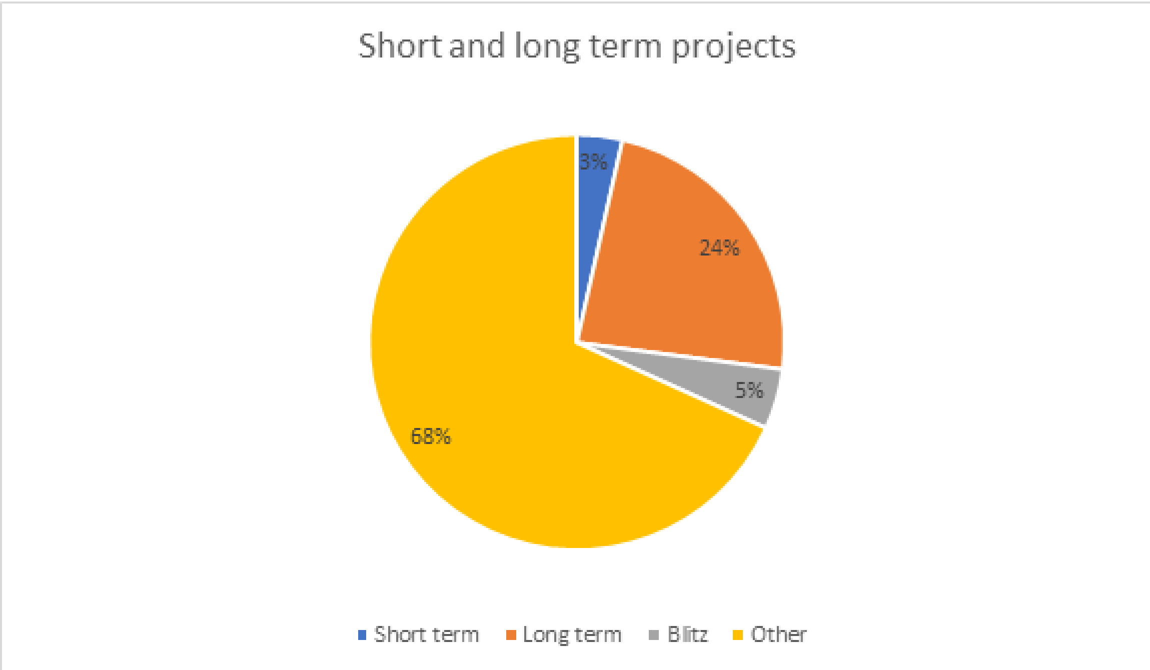

Figure 5. Short and long term type of projects (n=85).

The high number of publications listed under the ‘other’ category is due to the fact that only projects that are structured as citizen science ones were considered under the categories ‘short terms’, ‘blitz’, and ‘long term’. They were selected by looking at the project design and comparing them to the ten principles of citizen science delineated by the European Citizen Science Association (ECSA, 2015). Other types of research were thus categorised under ‘other’, here referring mostly to papers that talk about citizen science but are not citizen science projects, as in the case of literature reviews and studies made only by experts, among others. Furthermore, the difference between blitz and short-term lies in the fact that blitz-type research is a one time event in which all the fieldwork is done, contrary to short term projects in which more than one fieldwork events are held.

Since long term projects are more cost and effort demanding, why are they often still chosen over short term ones? Leaving aside the preferences made because of scientific purposes, from a social perspective long term ones tend to have a higher impact on participants and offer a higher potential to serve environmental policy making. In fact, it is widely reported in the literature that the preferable impacts of citizen science projects on participants are social diffusion and behaviour change (Church et al., 2019), increased environmental awareness among the general public through citizen scientists social networks (Johnson et al., 2014), and a more general positive environmental change in terms of "(1) environmental management; (2) evidence for policy; (3) behaviour change; (4) social network championing; (5) political advocacy; and (6) community action" (van Noordwijk et al., 2021).

Quality of paper (citizen involvement, …)

Alongside the work of selecting the relevant publications we built a graph comprising all the selected papers in order to try and rank them on a series of criteria. It must be kept in mind that what follows is a pure qualitative approach, and a very subjective one in that, so that it should be seen just as a partial and not standardised way of looking at the papers quality.
In order to analyse the papers we came up with a five point scale ranging from "very good" to "very weak", which we assigned for each of five different categories: citizen involvement; scientific practices; approach originality; associated impact; clarity of practices.
The categories can be summarised as follows: citizens involvement refers to the type of involvement, were they involved in multiple stages of the project or not? Scientific practices look at if the volunteers were autonomous in their sampling and analysis, or at the other side of the continuum if a lab was needed and thus the citizens were merely sampling, and if the scientific practices were grounded in the scientific literature. Approach originality tries to capture if there are many publications similar to the one analysed or is its approach innovative. Associated impact tries to understand if there was any (positive) associated impact stemming from the project. Clarity of practices, finally, looks at if the paper was transparent in terms of the research practices involved - e.g. was the volunteers training documented, who was involved, in what phases, etc.

After we finished ranking all of the selected publications, which we did by having one person doing the ranking, followed by an internal validation by having two more members of the team looking at such rankings, we built an aggregate scale. We did so in order to have an easier way of comparing the publications, and to have a quantitative way of doing so. The aggregate scale was made by assigning 2 points to each “very good”, 1 for “good”, and 0 for “average”, “weak”, and “very weak”, and then having a score for each row, or in other words each publication, by adding up the points obtained by it in the different categories. Therefore with a score of 1 papers were labelled as “limited”, with a score of 2 “average”, with a score of 3-4 “good”, and with a score of 5 or higher “very good”.

Starting from the aggregate scale we built the following figures (6 and 7). In the first (figure 6) we can look at the publications’ quality overall, which is to say with all the papers included. We can see that the majority of them fall in the categories “limited” and “average”, while only 10 and just above 20 are good or very good. We can look at the following figure to understand why this is the case.

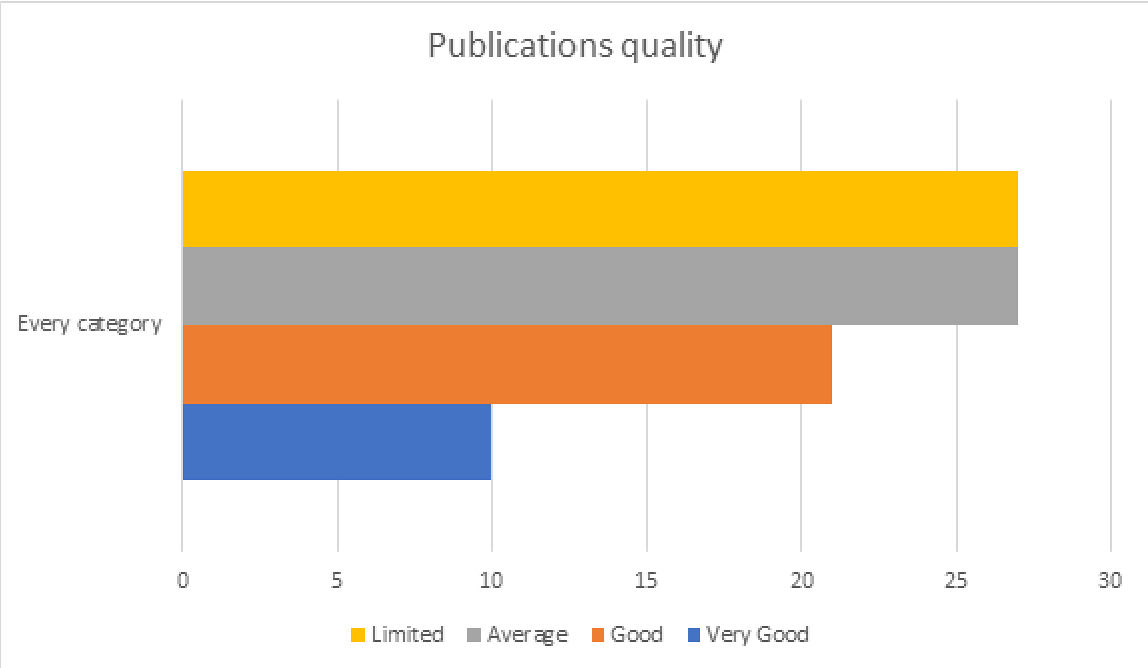

Figure 6. Quality of papers using the aggregate scale (n=85).

In figure 7 we can see the quality of papers by the categories used before, namely WFD, SDG, Environmental Agencies, Social perspective, Emerging Pollutants, Ecopsychology and Other. It is fairly easy to see that the majority of papers that are labelled as good or very good belong to either WFD, SDG, Regulatory Agencies and Emerging pollutants. This means that there are very few or none in the categories Social perspective, Ecopsychology, and Other. This has to do with the fact that the categories we used to rank the publications’ quality are skewed towards the scientific side, in other words they favour a paper that has citizens’ involvement and good scientific practices and clarity of such practices, which of course makes social perspective papers fall heavily in the average and limited categories, as they usually do not have any citizens' involvement and scientific practices involved. Nonetheless, it is interesting to see how papers that deal with Regulatory Agencies collaboration are ranked quite highly, which can be explained by the fact that since such collaboration is often not present, when we saw efforts in that direction we ranked them highly as it is an issue we tried to delineate in this paper too.

Figure 7. Quality of papers by category using the aggregate scale (n=85).

4. Environmental Agencies and Community Based Monitoring (CBM)

The monitoring of surface waters has been made mandatory by the WFD for all member states since 2000. However the environmental agencies, which are the authority responsible for official monitoring, cannot cover a dense network of watercourses, of which approximately 80% are of first and second degree and therefore of small or very small dimensions (Kelly-Quinn et al 2023).

The distribution of the "official" stations itself is often inadequate in order to identify, especially, point impacts along the main river channels. These inevitable gaps in monitoring left to the authorities alone could partly be resolved by virtuous collaboration with citizens in Citizen Science projects also known as CBM (community base monitoring).

If we want the gap in achieving the WFD objectives to be significantly reduced, and consequently that good ecological status is achieved by the vast majority of water courses by 2027 (next deadline), we should significantly increase active collaboration between EA and citizens. This collaboration could also give greater visibility to the problems encountered, thus requiring more incisive restoration measures. In fact, in some European countries more than in others, the monitoring results remain unheeded or provide for palliative and inefficient measures. This is confirmed by the limited improvements that have occurred since 2015, the first deadline defined by the EU to achieve "Good ecological status" in all water courses.

Unfortunately what surfaces in many instances in the literature is the lack of a stable and diffused collaboration between citizen science practitioners and Environmental Agencies (EA).

There are some virtuous examples of citizen science and EAs collaboration on water bodies scattered in the world, as the case of the UK, where historically the collaboration between governmental and non-governmental organisations has been strong, with projects like ARMI (Brooks et al., 2019; Moolna et al., 2020; Thompson et al., 2016), MoRPh (England et al., 2017), and PondNet (Ewald et al., 2018), the US with RARE (Kaufman et al., 2017), and other countries too (Kim et al., 2011; Venkatesh & Velkennedy, 2022). Some of these collaborations focus on the possibilities of citizen science to produce timely data with the possibility of capturing exceptional events such as pollution incidents that may not be covered by traditional Environmental Agencies, prompting the intervention of the latter after the reported events (ARMI). A less explored possibility offered by citizen science projects is to analyse the water quality of private water bodies such as ponds, which cannot be covered by Environmental Agencies (PondNet).

A number of scholars have shown in the last years that citizen science can help fill the knowledge gaps left open by EA due to a lack of resources and time constraints (Haywood & Besley, 2013; Hadj-Hammou et al., 2017; Owen & Parker, 2018; Wyeth, 2023; Peeters et al., 2023; Thornhill et al., 2016). So long as EAs can only focus on some areas, citizen science then becomes a reliable tool to cover wider areas of water bodies. With these ambitious objectives of positive synergistic collaboration, the state of the art, methods and projects already active in some European countries, examples are reported below.

To assess the ecological status of rivers and streams according to WFD standards, European freshwater monitoring examines three components: physicochemical state, biological communities and hydromorphology.

5. Chemical and optical monitoring

Freshwater ecosystems are facing an ever increasing range of chemical stressors, often connected to global and regional changes in population growth, agricultural intensification, urbanisation, limited wastewater treatment and climate change (van Rees et al., 2021). Nutrient enrichment, in particular, is a common challenge across the globe, and has been amplified by changes in land use, river morphology and climate. Eutrophication has led to the loss of river and lake functioning as well as the increased frequency of harmful algal blooms (HABs) (Birk et al., 2020; Reid et al., 2019).

The Water Framework Directive requires all EU member states to monitor the “ecological status” of surface waters in a consistent and strategic manner (Carvalho et al., 2019). However, national monitoring networks in many regions are either inadequately resourced, poorly coordinated, or non-existent (UN-Water, 2018). As part of the SDG 6 indicator framework, common strategies have been put forward, however, national monitoring networks in many regions are either inadequately resourced, poorly coordinated, or non-existent (UN-Water, 2018).

Citizen science monitoring of water quality are widely implemented and varied, covering watershed as well as local scale (Thornhill et al., 2018). Studies show that properly trained volunteers are able to provide data comparable with those collected by professional scientists (Fore et al., 2001; Moshi et al., 2022; Storey et al., 2016). However, most freshwater citizen science projects are place-based and therefore limited in geographic scope, resulting in a range of inconsistent citizen monitoring efforts across the globe, with many projects working in isolation and with different analytical methods (Cunha et al., 2017; Walker et al., 2021). In spite of its recognized potential to fill gaps in existing datasets, coordinated citizen science monitoring and evidence gathering on freshwater ecosystems on a global scale remains limited (Jackson et al., 2016).

Several global citizen science monitoring programmes focused on water quality have been developed to overcome these limitations.

The FreshWater Watch programme was created in 2012 by Earthwatch Europe as a globally consistent citizen science method to provide comparable data about the state of the freshwater environment. A central and globally consistent protocol was developed while also allowing for local priorities to be addressed and added. The methodology and supporting website, app., and training materials have been translated into more than 20 languages and have supported over 120 projects in 25 countries, with nearly 15000 citizen scientists. Other programmes have followed, often focused on similar water quality challenges (Ramirez et al. 2023).

Most robust citizen science water quality projects are focused on nutrient concentrations, optical conditions and basic chemical parameters. Of the former, nitrogen and phosphorus based measurements are usually the most useful, with direct links to eutrophication and nutrient pollution. Of nitrogen-based components, nitrate is typically the most abundant in most rivers and lakes that are in mesotrophic and eutrophic conditions (Durand et al., 2011). Major sources of elevated nitrate concentrations include agricultural and livestock activities, with typically less important point sources related to industrial and wastewater treatment discharge. Phosphorus is often the limiting nutrient in unimpacted freshwater ecosystems, controlling plant growth. High concentrations of available phosphorus favour the formation of harmful algal blooms as well as epiphytic and benthic algae (Amorim & Moura, 2021). This can lead to hypoxic “dead zones” that reduce fish populations as well as generate compounds harmful for the safety of water supplies and the recreational use of the waterbody. There are multiple phosphorus sources in most catchments, with those most important being sewage effluent, agricultural (including livestock), industrial effluents and runoff from impervious surfaces (roads). Optical measurements, such as water colour using the Forel-Ule scale (Malthus et al. 2020) as well as Secchi tubes and disks, have been used successfully in a wide range of citizen science projects on water quality (George et al. 2021). Basic chemical parameters such as pH and dissolved oxygen are also commonly used but are sensitive to daily cycles, while low cost measurements of specific conductance have proven to be particularly useful (Shupe 2017).

6. Biological community

Macroinvertebrate

Macrobenthic communities exhibit dynamic responses to various environmental features, with a pivotal consideration being the influence of pollutants. These pollutants have been identified as significant contributors to adverse impacts on community well-being, affecting both taxa diversity and trait diversity. The evaluation of ecological quality relies on assessing the tolerance levels of different taxa to pollution, encompassing a spectrum of characteristics that respond differently. Consequently, lotic water environments impacted by pollution tend to exhibit more homogenous communities with minimal seasonal variability

Beyond the direct impact of pollution, macroinvertebrates demonstrate correlations with other significant factors affecting freshwater ecosystems, such as morphological alterations that reduce riverine habitat diversity. Habitat availability, influenced by substrate nature and interstitial spaces, plays a crucial role in sustaining sensitive groups like Ephemeroptera, Plecoptera, and Trichoptera (EPT).

The management of riparian zones further influences the presence of sensitive taxa, with healthy riparian woods contributing to improved habitat quality, including cooler water temperatures, narrower channels, and enhanced food resource availability. Moreover, these areas serve as vital corridors facilitating the survival and dispersal of winged adults on land (Greenwood et al., 2012).

In addition to the aforementioned environmental considerations, it is imperative to address the role of Climate Change. The anticipated increase in the frequency, severity, and duration of droughts poses a significant threat to macrobenthic communities. Even in the absence of noticeable chemical changes, alterations in hydrology exert a profound impact on macroinvertebrate assemblages. Water scarcity disrupts ecological processes such as microbial breakdown and the establishment of permanent periphytic biofilms.

Main methods use in Europe

The Anglers' Riverfly Monitoring Initiative (ARMI) is a UK-wide citizen science project focused on river water quality assessment. There are currently >2000 ARMI volunteers monitoring >1600 sites that are organised into 35 regional hubs across the UK. ARMI is effective in the early detection of water pollution and complements the routine monitoring undertaken by the UK statutory environment agencies. ARMI volunteers are trained to take standardised 3-min kick-samples of freshwater invertebrates from a river site, and use these samples to produce an ARMI score based on the abundance of key pollution-sensitive taxa. ARMI scores and standard invertebrate monitoring metrics are closely correlated. Each sampling site has a 'trigger level' score set by the national regulatory authority—e.g., the

Environment Agency (EA) in England. If the ARMI score falls below this trigger level, the regulatory authority is notified and agency officers investigate the cause of the low score. This process has resulted in many reports of pollution incidents that otherwise may have gone undiscovered but were instead rapidly detected and neutralised. In some cases, investigations resulted in fines being levied against those responsible. ARMI data have also proved useful in assessing the effectiveness of river restoration schemes.The effectiveness of ARMI as a structured citizen science program in improving the environmental protection of rivers has been demonstrated. The ARMI program complements the work of statutory authorities and describes how it promotes community engagement with river environments. It has been active since 2007 (Brooks et al., 2019), allowed to evaluate the reliability of the collected data, showing a strongly positive correlation between ARMI and BMWP ( ) scores across England and Wales.

RiuNet

RiuNet is a citizen science tool derived from the official IBMWP protocol (..). A specific correlated APP was designed for smartphones and tablets, empowering citizens to evaluate the hydrological status and ecological quality of rivers in accordance with the guidelines of the EU Water Framework Directive. Using a simplified and interactive approach, this app guides the user to evaluate the ecological status with hydromorphological and biological quality tests.

Utilising data derived from the official monitoring program conducted by the Catalan Water Agency (ACA), comparative analyses were conducted using a subset of RiuNet assessments within the inland basins of Catalonia. The findings underscore the invaluable contribution of citizens, revealing their capacity to provide pertinent information about the ecological state of rivers across the territory. Importantly, these contributions offer a more comprehensive understanding of river conditions, both spatially and temporally, compared to the limitations of official monitoring programs.

Beyond its data-driven impact, RiuNet is driven by several overarching objectives. Firstly, it aims to draw attention to the ongoing degradation of rivers. Secondly, it seeks to enhance public awareness regarding the imperative need for the protection and restoration of these vital water bodies. Thirdly, the app strives to foster scientific engagement by encouraging the contribution of citizen-generated data. Lastly, RiuNet aims to elevate the level of understanding of river ecosystems, shedding light on lesser-recognized types, such as intermittent rivers or ephemeral streams, which are often overlooked in social discourse. Through these multifaceted goals, RiuNet emerges not only as a tool for ecological assessment but as a catalyst for positive change and public involvement in safeguarding our precious river ecosystems.

RiuNet offered an interesting possibility for CS practice, as it requires a simpler sampling compared to the other methods, on the other hand it requires a good ability in taxonomic determination, as it comprehends 45 taxa mostly to be determined to the family level (Verkaik et al., 2019), which could pose a challenge for volunteers approaching freshwater macroinvertebrates for the first time.

Flow

In the FLOW project, citizens learn how to assess and document the ecological condition of streams and small rivers in a standardised way. This standardised approach is imparted through comprehensive training courses and water surveys conducted across Germany. The primary objective is to establish an extensive database on the state of watercourses, contributing significantly to river research and laying the foundation for targeted protection and renaturalization efforts.

Volunteers actively engage in collecting water body data, which is subsequently integrated into ecotoxicological and ecological studies.This collective effort forms the basis for developing local and regional water protection strategies. The FLOW program facilitates citizen scientists by providing training, support, and field equipment, empowering them to gather data on macroinvertebrate community composition, taxa abundance, and other key parameters. This includes calculating the SPEARpesticide bioindicator, assessing stream hydromorphology, and evaluating the physicochemical status of water bodies.

As a criterion for CS data accuracy (i.e. the “degree to which data are correct overall”, Kosmala et al., 2016) we applied the concept of fitness for use (Bowser et al., 2020). To meet the specific research objectives, CS data must deliver assessments of ecological status that are not only comparable but also highly correlated with professional data across diverse environmental conditions. This stringent criterion underscores the commitment to the reliability and utility of citizen-generated data in advancing our understanding of water ecosystems and guiding effective conservation efforts.

Non-indigenous Species and Fish community

In freshwater ecosystems, biological invasions have witnessed a notable increase in recent decades, attributed to globalisation and human activities. These invasions are currently one of the main threats to biodiversity, and their early detection is essential for a rapid and effective response. Establishing early alert networks plays a pivotal role in swiftly transferring knowledge about detected changes to researchers and authorities. Recognizing the potential of local citizens as early detectors of pivotal changes in river ecosystems and the introduction of exotic species becomes crucial in this context. Research indicates that citizen action at the ecosystem level can efficiently manage the presence of non-native species. Moreover, the development of citizen science programs not only has the potential to heighten public interest in intervening against Non-Indigenous Species (NIS) but also serves to keep citizens closely connected with scientific knowledge. A study by Clusa et al. (2018) conducted in Asturia underscores the significance of incorporating citizens' knowledge and opinions in addressing biodiversity issues. Despite limited knowledge about NIS, citizens demonstrated awareness of associated risks and exhibited a positive attitude toward eradicating NIS affecting native aquatic fauna, aligning with findings in Scotland. However, discrepancies surfaced between citizen-reported data and official reports concerning NIS. Citizens, through techniques like electrofishing, accurately identified over 50% of native species, even detecting the presence of an exotic species, *Trachemys scripta*, previously believed to be confined to artificial ponds. This emphasizes the pivotal role of citizen scientists in supplementing official reports on invasive species. Another interesting result of the study conducted by Clusa et al highlighted that in regions with lower environmental quality, such knowledge about both native and exotic species was notably lower, potentially influenced by a perceived lack of aquatic fauna and the notion that conservation efforts were not worthwhile. Enhancing environmental education emerges as a potential solution to augment public awareness of NIS and decrease intentional releases of aquatic species. The combination of citizen science and molecular methods like environmental DNA (eDNA) presents a promising avenue for early detection and monitoring of non-native species. Collaborative efforts, encompassing media, public education, and citizen science, are deemed crucial in preventing the spread of NIS and fostering improved management programs for biodiversity conservation.

Hydromorphology

The experience accumulated thus far in the implementation of the Water Framework Directive underscores the imperative to accord greater significance to hydromorphology in ecological status assessment, monitoring, characterization, and the formulation of effective measures. Specifically, there is a pressing need to substantially enhance the evaluation of hydromorphological pressures. It is crucial to recognize that hydromorphological processes manifest at diverse spatial and temporal scales, necessitating the utilisation of evaluation methods capable of accommodating these variations (multiscale methods).

Although hydromorphology supports the diverse flora and fauna of our waters, and with the ever-increasing pressure of climate change and changes in politics, society and economics, restoring natural habitats in our aquatic environment is often not a priority. While the adoption of the hydromorphology concept has gained traction since the inception of the European Commission's Water Framework Directive (WFD), it is essential to note that it is currently relegated to a 'supporting element.' This means that, for water bodies where the ecological status falls below the High category, the hydromorphological state is not factored into the comprehensive assessment of the overall ecological condition.

Furthermore, a technical review of biological quality assessment methods used across Europe found that there are few methods sensitive to hydromorphological pressure, meaning that hydromorphological pressures and their effects can remain unnoticed in the assessment process. Consequently, the impacts of such pressures may go unnoticed in the assessment process, leaving member states to design programs of measures aimed at achieving good ecological status without a comprehensive understanding of all pertinent pressures and their impacts.

It is a common temptation in water management to hone in on singular issues, such as addressing point source pollution through enhanced wastewater treatment. Pressures and measures with easily identifiable sources often appear more manageable than hydromorphological pressures, which frequently stem from legacy issues or multiple stressors. The Water Framework Directive (WFD) underscores the principle of "cost-recovery" for water services, emphasising the need to appropriately "recover" financial, resource, and environmental costs from various water service users, guided by principles like the polluter pays principle.

In practice, implementing cost-recovery becomes a formidable challenge, especially in the realm of hydromorphology management. The intricacies of river restoration, for instance, often place the financial burden on the public purse, where budgets are constrained and public attitudes toward the imperative of restoring natural habitats can be variable.

Moreover, public attitudes towards the necessity of restoring natural habitats introduce an additional variable into the equation. The perceived value of such endeavours may fluctuate, making it difficult to garner consistent public support for the financial investments required. Thus, achieving the ideal of cost-recovery in hydromorphological management proves to be a multifaceted challenge, requiring not only financial ingenuity but also a nuanced understanding of public perceptions and a commitment to navigating the complexities inherent in ecological restoration.

MoRPh

The Modular River Survey (MoRPh) is a valuable tool for citizen scientists engaged in monitoring river channels and riparian physical habitats. Developed in 2016, MoRPh has gained gradual adoption across England, Wales, and the Republic of Ireland. This survey methodology allows citizen scientists to collect data at different spatial scales, providing insights into river morphology and functioning.

Key features of MoRPh include its ability to complement biological surveys by characterising the physical structure of river channels and vegetation. Unlike many citizen science surveys that focus on biological or water quality aspects, MoRPh fills a crucial gap by addressing the physical structure of rivers. The survey tool, accessible at https://modularriversurvey.org/, offers manuals, field guides, survey forms, and indicator formulations for public use.

The MoRPh survey methodology covers physical habitat, vegetation structure, sediments, geomorphic features, and human interventions and pressures. Geometric/visual guidance is provided to aid non-specialist citizen scientists in data collection. After uploading surveys to the web-based information system, values for 14 indicators are calculated and mapped. The indicators synthesise natural properties and assess anthropogenic influences. Over 350 active citizen surveyors have conducted approximately 2300 MoRPh modules, revealing variability in indicator scores across surveyed lowland rivers in England and Wales, with potential for future surveys in upland rivers

The citizen River Habitat Survey (cRHS)

The River Habitat Survey (RHS) is an established standard methodology for characterising and assessing the physical character of freshwater streams and small rivers. The methodology is used across the UK and has a database >25,000 sites, with 2,500 in Wales collected since 1994. RHS data is used to calculate a series of quality scores relating to the hydromorphological condition of rivers that can support WFD assessment including: habitat modification score, habitat quality scores, riparian quality indexes and river habitat quality index. The data is widely used in the environmental sector to support planning, management and river restoration and it was applied towards assessing the state of the environment in Wales, the implementation of the Water Framework Directive and prioritising for river restoration. The River Restoration Centre (RRC) has adapted the RHS for citizen science (cRHS) so that it can be applied by members of the public after attending a short training course. The data will be used to introduce citizen scientists to hydromorphology, the science describing the way rivers shape and maintain habitats for species. The aim of cRHS is to have citizen scientists collect, input and interpret habitat data with the help of more experienced surveyors so as to produce assessments of habitat quality and river restoration plans and projects. The cRHS involves recording habitat features, engineered structures and other pressures and taking measurements, photos and videos.

https://www.therrc.co.uk/crhs

Catchment Based Approach

https://catchmentbasedapproach.org/learn/

To be written

Riverine and Freshwater Plastics

Citizen science can contribute in collecting riverine plastic data, as, for other parameters, it can provide high temporal and spatial scales at reduced costs with respect to the professional monitoring conducted by research institutes and environmental agencies. Additionally, the fact that the public is engaged in the research process facilitates the awareness of the plastic problem and its sources, promoting the creation of zero-pollution attitudes and a behaviour towards litter reduction at its source (Popa et al. 2022).

In general citizen science projects targeting riverine plastics are mostly focused on macrolitter as the visual identification and characterization of larger debris does not require specific tools or laboratory equipment otherwise not accessible to citizens. In some projects citizens were engaged in the collection of water samples, but the analysis to identify microplastics (< 5 mm in size and smaller) was conducted by research staff in laboratories equipped with microscopes and other instrumentation, so citizens were not involved in the analysis or interpretation of the data (eg. Kiesseling et al., 2019 and 2021, Barrows et al., 2018). When the citizens receive enough training and clear guidelines, and there are criteria in place for data verification, citizen scientists' data are reliable as those of professionals: in fact, missing information rather than methodological errors are the limiting factor in many citizen science projects (Kiesseling et al., 2021). Data collected by citizen scientists on riverine litter presence include: floating macrolitter, riverbanks litter, and microplastics. This data can be collected through structured citizen-science projects, that include co-design and data interpretation, as well as via personal initiatives or crowd-based observations where the direct interaction with the volunteers is absent, participants are asked to follow certain guidelines, and either ship samples to a laboratory or upload photos and observations of litter and plastics through a custom-developed app for smartphone. In the latter cases, the area coverage is wider, reaching otherwise inaccessible places, and data collection is relatively quick and cost-effective. The temporal and spatial coverage may ultimately counterbalance less precise individual measurements and the lack of data validation (Van Emmerik et al., 2020), but citizen engagement and the project's reach might be limited to already environmentally active communities. Some of the projects are summarised here below.

Projects:

Plastic Pirates and Plastic Pirates EU (Germany and Europe, 2016-2024)

Plastic Pirates is a successful citizen science campaign which contributed to research on the distribution of macro- and microplastics along German rivers and riverbanks. It was part of the Science Year 2016/17 - Seas and Oceans and of the research focus "Plastics in the Environment" of the German Federal Ministry of Education and Research (BMBF). It was carried out by the Ecologic Institute in cooperation with ozean:labor at Kieler Forschungswerkstatt, 2016 – 2020. In the project, school classes and youth groups collect plastic samples from streams and rivers and document their findings. The collected data is then analysed by scientists and researchers, making an important contribution to researching the state of European rivers and the extent of pollution caused by plastic waste. The project has been upscaled by PlasticPiratesEU (Horizon Europe project, https://www.plastic-pirates.eu/en) and the Plastic Pirates – Go Europe! initiative launched by the Trio-Presidency of Germany, Portugal and Slovenia into a pan-European citizen science initiative (2020).

In Plastic Pirates, approximately 5500 schoolchildren participated in the sampling, forming 408 project groups from about 340 schools and youth organisations throughout Germany, sampling from small rivers and channels to major rivers (Kiesseling et al., 2021). Participants were provided with a guidebook with sampling instructions and a booklet with background information about environmental litter pollution for local supervisors. Samples were taken for floating macrolitter (> 25 mm) and meso (24.99 - 5 mm) and microplastics (1-5mm) (Kiesseling et al., 2021), and for riparian litter (Kiesseling et al., 2019).
Floating litter is visually observed and counted in at least 30 minutes surveys, taking pictures whenever possible; meso-and-microplastics are samples with custom-made nets with a mesh size of 1000µm, deployed for 60 minutes. Participants are also asked to quantify the water velocity in three repeated measures by throwing a wooden stick in the water and recording the time it needs to pass from two points 20 m distant from each other along the riverbank. Riverside litter is instead recorded in an area of at least 1000m2 by establishing up to three transects perpendicular to the river course, each transect with a defined number of sampling stations, in predefined zone: the river edge (0-5m distance to river, regular contact with the river water), the river bank (5-15m distance to river, irregular contact with water of river during flood events), and the river crest (15m or more distance to river, not in contact with the river) (Kiesseling et al., 2019). The litter items are counted by participants in circles with a radius of 1.5 m and classified according to the following categories: paper, cigarettes, plastic, metal, glass, food leftovers, and other items.
The datasets collected are stepwise validated with the schools mentors and supervisors and only complete datasets that report correct measurement times and a proper identification of the sampling site are considered. Samples collected are sent to the laboratory of the Kieler Forschungwerkstatt for polymer identification.

The Global Microplastics Initiative and the Gallatin Microplastic Initiative (Global and US)https://www.adventurescientists.org/microplastics.html

In this project, data were collected by volunteers between 2013 and 2017 in a project developed by Adventure Scientists and in close partnership with the Marine & Environmental Research Institute (MERI) and College of the Atlantic. The project aimed at better understanding the global distribution, concentration, and type of microplastics in marine and freshwater environments. Volunteers were given a field protocol with a focus on high data-quality assurance, sufficient data collection, and ease of use. The protocol consisted in water collection in a 1-L sample bottle provided by the volunteer, using the “grab method,” adapted from EPA grab sampling protocols. Volunteers were recruited among outdoors and adventure communities engaged in hiking, backpacking, mountain biking, climbing, kayaking, and mountaineering. Professional athletes served as ambassadors to help recruit volunteers through their networks. After receiving acceptance into the project, global volunteers were required to complete an online training on project protocols and to pass a protocols test with a 100% score. Samples were collected opportunistically from locations in regions where volunteers were visiting for personal travel. This resulted in 2,677 samples being collected for the Global Microplastics Initiative from sites disbursed irregularly around the world. At the conclusion of a sampling effort, global volunteers shipped samples directly to Ocean Analytics in Deer Isle, Maine, for microscopy analysis of the particles in their 1-L bottles. A randomly-selected subset of samples underwent μFTIR (Fourier-transform infrared spectroscopy) analysis. The dataset is composed of 66% marine samples and 34% freshwater samples. By applying the same protocol for freshwater environments, Adventure Scientists implemented the Gallatin Microplastic Initiative (Barrows et al., 2018), which had the aim to examine the presence, size, and type of microplastics in the Gallatin Watershed over two years and to describe the seasonality of microplastic pollution in the headwaters of a watershed. In the Gallatin River Watershed 72 sample sites were selected for seasonal collection. Of these, 22 sites were along the mainstem of the Gallatin River and 50 sites were from tributaries. The method used for sample collection was still the "grab" method and in this initiative, as opposed to the Global effort, pre-trained volunteers visited pre-assigned sample sites four times per year (September, December, March, and June, according to the hydrological flows), in a sampling window of 10 days. Each sample season, 10 randomly selected sites were chosen to collect duplicate samples as a quality assurance measure. In total, 774 samples were analyzed. Field data including water temperature, sample location coordinates, and site substrate type were recorded using a form-based application and/or on paper data sheets. Samples from the Gallatin Microplastic Initiative returned sample bottles in-person to Adventure Scientists' office, which were then shipped to Ocean Analytics. The results of each seasonal collection effort were shared with volunteers at the following pre-sample seasonal refresher event. All global and Gallatin volunteers were asked to complete a survey at the conclusion of the projects. The survey assessed volunteer experience, project impact, and conservation outcomes.

POSEIDOMM (www.poseidomm.eu, Italy) POSEIDOMM is a EU-funded project focused on microplastics, that had an important aspect of citizen engagement through citizen science in the Arno river watershed in Central-Northern Italy. The citizen science initiatives of the POSEIDOMM project consisted in the engagement of about 40 volunteers between 2016 and 2018, including school kids with their teachers, and retired people, in the seasonal (5 times per year) monitoring of chosen sampling sites along the Arno river, its tributaries and a couple of lakes for water quality parameters (nutrients, turbidity, riverbanks conditions, presence of algal blooms) through the FreshwaterWatch platform, which had been modified to include banks' macro litter. The litter was collected in an area of 20 x 20 m along the river's or lake's shore, catalogued, and properly disposed afterwards, following a similar initiative (Levesque et al. 2017). The categories for classification of the litter items found were based on the activity originating them: a) shoreline and recreational activities (bags, beverage bottles/cans, 6-pack holders); b) fishing activities (bait containers, fishing lines, fishing lures); c) smoking-related activities (cigarettes/cigarette filters, lighters, tobacco wrappers); d) dumping activities (appliances, car parts, tires, building material); e) medical/personal hygiene (condoms, diapers, syringes, tampons/tampon applicators); f) other debris/items of local concern (discarded food, firework debris, drug). The number of items belonging to each litter category was estimated using four abundance classes (0, 1, 2–10, >10 items). In the 2 years project, over 1000 macro litter items were collected and removed from rivers and lakes' shores, results that contributed to inform the local administration about point sources of litter and dumping sites. Prior to data collection, group citizens' training and multiple joint monitoring with the researchers were performed. Data were validated with the researchers as soon as the data were uploaded on the FreshwaterWatch subproject's web space, accessible by all project's participants, and in-person in several informal meetings to discuss the results. When doubts arose in the group of citizens and schoolkids for any water quality parameter data and riverbank litter, a constant communication channel was in place with the researchers to discuss any issue (Galgani & Loiselle, personal communication).

TrashAI https://www.trashai.org/ (International) TrashAI is an open source code that can be used by anyone who uploads images of litter from any environment. It can be a powerful tool for the classification of litter and get back data about the trash in the image, including the classification of trash and bounding box of where the trash is in the image. Data validation is made with AI and although still at its beginning, the open source code can leverage citizen science collected data on riverine plastic pollution provided that enough information is given on the sampling sites where pictures are taken. In this project, anyone can contribute but the social aspects of citizen science are not implemented. The code can be seen as a very useful service and implementation for citizen science projects on any type of habitat.

The Ocean Cleanup https://theoceancleanup.com/research/citizen-science/ (survey app for rivers). The Ocean Cleanup has implemented an app (The Ocean Cleanup Survey App for Rivers) that allows tracking plastic debris transport in rivers. Citizens are required to find a safe location (a bridge is ideal) over their nearest or chosen canal, stream or river, and start counting objects that float by, by using this app on the smartphone or tablet. The data are used by the Ocean Cleanup to refine global river transport models and to identify pollution hotspots where to concentrate cleanup efforts. The app provides a short guide for monitoring including information on the best position for counting floating litter. The categories under which floating plastic objects and other debris need to be classified are: a) hard plastic (crates, baskets, toys..); b) soft plastic (plastic bags and wrappers); c) foam (styrofoam disposable items); d) bottles of any kind; e) other plastics (diapers, nappies, sanitary products); f) clothing & textiles (shoes, garment, nets, strings, clothes, textile bags); g) organic (wood, seaweed, leaves); and h) human non-plastic (metal, glass, paper, cardboard, rubber). The location of the survey is shared by GPS through the tablet or smartphone. However, there is no information on if and how the data are validated since volunteers are only required to report the number of floating items per category they identify. Likewise, the social component of citizen science is not implemented in this project, including citizens training, so the app can rather prove to be a useful tool to complement other more structured citizen science initiatives focused on riverine and freshwater habitats.

Preventig Plastic Pollution https://preventingplasticpollution.com/about-the-project/ **by The RiversTrust** https://theriverstrust.org/our-work/our-projects/preventing-plastic-pollution-ppp

Rivers Trusts in the United Kingdom aims to protect and restore freshwater ecosystems. This is done also through citizen science opportunities that encompass water quality monitoring, assessment of polluting outfalls, surveying riverine plastic pollution, mapping and control of freshwater invasive species and assessment of the biological health of rivers (Collins et al., 2023). Rivers Trusts worked in partnership with 18 organisations from across France and England in a project called “Preventing Plastic Pollution”, sought to understand and reduce the impacts of plastic pollution in the marine and freshwater environment. By looking at the catchment from source to sea, the project identified and targeted hotspots for plastic, embedded behaviour change in local communities and businesses, and implemented effective solutions and alternatives. The project created an initiative to pick and monitor litter from source to sea to address the lack of data in river catchments and amplify the efforts of existing litter picking groups. Volunteers were trained to use standardised survey methods, aligned to the OSPAR Commission’s guidelines for monitoring marine litter (OSPAR Commission, 2010) to ensure data comparability, while Rivers Trusts created and open access data platform on plastics where all guidelines and resources, survey findings, data visualisation and export were accessible by the community groups. The platform had the objective to provide information on similar surveys across the UK to provide users a comprehensive magnitude of the issue and of similar initiatives, and allowing volunteers to seek and join new groups and initiatives, thus helping in engagement and recruitment. The Preventing Plastic Pollution project was approved by the Interreg France (Channel) England Programme, and worked across seven pilot sites: Brest Harbour, Bay of Douarnenez, Bay of Veys, Poole Harbour, and the Medway, Tamar, and Great Ouse estuaries.

CrowdWater (Switzerland and International, https://crowdwater.ch/en/welcome-to-crowdwater/). CrowdWater is a SNF-funded project at the University of Zurich, Department of Geography, Unit Hydrology & Climate. The long-term goal of the project is to collect a large number of observations and thus improve the prediction of hydrological events such as drought or flooding. To reach these goals, the CrowdWater app is used to collect data in various categories:

- Water level data with physical and virtual staff gauges
- Qualitative data on soil moisture
- Data on the dynamics of temporary streams
- Data on the documentation of plastic pollution in and around water bodies
- General data on various watercourses

All data collected is published in the data overview. Current research focuses of the project are the use of data on temporary streams and the implementation of the citizen science approach to collecting water quality data. Users can download the app and record floating macroplastic items, or stranded plastic items on the rivers' shore (Van Emmerik et al., 2020). The location of the monitoring is provided with the GPS. No information on co-design, citizens training, data quality and validation is provided, and as for the Ocean Cleanup app, this project relies on citizens' observations, constituting a useful tool to complement more structured citizen science approaches.Pescadores de Plastic (Spain, 2019-2023 https://mon.uvic.cat/pescadors-de-plastic/). The project aimed at assessing the presence of plastic pollution in Catalunian rivers and investigating the role of these systems as transporters of plastic waste from terrestrial to marine ecosystems through citizen science carried out by school children. One of the objectives was also to promote scientific culture among school children, to increase citizen engagement in scientific monitoring, and to upraise the public awareness of the impact of plastic pollution in aquatic ecosystems and the role of rivers in litter distribution. The project saw school kids as citizen scientists in the co-design of research questions, research steps, and analysing, interpreting, discussing and communicating results under the supervision and support of the researchers. Groups of school kids chose a river that was monitored following sampling guidelines and with the help of a sampling kit. Pre-monitoring workshops provided the information on the standardised methods for sample processing of macro- and microplastics, and the results were discussed and validated together with the researchers' coordination team. The project's protocol is based on the guidelines for macrolitter surveys in rivers of the Chilean project "Cientificos de la Basura" (http://www.cientificosdelabasura.cl/). In 2023, the Pescadors de Plastic project adhered to Plastic Pirates continuing the activities through the Plastic Pirates network and the Plastic Pirates Go Europe initiative, by using the project's sampling protocols and approaches.

Community-Driven Freshwater Plastic Monitoring in Western Africa (March - October - 2023).

https://www.museumfuernaturkunde.berlin/en/science/community-driven-freshwater-plastic-monitoring-western-africa. This project is funded by UNEP and follows the UNEP guidelines for plastic monitoring in rivers and lakes (UNEP, 2020). This project is a participatory monitoring activity aimed at understanding the role and effects of citizen science in the monitoring of plastics in freshwater systems in the Odaw river basin in the Greater Accra Region of Ghana. The project is a collaboration between the Museum für Naturkunde Berlin (MfN, Germany), Wageningen University & Research (WUR, Netherlands), and the Helmholtz Centre for Environmental Research (UFZ, Germany). The project firstly engages citizens in the monitoring of plastics based on the UNEP guidelines and analyses how citizen science monitoring activities affect the citizen's knowledge, awareness, and further engagement in addressing plastics pollution. The Republic of Ghana is experiencing a plastic waste crisis due to insufficient recycling and plastic waste management infrastructure, resulting in high plastic waste pollution on land and in water bodies. The impact of plastic pollution on freshwater ecosystems raises concerns about health and environmental issues and has negative socio-economic implications for the Ghanaian population. The government has therefore opened a platform for solutions on reducing plastic waste, that includes various stakeholders and also addresses the role of citizen science in plastic monitoring, activity to which the project contributes. **Conclusion**

To be completed

Similar to chemical and optical tools used by citizen scientists, with differences between projects often related to different analytical methods, for macroinvertebrates the variability is also linked to different methods but also potentially different target communities. However, there is an ongoing effort to simplify the "official" methods used for the framework directive where indices differ between the various member countries. The variables that determine this diversity are generally: sampling method, level of determination, reference list of target species. While for sampling methods the kick can be identified as the most common one and the family as the most used taxonomic level, the list of target species changes considerably.

The conclusion of the study highlights that, similar to chemical and optical tools employed by citizen scientists, variations in the assessment of macroinvertebrates are associated with different analytical methods. However, the variability is not only method-dependent but may also be influenced by the diverse target communities chosen for analysis. The research notes ongoing efforts to simplify official methods aligned with the framework directive, despite variations in indices among member countries. The key determinants of this diversity include sampling methods, level of determination, and the reference list of target species. While the kick method and family level are commonly used, the list of target species exhibits considerable variability.

(on plastics but maybe valid for other parameters too: in general there are a very few projects on riverine plastics that could encompass all characteristics of citizen science: co-design, social interaction, data validation, samples analysis and data interpretation by citizens and volunteers. Most projects are either “tools” useful for citizen science where there is no interaction with the citizen (e.g. apps for counting floating litter, which however are repetitive, are not harmonised in terms of plastic litter categories for classification, and could just be unified into one global initiative or into the same guidelines to allow data intercomparison), tools that rely on already engaged communities; or the projects do not actively involve citizens in the analysis of the samples and data interpretation (samples are shipped to a laboratory). This latter is particularly true for projects aiming at analysing microplastics. Harmonisation of monitoring efforts (floating and riverbanks litter survey guidelines for example), classification guidelines (plastic and other litter categories), are urgently needed. A citizen-science microplastics cut-off size should be decided (e.g. all plastics visible to the naked eye, > 1 mm) allowing for the exact determination of the materials of particles collected as plastic/not plastic (by the melting approach) after classification according to size, colour, shape, etc. Colour classification for both macro and microplastics should follow a clear protocol and colour codes (e.g. Pantone colours system, or the open-source RGB colour codes). Timing of surveys (for floating litter as well as for nets for microplastics) should be harmonised. The size and shape characteristics of areas of river/lakes banks surveyed for stranded litter should be unified (e.g. transects, circles, squares, and how extended these areas should be), and replicates and blank controls should be decided. All these implementations could help make citizen collected riverine plastic data comparable, robust and useful in research studies as well as in informing policy making strategies. Useful guidelines on the visual identification of plastic particles were just published (Markley et al., 2024) as a first step for providing ease of access and affordability to microplastic identification for broad use across volunteer groups, research labs, organisations, and others.

Future challenges

What scientists try to achieve when embarking in citizen science projects is not only scientific advancements and a growing knowledge of the surrounding environment, but also a sensible impact on participants, especially in terms of attitudes' change and scientific knowledge increase. Yet it is far from being clear and easy how these are to be achieved, rather some good practices have been put into place to try and foster such achievements, such as proper citizen involvement and sustained efforts in time, among others. It is therefore an expanding field of research, the one that concerns the impacts of citizen science projects on participants.

One useful concept is that of environmental citizenship, which has been defined as a citizenship guided by green ideas that results in environmentally-friendly attitudes and actions, highlighted as needed to foster the transition to sustainability (Dobson & Bell, 2006; Barry, 2002; Bauer et al., 2020). Experts have identified strategies to foster environmental citizenship within citizen science projects and help change attitudes towards the environment: "First, collectiveness: a key component of citizenship is participation in the collective. Second, situatedness: citizen science initiatives need to cultivate situated citizenship. Third, connectedness: citizen science projects should help their participants make connections between the data they collect and larger environmental problems." (Jørgensen & Jørgensen, 2021), while others have pointed at the fact that scientists need to approach their projects from different social dimensions in order to encourage social learning and attitudes' changes (Fielke et al., 2022). Social learning, or collaborative learning, is here defined as the process of specific knowledge sharing that happens in a structured or unstructured way between stakeholders and scientists, thanks to which both can learn something more about the problem at hand (Mackenzie et al., 2012).

What has been observed by practitioners is the possibility of integrating citizens who are already sensitised on environmental matters and schools, or rather students and teachers. This could be interesting in terms of engagement above all, as it is a well known issue that when dealing with schools scientists face a double faced situation, since on the one hand

there are often highly engaged teachers that participate with passion and can be good motivators and help spread knowledge regarding projects, and on the other hand there are often not so highly engaged students, who after all cannot be considered as volunteers since their teachers volunteered for them, and are thus more difficult to engage.
There are some major possibilities when involving schools: first and foremost involving schools means opening them to what happens in the scientific world, possibly linking schools and researchers and creating networks of different schools too. Widening the engagement is also a thing, as having more than the original participants - the already sensitised individuals, often already involved in other associations dealing with environmental change - is a good goal in itself. Not to forget are the long term possibilities of spillover effects when students talk with their families in terms of scientific knowledge, as well as what teachers have to offer, which goes from dissemination within their classes to more willingness to participate in future projects. Last but not least, it is a shared thought in the literature that citizen science holds a considerable potential for science education and learning (Bonney et al., 2009).
It is here useful to distinguish between formal and informal learning, which following Roche et al. (2020) are for the former case formal learning programs and lessons plans based in already existing learning environments such as schools and universities, established in conjunction between scientists and teachers who play a crucial role in fostering the learning of their students, especially since such programs are agreed on by teachers, while students become willingly or not volunteers of the project. In the latter case instead, informal learning is to be appreciated in other non-traditional learning contexts which become the theatre of operations for many citizen science projects, in which people find themselves learning something about science or the world surrounding them even though no formal learning plan had been established in advance by the researchers. The potential of citizen science projects lies naturally in the informal learning, which can provide a valid alternative in the learning process of hard sciences, subjects that students tend to consider more challenging (Araujo et al., 2022).

The knowledge regarding the possibilities in engaging schools comes from personal exchanges with scientists who have experience in citizen science projects with schools, as in the projects MICS (Gumiero) and POSEIDOMM. (Galgani).

Bibliography

Altman K., Yelton B., Porter D.E., Heath Kelsey R., Friedman D.B. (2023) The Role of Understanding, Trust, and Access in Public Engagement with Environmental Activities and Decision Making: A Qualitative Study with Water Quality Practitioners. in Environmental Management 71, pp.1162–1175, DOI https://doi.org/10.1007/s00267-023-01803-2

Araújo, J.L., Morais, C., Paiva, J.C. (2022). Student participation in a coastal water quality citizen science project and its contribution to the conceptual and procedural learning of chemistry. In Chemical Education Research Practice, 2022, 23, 100-112

Balbo A., Galimberti G. (2016) Citizen hydrology in River Contracts for water management and people engagement at basin scale. in COWM2016 - International Conference on Citizen Observatories for Water Management, Venice, 7-9 June 2016

Ballard H.L., Dixon C.G.H., Harris E.M. (2017) Youth-focused citizen science: Examining the role of environmental science learning and agency for conservation. in Biological Conservation, vol 208, pp.65-75, DOI: https://doi.org/10.1016/j.biocon.2016.05.024

Ballerini L., Bergh S.I. (2021) Using citizen science data to monitor the Sustainable Development Goals: a bottom-up analysis. in Sustainability Science, vol 16, pp. 1945-1962, DOI: https://doi.org/10.1007/s11625-021-01001-1

Barrows A.P.W., Christiansen K.S., Bode E.T., Hoellein T.J. (2018) A watershed-scale, citizen science approach to quantifying microplastic concentration in a mixed land-use river. in Water Research, vol 147, pp. 382-392, DOI: https://doi.org/10.1016/j.watres.2018.10.013

Barry, B. (2002). Culture and equality: An egalitarian critique of multiculturalism. Harvard University Press

Bauer N., Megyesi B., Halbac-Cotoara-Zamfir R., Halbac-Cotoara-Zamfir C. (2020) Attitudes and Environmental Citizenship. in Conceptualizing Environmental Citizenship for 21st Century Education, Springer Open Publications, 2020

Beketov M.A., Foit K., Schafer R.B., Schriever C.A., Sacchi A., Capri E., Biggs J., Wells C., Liess M. (2009) SPEAR indicates pesticide effects in streams – Comparative use of species- and family-level biomonitoring data. in Environmental Pollution, vol 157, Issue 6, pp.1841-1848, DOI: https://doi.org/10.1016/j.envpol.2009.01.021

Bellasi A., Binda G., Pozzi A., Galafassi S., Volta P., Bettinetti R. (2020) Microplastic Contamination in Freshwater Environments: A Review, Focusing on Interactions with Sediments and Benthic Organisms. in Environments, 7, 30, DOI: https://doi.org/10.3390/environments7040030

Biraghi C.A., Carrion D., Brovelli M.A. (2022) Citizen Science Impact on Environmental Monitoring towards SDGs Indicators: The CASE of SIMILE Project. in Sustainability, vol 14, issue 13, DOI: https://doi.org/10.3390/su14138107

Bishop I.J., Warner S., van Noordwijk T.C.G.E., Nyoni F.C., Loiselle S. (2020) Citizen Science Monitoring for Sustainable Development Goal Indicator 6.3.2 in England and Zambia. in Sustainability, 12(24), 10271; https://doi.org/10.3390/su122410271

Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., et al. (2009). Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education. In A CAISE Inquiry Group ReportAQ publisher

Bonney R., Phillips T.B., Ballard H.L., Enck J.W. (2015) Can citizen science enhance public understanding of science? in Public Understanding of Science, vol 25, issue 1, DOI: https://doi.org/10.1177/0963662515607406

Breuer L., Hiery N., Kraft P., Bach M., Aubert A.H., Frede H.G. (2015) HydroCrowd: a citizen science snapshot to assess the spatial control of nitrogen solutes in surface waters. in Scientific Reports, vol 5, DOI: https://doi.org/10.1038/srep16503

Brooks S., Fitch B., Davy-Bowker J., Alvarez Codesal S. (2019) Anglers' Riverfly Monitoring Initiative (ARMI): a UK-wide citizen science project for water quality assessment. in Freshwater Science, vol 38, n. 2, University of Chicago Press, DOI: https://doi.org/10.1086/703397

Cameron R.W.F., Brindley P., Mears M., McEwan K., Ferguson F., Sheffield D., Jorgensen A., Riley J., Goodrick J., Ballard L., Richardson M. (2020) Where the wild things are! Do urban green spaces with greater avian biodiversity promote more positive emotions in humans? in Urban Ecosystems, vol 23, pp.301–317, DOI: https://doi.org/10.1007/s11252-020-00929-z

Carlson T., Cohen A. (2018) Linking community-based monitoring to water policy: Perceptions of citizen scientists. in Journal of Environmental Management, vol 219, pp.168-177, DOI: https://doi.org/10.1016/j.jenvman.2018.04.077

Carvalho L., Mackay E.B., Cardoso A.C., Baattrup-Pedersen A., Birk S., Blackstock K.L., Borics G., Borja A., Feld C.K., Ferreira M.T., Globevnik L., Grizzetti B., Hendry S., Hering D., Kelly M., Langaas S., Meissner K., Panagopoulos Y., Penning E., Rouillard J., Sabater S., Schmedtje U., Spears B.M., Venohr M., van de Bund W., Solheim A.L. (2019) Protecting and restoring Europe's waters: An analysis of the future development needs of the Water Framework Directive. in Science of The Total Environment, vol 658, pp.1228-1238, DOI: https://doi.org/10.1016/j.scitotenv.2018.12.255

Charles K.J., Shaylor E. (2023) Rapid water quality field tests: Data revolution or dead end? in PLoS Water, DOI: https://doi.org/10.1371/journal.pwat.0000139

Church S.P., Payne L.B., Peel S., Prokopy L.S. (2019) Beyond water data: benefits to volunteers and to local water from a citizen science program. in Journal of Environmental Planning and Management, vol 62, issue 2, pp.306-326, DOI: https://doi.org/10.1080/09640568.2017.1415869

Clusa L., Miralles L., Fernandez S., Garcia-Vazquez E., Dopico E. (2018) Public knowledge of alien species: a case study on aquatic biodiversity in North Iberian rivers. in Journal for Nature Conservation, vol 42, pp.53-61, DOI: https://doi.org/10.1016/j.jnc.2018.01.001

Collins R., France A., Walker M., Browning S. (2023) The potential for freshwater citizen science to engage and empower: a case study of the Rivers Trusts, United Kingdom. in Frontiers in Environmental Science DOI:10.3389/fenvs.2023.1218055

Cook S., Abolfathi S., Gilbert N.I. (2021) Goals and approaches in the use of citizen science for exploring plastic pollution in freshwater ecosystems: A review. in Freshwater Science, vol 40, DOI: https://doi.org/10.1086/717227

de Sherbinin A., Bowser A., Chuang T.-R., Cooper C., Danielsen F., Edmunds R., Elias P., Faustman E., Hultquist C., Mondardini R., Popescu I., Shonowo A., Sivakumar K. (2021) The Critical Importance of Citizen Science Data. in Frontiers in Climate, vol 3, DOI: https://doi.org/10.3389/fclim.2021.650760

Dobson, A., & Bell, D. (2006). Environmental citizenship (p. 296). Cambridge: MIT Press

ECSA (European Citizen Science Association). 2015. Ten Principles of Citizen Science. Berlin. http://doi.org/10.17605/OSF.IO/XPR2N

England J., Beach E., Finn Leeming B., Shuker L. (2017) Characterising Hertfordshire chalk stream habitats using MoRPh. in Trans. Herts. Nat. Hist. Soc. 49(1)

Erba S., Buffagni A., Cazzola M., Balestrini R. (2022) Italian reference rivers under the Water Framework Directive umbrella: do natural factors actually depict the observed nutrient conditions? in Environmental Sciences Europe, vol 34, DOI: https://doi.org/10.1186/s12302-022-00642-y

European Commission, Directorate-General for Environment (2018) Citizen science for environmental policy : development of an EU-wide inventory and analysis of selected practices. Publications Office, 2018, DOI: https://data.europa.eu/doi/10.2779/961304

European Commission, Directorate-General for Research and Innovation, Chimini, G., Failler, P., Galgani, L. et al., Portfolio analysis, EU mission “Restore our Ocean and Waters by 2030” – Analysis of a portfolio of projects financed by sixteen EU programmes contributing to the objectives and enablers of the mission ocean and waters, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/683

European Commission, JRC news and update (2018) Citizen science for environmental policy: Development of an EU-wide inventory and analysis of selected practices

Ewald N., Quinlan L., Case P., Dunn F., Heathcote A., Shaw H., Worker H., Williams P., Biggs J. (2018) People, Ponds and Water Project Summary report

Fielke S., Taylor B.M., Coggan A., Jakku E., Davis A.M., Thorburn P.J., Webster A.J., Smart J.C.R. (2022) Understanding power, social capital and trust alongside near real-time water quality monitoring and technological development collaboration. in Journal of Rural Studies, vol 92, pp.120-131, DOI: https://doi.org/10.1016/j.jrurstud.2022.03.022

Forrest S.A., Holman L., Murphy M., Vermaire J.C. (2019) Citizen science sampling programs as a technique for monitoring microplastic pollution: results, lessons learned and recommendations for working with volunteers for monitoring plastic pollution in freshwater ecosystems. in Environmental Monitoring and Assessment, vol 191, DOI: https://doi.org/10.1007/s10661-019-7297-3

Fraisl D., Campbell J., See L., Wehn U., Wardlaw J., Gold M., Moorthy I., Arias R., Piera J., Oliver J.L., Masò J., Penker M., Fritz S. (2020) Mapping citizen science contributions to the UN sustainable development goals. in Sustainability Science, vol 15, pp.1735-1751, DOI: https://doi.org/10.1007/s11625-020-00833-7

Fritz S., See L., Carslon T., Haklay M., Oliver J.L., Fraisl D., Mondardini R., Brocklehurst M., Shanley L.A., Schade S., Wehn U., Abrate T., Anstee J., Arnold S., Billot M., Campbell J., Espey J., Gold M., Hager G., He S., Hepburn L., Hsu A., Long D., Masò J., McCallum I., Muniafu M., Moorthy I., Obersteiner M., Parker A.J., Weisspflug M., West S. (2019) Citizen science and the United Nations Sustainable Development Goals. in Nature Sustainability, vol 2, pp.922-930, DOI: https://doi.org/10.1038/s41893-019-0390-3

Hadj-Hammou J., Loiselle S., Ophof D., Thornhill I. (2017) Getting the full picture: Assessing the complementarity of citizen science and agency monitoring data. in PLoS ONE, vol 12, issue 12, DOI: https://doi.org/10.1371/journal.pone.0188507

Haywood B.K., Besley J.C., (2013) Education, outreach, and inclusive engagement: Towards integrated indicators of successful program outcomes in participatory science. in Public Understanding of Science, vol 23, issue 1, DOI: https://doi.org/10.1177/0963662513494560

Hegarty S., Hayes A., Regan F., Bishop I., Clinton R., (2021) Using citizen science to understand river water quality while filling data gaps to meet United Nations Sustainable

Development Goal 6 objectives. in Science of the Total Environment, vol 783, DOI: https://doi.org/10.1016/j.scitotenv.2021.146953

Johnson M.F., Hannah C., Acton L., Popovici R., Karanth K.K., Weinthal E. (2014) Network environmentalism: Citizen scientists as agents for environmental advocacy. in Global Environmental Change, vol 29, pp.235-245, DOI: https://doi.org/10.1016/j.gloenvcha.2014.10.006

Jørgensen F.A., Jørgensen D. (2021) Citizen science for environmental citizenship. in Conservation Biology, 35(4), pp.1344–1347, DOI: https://doi.org/10.1111%2Fcobi.13649

Jovanovic S., Carrion D., Brovelli M.A. (2019) Citizen science for water monitoring applying FOSS. in Contributo Atto di Convegno, PoliMi

Kaika M. (2003) The Water Framework Directive: A New Directive for a Changing Social, Political and Economic European Framework. in European Planning Studies, vol 11, issue 3, pp.299-316, DOI: https://doi.org/10.1080/09654310303640

Kaplan Mintz K., Arazy O., Malkinson D. (2023) Multiple forms of engagement and motivation in ecological citizen science. in Environmental Education Research, vol 29, issue 1, pp.27-44, DOI: https://doi.org/10.1080/13504622.2022.2120186

Kaufman A., Williams R., Barzyk T., Greenberg M., O'Shea M., Sheridan P., Hoang A., Ash C., Teitz A., Mustafa M., Garvey S. (2017) A Citizen Science and Government Collaboration: Developing Tools to Facilitate Community Air Monitoring. in Environmental Justice, vol 10, n.2, DOI: https://doi.org/10.1089/env.2016.0044

Kiessling T., Hinzmann M., Mederake L., Dittman S., Brennecke D., Bohm-Beck M., Knickmeier K., Thiel M. (2023) What potential does the EU Single-Use Plastics Directive have for reducing plastic pollution at coastlines and riversides? An evaluation based on citizen science data. in Waste Management, vol 164, pp.106-118, DOI: https://doi.org/10.1016/j.wasman.2023.03.042

Kiessling T., Knickmeier K., Kruse K., Gatta-Rosemary M., Nauendorf A., Brennecke D., Thiel L., Wichels A., Parchmann I., Kortzinger A., Thiel M. (2021) Schoolchildren discover hotspots of floating plastic litter in rivers using a large-scale collaborative approach. in Science of the Total Environment, vol 789, DOI: https://doi.org/10.1016/j.scitotenv.2021.147849

Kim S., Robson C., Zimmerman T., Pierce J., Haber E.M. (2011) Creek watch: pairing usefulness and usability for successful citizen science. in Proceedings of SIGCHI Conference 2011 DOI: https://doi.org/10.1145/1978942.1979251

Mackenzie J., Tan P.-L., Hoverman S., Baldwin C. (2012) The value and limitations of Participatory Action Research methodology. in Journal of Hydrology, vol 474, pp.11-21, DOI: https://doi.org/10.1016/j.jhydrol.2012.09.008

Moolna A., Duddy M., Fitch B., White K. (2020) Citizen science and aquatic macroinvertebrates: public engagement for catchment-scale pollution vigilance. in Ecoscience, vol 27, issue 4 DOI: https://doi.org/10.1080/11956860.2020.1812922

Nardi F., Cudennec C., Abrate T., Allouch C., Annis A., Assumpção T., Aubert A.H., Bérod D., Braccini A.M., Buytaert W., Dasgupta A., Hannah D.M., Mazzoleni M., Polo M.J., Sæbø O., Seibert J., Tauro F., Teichert F. Teutonico R., Uhlenbrook S., Wahrmann Vargas C., Grimaldi S. (2022) Citizens AND HYdrology (CANDHY): conceptualizing a transdisciplinary framework for citizen science addressing hydrological challenges. in Hydrological Science Journal, vol 67, pp.2534-2551, DOI: https://doi.org/10.1080/02626667.2020.1849707

Newson M. (2021) Fluvial geomorphology and environmental design': Restitution for damage, rehabilitation, restoration or rewilding? in Earth Surface Processes & Landforms, vol 47, issue 2, pp.409-421, DOI: https://doi.org/10.1002/esp.5256

Owen R.P., Parker A.J. (2018) Citizen science in environmental protection agencies. In: Hecker S. and Haklay M. and Bowser A. and Makuch Z. and Vogel J. and Bonn A., (eds.) Citizen Science - Innovation in Open Science, Society and Policy. (pp. 284-300). UCL Press, London

Peeters E.T.H.M., Wilhelm M., Gerritsen A.A.M., Seelen M.L.S. (2023) Ecological characterisation of urban ponds in the Netherlands: a study based on data collected by volunteers. in Frontiers of Biogeography, vol 15, issue 1, DOI: https://doi.org/10.21425/F5FBG57816

Pinto P., Oliveira-Junior J.M.B., Leitão F., Morais M.M., Chícharo L., Vaz P., Delgado S.M.A., Voreadou C., Morales E.A., Teodósio M.A. (2020) Development of a Metric of Aquatic Invertebrates for Volunteers (MAIV): A Simple and Friendly Biotic Metric to Assess Ecological Quality of Streams. in Water, vol 12, 654, DOI: https://doi.org/10.3390/w12030654

Prat N., Rieradevall M., Fortuno P., Ladrera R., Verkaik I., Becerra M., Menendez S. (2016) Riu.Net application: citizen science in rivers. in International Conference on Citizen Observatories for Water Management, Venice, 2016

Quinlivan L., Chapman D.V., Sullivan T. (2020) Applying citizen science to monitor for the Sustainable Development Goal Indicator 6.3.2: a review. in Environmental Monitoring Assessment, vol 192, issue 218, DOI: https://doi.org/10.1007/s10661-020-8193-6

Rambonnet L., Vink S.C., Land-Zastra A.M., Bosker T. (2019) Making citizen science count: Best practices and challenges of citizen science projects on plastics in aquatic environments. in Marine Pollution Bulletin, vol 145, pp.271-277, DOI: https://doi.org/10.1016/j.marpolbul.2019.05.056

Rimmert M., Baudoin L., Cotta B., Kochskämper E., Newig J. (2020) Participation in river basin planning under the Water Framework Directive – Has it benefitted good water status?. in Water Alternatives, 13(3), pp.484-512

Roche J., Bell L., Galvao C., Golumbic Y.N., Kloetzer L., Knoben N., Laakso M., Lorke J., Mannion G., Massetti L., Mauchline A., Pata K., Ruck A., Taraba P., Winter S. (2020) Citizen Science, Education, and Learning: Challenges and Opportunities. in Frontiers in Sociology, vol 5, DOI: https://doi.org/10.3389/fsoc.2020.613814

Roszak, T., Gomes, M. E., & Kanner, A. D. (Eds.). (1995). Ecopsychology: Restoring the earth, healing the mind. Sierra Club Books.

Seelen L.M.S., Flaim G., Jennings E., De Senerpont Domis L.N. (2019) Saving water for the future: Public awareness of water usage and water quality. in Journal of Environmental Management, vol 242, pp.246-257, DOI: https://doi.org/10.1016/j.jenvman.2019.04.047

Smith B., Clifford N.J., Mant J. (2014) The changing nature of river restoration. in WIREs Water, DOI: https://doi.org/10.1002/wat2.1021

Stankiewicz, J., Konig, A., Pickar, K., Weiss, S. (2023) "How certain is good enough? Managing Data quality and uncertainty in ordinal citizen science data sets for evidence-based policies on fresh water" in Citizen Science: Theory and Practice, Ubiquity Press. DOI: 10.5334/cstp.592

Stenekes S., Parlee B., Seixas C. (2020) Culturally Driven Monitoring: The Importance of Traditional Ecological Knowledge Indicators in Understanding Aquatic Ecosystem Change in the Northwest Territories' Dehcho Region. in Sustainability, 12(19), 7923, DOI: https://doi.org/10.3390/su12197923

Tasseron P., Zinsmeister H., Rambonnet L., Hiemstra A.-F., Siepman D., van Emmerik T. (2020) Plastic Hotspot Mapping in Urban Water Systems. in Geosciences, vol 10, 342, DOI: https://doi.org/10.3390/geosciences10090342

Taylor J., Graham M., Louw A., Lepheana A., Madikizela B., Dickens C., Chapman D.V., Warner S. (2022) Social change innovations, citizen science, miniSASS and the SDGs. in Water Policy, vol 24, issue 5, DOI: https://doi.org/10.2166/wp.2021.264

Thompson M., Bankier C., Bell T., Dumbrell A., Gray C., Ledger M., Lehmann K., McKew B., Sayer C., Shelley F., Trimmer M., Warren S., Woodward G. (2016) Gene-to-ecosystem impacts of a catastrophic pesticide spill: testing a multilevel bioassessment approach in a river ecosystem. in Freshwater Biology, vol 61, issue 12, DOI: https://doi.org/10.1111/fwb.12676

Thornhill I., Loiselle S., Lind K., Ophof D. (2016) The citizen science opportunities for researchers and agencies. in BioScience, vol 66, Issue 9, pp.720–721, DOI: https://doi.org/10.1093/biosci/biw089

Torres A.-C., Bedessem B., Deguines N., Fontaine C. (2023) Online data sharing with virtual social interactions favor scientific and educational successes in a biodiversity citizen science project. in Journal of Responsible Innovation, in 10, issue 1, DOI: https://doi.org/10.1080/23299460.2021.2019970

Turbé A., Barba J., Pelacho M., Mugdal S., Robinson L.D., Serrano-Sanz F., Sanz F., Tsinaraki C., Rubio J.-M. and Schade S. (2019) Understanding the Citizen Science Landscape for European Environmental Policy: An Assessment and Recommendations. in Citizen Science: Theory and Practice, 4(1), pp.34, DOI: https://doi.org/10.5334/cstp.239

Valeriani F., Zinnà L., Vitali M., Romano Spica V., Protano C. (2015) River water quality assessment: comparison between old and new indices in a real scenario from Italy. in International Journal of River Basin Management, vol 13, issue 3, DOI: https://doi.org/10.1080/15715124.2015.1012208

van der Heijden J., ten Heuvelhof E. (2012) The Mechanics of Virtue: Lessons on Public Participation from Implementing the Water Framework Directive in the Netherlands. in Environmental Policy and Governance, vol 22, issue 3, pp.177-188, DOI: https://doi.org/10.1002/eet.1583

van Noordwijk T., Bishop I., Staunton-Lamb S., Oldfield A., Loiselle S., Geoghegan H., Ceccaroni L. (2021) Creating Positive Environmental Impact Through Citizen Science. in Vohland, K., et al. The Science of Citizen Science. Springer, Cham. https://doi.org/10.1007/978-3-030-58278-4_19

van Emmerik T., Schwarz A. (2019) Plastic debris in rivers. in WIREs Water, vol 7, issue 1, DOI: https://doi.org/10.1002/wat2.1398

van Emmerik T., Seibert J., Strobl B., Etter S., den Oudendammer T., Rutten M., Shahrizal bin Ab Razak M., van Meerveld I. (2020) Crowd-Based Observations of Riverine Macroplastic Pollution. in Frontiers in Earth Science, vol 8, DOI: https://doi.org/10.3389/feart.2020.00298

Vasantha Raman N., Dubey A., Millar E., Nava V., Leoni B., Gallego I. (2023) Monitoring contaminants of emerging concern in aquatic systems through the lens of citizen science. in Science of the Total Environment, vol 874, May 2023. DOI: https://doi.org/10.1016/j.scitotenv.2023.162527

Venkatesh B., Velkennedy R. (2022) Formulation of citizen science approach for monitoring Sustainable Development Goal 6: Clean water and sanitation for an Indian city. in Sustainable Development, vol 31, issue 1, pp.56-66, DOI: https://doi.org/10.1002/sd.2373

von Gonner J., Bowler D., Groning J., Klauer A-K., Liess M., Neuer L., Bonn A. (2023) Citizen science for assessing pesticide impacts in agricultural streams. in Science of the Total Environment, vol 857, DOI: https://doi.org/10.1016/j.scitotenv.2022.159607

Woods S.M., Daskolia M., Joly A., Bonnet P., Soacha K., Liñan S., Woods T., Piera J., Ceccaroni L. (2022) How Networks of Citizen Observatories Can Increase the Quality and Quantity of Citizen-Science-Generated Data Used to Monitor SDG Indicators. in Sustainability, 14(7):4078, DOI: https://doi.org/10.3390/su14074078

Wyeth G. (2023) Integrating Citizen Science into the Work of United States Environmental Agencies. in Citizen Science: Theory and Practice, vol 8, issue 1, DOI: https://doi.org/10.5334/cstp.490

Zhou X., Tang J., Zhao Y.C., Wang T. (2020) Effects of feedback design and dispositional goal orientations on volunteer performance in citizen science projects. in Computers in Human Behaviour, vol 107, DOI: https://doi.org/10.1016/j.chb.2020.106266