Towards Digital Environmental Stewardship: the Work of Caring for the Environment in Waste Management

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ABSTRACT

This paper discusses *Digital Environmental Stewardship* as an analytical framework that can help HCI scholarship to understand, design, and assess sociotechnical interventions concerned with sustainable waste management practices. Drawing on environmental studies, we outline key concepts of environmental stewardship – namely actors, capacity, and motivations – to unpack how different initiatives for handling waste are organised, both through grassroots and top-down interventions, and through varying sociotechnical configurations. We use these dimensions to analyse three different cases of waste management that illustrate how actions of care for the environment are ecologically organised, and what challenges might hinder them beyond –or besides– behavioural motivations. We conclude with a discussion on the orientation to action that the suggested framework provides, and its role in understanding, designing and assessing digital technologies in this domain. We argue that examining how stewardship actions fold into each other helps design sociotechnical interventions for managing waste from within a relational perspective.

CCS CONCEPTS

• **Human-centered computing** → **HCI theory, concepts and models**; **Empirical studies in HCI**.

KEYWORDS

Environmental sustainability, digital environmental stewardship, community-led initiatives, waste management, theory

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1 INTRODUCTION

Infrastructures, policies, legislation and waste practices vary across countries, and are often organised by local governance, through coordinated interventions of both public and private actors. Nevertheless, recent technological advances (digital platforms, such as TipTapp [83], Litterati [53], Rubicon Global Analytics [76]), and the proliferation of both older and more recent people-led initiatives (e.g., Zero Waste [87], Plogga [67], Ocean Blue [10], Recycling Networks [62]) illustrate a more complex picture. Here, different forms of participatory practices for waste removal are organised from the bottom up, through citizens' efforts to (re)appropriate cities, manage, and protect them [51]. This calls for new understandings of the ways practices of waste management, and environmentally sustainable actions more broadly, are enacted by hybrid networks of actors, through structural interventions and bottom-up initiatives, and varying configurations of digital technologies.

We draw on environmental stewardship literature from Environmental Studies [5, 32] to analyse three illustrative cases concerned with waste removal in urban areas. Two of the cases, Plogga and Litterati, are concerned with waste removal from public spaces, but only the latter uses a bespoke platform. The other case exemplifies the work of a formal organisation, whose role is to manage waste in multi-apartment buildings. The three examples are used as entry points to unpack different forms of stewardship in waste management practices, and the work of technology in shaping them. Environmental stewardship is concerned with the collective actions taken by individuals, institutions or grassroots collectives, with various motivations and capacities to act, to protect and responsibly use the environment [5]. The notion provides an analytic lens and a vocabulary to describe the ways diverse actors connect to and care for the environment, along with the commitments and dependencies that characterise emerging relationships and attachments (see [58]). We build on three key dimensions of environmental stewardship, specifically actors, motivations and capacity to act [5], to examine the different ways initiatives of waste management can be mobilised, organised, and configured through digital technologies, and multi-party involvement.

Building on this analytical work, we introduce *digital environmental stewardship* as an analytical and design lens that can help HCI scholarship to envision, design and assess sociotechnical systems of care for the environment. We argue that, by attending to the ethical, affective and political work of caring for the environment (see [68]), digital environmental stewardship can respond to some of the issues previously identified within sustainable HCI [13, 26, 45]; this includes accounts of ecological relations [9], reductive design interventions [13, 54], and the production of meaningful engagement with the world [52]. As problems connected to a global environmental crisis are increasingly pressing, we discuss the potential of digital environmental stewardship to outline how different initiatives concerned with waste management can be organised in private and public spaces, from the bottom-up and through formally defined interventions, and by using bespoke and generic digital platforms. Connecting to recent work [27], the framework focuses on social relations and local capacities rather than universal design solutions. Moreover, it resonates with calls [29] to consider the context-specific, sociocultural and political aspects that shape both individual and collective awareness of environmental sustainability.

Digital environmental stewardship extends the framing of sustainable action within HCI research. It offers a complementary, relational perspective alongside a set of analytic dimensions with which to critically assess technology-mediated stewardship actions, and from which to generate novel design interventions. At the core of the framing is an orientation to action that positions the impact of stewardship as having environmental, social, and interpersonal consequences [5, 19, 46]. By avoiding the atomisation of action that has been associated with behaviour change models in sustainable HCI research [55], the framework moves beyond persuasive technologies in favour of a more ecological and socially grounded approach to designing for sustainability. To unravel the analytical and design potential of digital environmental stewardship, we introduce the concept of *folding in actions*, which accounts for the connectedness of stewardship interventions, and the power of single initiatives to activate new ones. We conclude by highlighting the role of digital technology in enabling –or inhibiting– acts of care for the environment, and how designing with digital environmental stewardship can scope design.

2 BACKGROUND

In what follows, we first establish the current landscape of HCI research on sustainability and waste management. Thereafter, we introduce work on environmental stewardship, and outline how it extends research in sustainable HCI.

2.1 Sustainable HCI

Since its first consolidation through Blevis' foundational paper [8], sustainable HCI has oscillated between various framings of its scale, ontological constitution, and possibilities for technological intervention grounded in different epistemological stances. These span from theories of behaviour change to social practice theory, to more recent ecological and relational perspectives that include more-than-human framings. A key motivation for articulating the perspective on sustainable interaction design [8] has been the ethical necessity to make sustainable design choices. This includes seeing design as an ethical practice involving *future ways of being* [9], and as one that should reorient its methods and reasoning towards more sustainable values – e.g., reuse, sharing, or (re)valuing degradation. However, across a full decade of inquiry, and several review papers [13, 26, 45], sustainability research in HCI has struggled with how to achieve this. As Szu-Yu Liu and colleagues [55] have noted, a main challenge is to balance between stances associated with paternalistic interventions and relational perspectives. The former ones have typically chosen to bound the scope of knowing to cognitivist, behaviourist and rationalist models; the latter have been bound by the necessity to demonstrate efficacy and causality, without taking an interventionist perspective. Historically dominating the field of sustainable HCI, the former perspectives have typically focused on designing new technologies for promotion of more – or cessation of less – sustainable behaviours. They have been grounded in theories of behaviour change (e.g., Persuasive Technology), and theories of motivation (e.g., the theory of self-determination) [26]. The projects associated with this approach have identified aspects of unsustainable behaviours, and produced informational and practical interventions tackling them [55]. Examples include the impact of the visibility of behaviours to others [33], gamification [63], ecofeedback [35], and intentional and unintentional adverse feedback [34, 82]. While many of these studies could demonstrate behavioural changes, most of them are short in duration, and claims about long-term behaviour change are unfounded. In a systematic review in the context of sustainable food consumption, Hedin and colleagues [40] found that, due to issues of study design, not one study within the examined corpus could demonstrate significant behaviour change.

However, this is not only an issue of study design. Across three reviews of Sustainable HCI, Brynjarsdóttir [13], DiSalvo [26], and Knowles [45], and their respective colleagues, have argued against the conceptualisation of sustainability as an individual choice - whether that is through persuasive technologies, rational choice models of change, or individual notions of responsibility. Overall, this research has pointed to the need to more thoroughly consider how sustainable practices are political, and entangled both with local governance and diverse aspects of everyday life [29]. More holistic approaches have been proposed, including social practice theory [22, 47, 80], ecological perspectives (e.g., permaculture [55]), and relational perspectives (e.g., more-than-human perspectives [21, 54]). Social practice theory has been most dominant in the response to behaviour change, particularly where it helps demonstrate how interventions must not be understood in isolation from other practices, and social meanings. Energy consumption, often a target of behaviour change techniques, has been shown to relate to conceptions of cleanliness, comfort and convenience, which are concepts shaped by our social and cultural lives [79]. Hasselqvist and colleagues [39] show how even radical material changes (e.g., taking away the family car for a year) are complicated by their entanglements with public infrastructures, policies, and societal norms. Thus, while ostensibly targeting material interventions through digital technologies, sustainability research has to grapple with the meaning of moral and ethical positioning of specific practices within society. In their manifesto for sustainability research, Knowles et al. [45] argue for a more aggressive confrontation of societal norms, including socio-economic, political, and environmental justice issues.

Finally, Light et al. [52] have argued for a humanist engagement with sustainability challenges. This work marks a move towards an ethics of sustainability that not only engages the moral responsibility to act, but also the value of making meaning (not only finding solutions) in the practices of sustainable living.

2.2 Waste and HCI

Mirroring questions of sustainability 'in' and 'through' design [56], HCI research has addressed waste as a concern for both design processes and interventions. While the sustainability of design processes [8] is a large concern for its foundations [25, 44], designing for waste has been a prevalent research approach. Studies of e-waste workers [72] and of making in low-income communities [86] have outlined the ways resourcefulness, along with care and maintenance, can have implications in designing technologies for sustainable practices. Relatedly, recent work has explored how waste and left-over materials can be re-purposed in new contexts [25], or how e-waste can be creatively re-used in design [44].

A dominant line of work within HCI has explored the role of technologies in supporting waste practices. An early example is BinCam [82], designed to motivate change in waste management habits through negative reinforcement, reflection and social influence. Studies of BinCam [23] have shown that sharing images of waste on social media caused feelings of shame, with participants experiencing tensions between their attitudes and actual recycling behaviours. As much of the practices of waste management are habitual, rather than rational, this technological intervention became disruptive of old habits instead of enabling new ones. More recently, Møberg Jacobsen and colleagues [43] have studied the use of Waste Wizard, an automatic waste sorting bin using machine learning to classify and sort waste in public places. Another example includes the application Close-the-Loop [16], which uses iBeacon technology to help people recycle correctly. The study has illustrated that convenience can override people's concerns for sustainability, that knowledge about proper recycling is often limited, and that the needed infrastructure is not always easily accessible.

Outside HCI, work on the sociology of waste has characterised waste management in urban spaces as a complex social process [15, 36], involving multiple actors and stakeholders – e.g., from single citizens to waste operators – diverse expertise, knowledge, and multiple physical infrastructures – i.e., from home recycling to urban sorting facilities. Sociological investigations have focused on the social construction of waste [37], on micro-level practices, such as waste work [71] and practices of reuse [64], or on macro analyses of waste governance and politics [36].

To sum up, HCI research has explored digital technologies to support sorting practices, or persuade people to change them. We see this as reflecting a concern for sustainability-through-design, rather than (re)scoping research. While attempting to reshape the broader design process (i.e., [44]), these studies emphasise the work of single individuals, but overlook the role of institutions, organisations, and context-specific factors in shaping waste practices.

2.3 Environmental Stewardship

Environmental stewardship has recently become a central concept in ecosystem research that aims at fostering social-ecological sustainability [32]. At the core of this notion lies a focus on providing social groups with instruments to improve the resilience of our social-ecological lifeworld. The notion is associated with a shift away from techno-managerial, centralised processes of environmental management, towards more participatory, multi-party forms of engagement, where social and environmental benefits are equally important [31, 88]. Scholarship [46] has characterised environmental stewardship as a set of civic practices, while outlining stewards' capacity to develop relationships with third parties (e.g., governmental agencies, NGOs, private organisations), and to contribute to the well-being of the environment, communities and individuals. Research has shown [5, 18, 19, 32, 46] that practices of stewardship often occur among informal networks of individuals that value collaboration, trust, and the social impact of their actions (e.g., sense of community), rather than mere economic benefits.

Research within environmental studies has described the multifaceted nature of stewardship. Peçanha Enqvist et al., [66], for instance, have identified *care*, *knowledge*, and *agency* as central dimensions of stewardship. Care refers to the feelings of attachment and responsibility towards ecosystems, which can include values, ideals, and moral attitudes towards the environment [20]. Care can be connected to either values or principles stemming from particular relationships, or articulated by policies and social norms [17]. Knowledge betokens the variety of information about the ecosystem resources that are being protected. Related understandings might come from scientific sources [42], indigenous knowledge [81], practical experience [24], or collective, place-related memories [2]. Agency relates to the capacities of individuals, organisations, and collectives to protect the environment and/or manage common-pool resources [65]. It can be connected to grassroots initiatives and innovation [59], or to the more structural, political power to protect the environment [12].

An important feature of environmental stewardship, with relevance to debates in Sustainable HCI [13], is the move away from a paternalistic ethics of sustainability. The concept entails an ethical stance on agency and self-determination, rather than a moral and paternalistic assessment of the performance of particular ways of sustainable living. The relational production of action, when that action is framed as care, allows us to investigate the situated configurations, rather than the prescriptions of how that action should be (see [70]). As such, environmental stewardship is often characterised by diverse acts of care for the environment [32], such as creating protected areas, monitoring air or water quality, replanting trees and limiting harvests, creating community gardens, or organising neighbourhood clean-ups. [5, 32, 89]. Just like acts of care [70], stewardship actions connect to everything that is done to maintain, continue, and repair the world. Expressing both the work and relations of care as active components, environmental stewardship aligns with the radical democratic perspectives in HCI on the active role of citizens in creating ownership and responsibility for their own ecological relations [41]. However, as shown by research on wildlife conservation [28] and environmental care [69], the work and technologies of care are not neutral nor always benign. In documenting the care work of conservation for endangered Whooping Cranes, van Dooren [28] has highlighted the strain between care for a species and the violence of care (e.g., captivity, and artificial insemination of individual birds). This points to concerns to be

explicit about how environmental care is performed, who might benefit from it, and what tensions it might create [11].

Environmental stewardship foregrounds analytical and interventional concerns that well resonate with the ambitions of sustainable HCI. Echoing work on publics and digital civics [50, 85], stewardship actions generally involve multi-stakeholder partnerships, and acknowledge the power of grassroots initiatives, and their co-operation with local institutions, to organise acts of care for the environment. Stewardship interventions are concerned with local practices and actors [5, 19], which directly connects to HCI commitments to understand specific sites of design. Environmental Stewardship allows us to attend to the relational production of sustainable actions, and to ecologically frame technological interventions beyond ideals of persuasion. With this in mind, we now introduce the framework of environmental stewardship we use for the analysis of our cases.

2.3.1 Articulating environmental stewardship. Concerned with outlining what different definitions and empirical accounts of stewardship have in common, Bennett and colleagues [5] have identified *actors*, *capacity to act* and *motivations* as the three aspects that are shared by many *stewardship actions* (Figure 1). As they note [5], *stewardship actions* are the variety of approaches, activities, behaviours, and technologies that are applied to protect, restore or sustainably use the environment. Actions can be taken collectively by public agencies, civil society organisations, funding bodies, NGOs, individual citizens, or grassroots communities. They can emerge informally or through formal decision-making processes. *Capacity to act* [5] relates to the stewards' role to protect specific resources. It can be shaped by factors such as local governance, and it encompasses the variety of assets available for organising action. This includes, for instance, the social capital (formal and informal relationships between people and institutions), the cultural capital (processes of connections to place, along with knowledge and context-specific practices), the financial capital (the economic resources available), the physical capital (available technologies and infrastructures), the human capital (skills, past experience, education, and knowledge), and the institutional capital (laws and political interventions shaping stewardship actions). *Motivations* [5] entail the reasons that different actors might have to engage in environmental care. In section 4, we expand on the analytical relevance of this framework for the purposes of this paper.

3 ILLUSTRATIVE CASES

To unpack the analytical and design potential of environmental stewardship within HCI, we draw on three examples that illustrate how stewardship actions for waste management are infrastructured in practice, through partnerships, dedicated events, and varying sociotechnical configurations. Two of the selected cases are grassroots initiatives that seek to mitigate the environmental impact of waste. The other is an instance of formally structured, household-waste management in an urban area.

Plogga[1] is a movement combining jogging with litter picking-up activities. The term is a merger of the words 'plocka' ('to pick up', in the original language), and 'jogga' ('to jog'). 'Plogging' is generally carried out as a group activity, with people plogging together in areas such as parks, urban areas, or forest trails. *Litterati*[2] is a data-centred digital platform that supports the crowd-sourced documentation of litter collection. As stated on the dedicated website, the platform supports the creation of communities of environmental heroes connected by concerns to keep the environment free of litter. The last case is a housing community association (*samfällighetsförening* in the original language; plural: samfällighetsföreningar), which brings together five condominium associations (*Bostadsrättsförening* in the original language; plural: *bostadsrättsföreningar*)[3]. A samfällighetsförening typically manages areas shared among households, while a bostadsrättsförening is an economic association of residents through tenant-ownership of apartments. The two associations operate in many housing developments in Sweden, where it is common that multi-apartment buildings are managed by bostadsrättsföreningar. Becoming a member of a bostadsrättsförening is a requirement to own an apartment in these buildings. Both the samfällighetsförening and bostadsrättsförening are legal entities, run by board members periodically elected by residents. In our case, the samfällighetsförening manages a garage, a garden, and four, private recycling rooms.

In preparation for this article, we have, first, looked into different existing initiatives concerned with waste, and, then, purposely selected the ones above, in that the collective dimensions of managing waste were prominent and varied. Plogga shows a set of volunteer-run, loosely structured, stewardship actions concerned with waste removal that are easy to adopt across contexts. By contrast, Litterati illustrates the role of a digital platform and waste data in structuring actions and collaborations to collect other people's litter. The samfällighetsförening case betokens the work of a formal organisation to manage household waste in shared areas. It has been chosen as it outlines the middle-level work of this organisation, where interactions with residents, and formal actors (e.g., property developers, waste management providers) intersect. We do not regard the cases as complete representations of environmental stewardship, yet as sufficiently complex and coherent to help articulate a framework of digital environmental stewardship.

4 ANALYTICAL APPROACH

The analysis draws on the framework of environmental stewardship elaborated by Bennett and colleagues [5]. The framework provides a vocabulary and a relational perspective to systematically unpack how the selected cases promote, or neglect, processes of care for the environment, in both private and public spaces. The framework has been selected among others (see [19, 66]) as it resonates with key concerns for practices, and relational approaches within sustainable HCI. It highlights the role of multiple actors in organising environmentally-focused interventions, and how these actors' possibility to act and co-operate is shaped by their motivations,

[1] https://www.plogga.se/en/vi-ar-plogga/

[2] https://www.litterati.org

[3] Echoing efforts encouraging the use of context-sensitive concepts in the generalisation of research outcomes [60], we use the original Swedish terms, samfällighetsförening and bostadsrättsförening, to avoid the ambiguity introduced by the English translation. The two terms roughly translate into neighbourhood/housing community association and condominium associations, respectively.

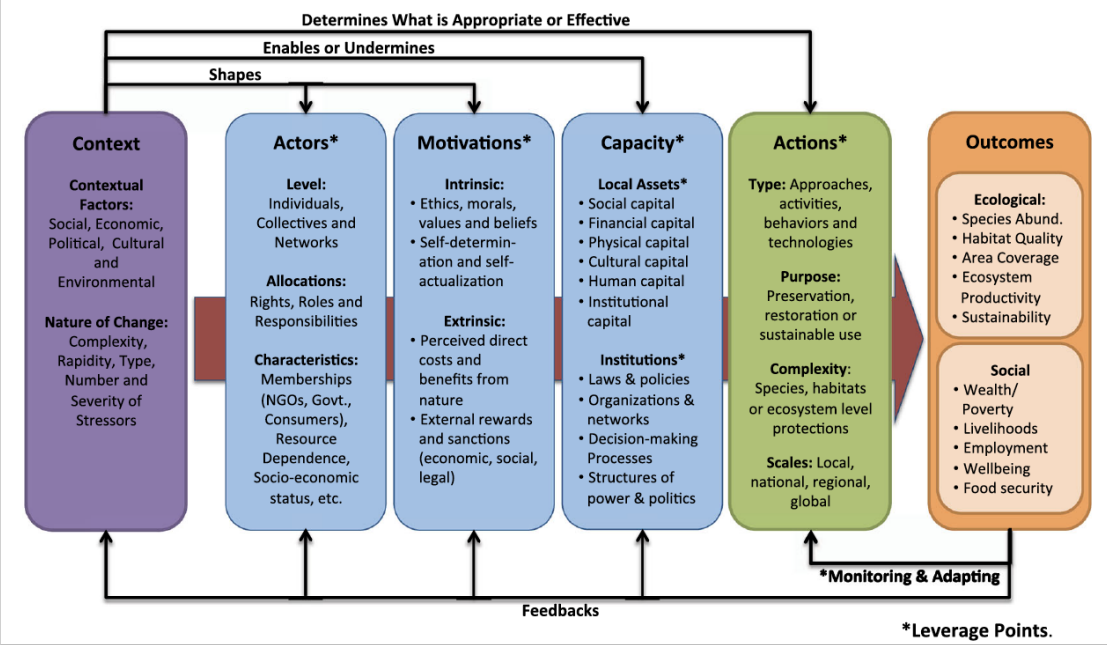

Figure 1: The framework of environmental stewardship as visualised by Bennett and colleagues [5]. The image is reproduced under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/).

available capacities, and various systemic aspects – e.g., regulations, governance, physical infrastructures, formal role of organisations.

The analysis is theory-driven, and was carried out during bi-weekly meetings held from January to June 2021. During a first iteration, we outlined each initiative's key practices, and unpacked how they are organised through the work of key actors, and of any available sociotechnical setup. In the case of Litterati, we walked through key functionalities and features of the platform. This was instrumental to reflect on the values that are embedded in its design, and on the narratives that frame its use. Both for Litteart and Plogga, we used online documentation – both written and video materials – as a means to understand how waste-picking events are organised, what forms of participation are expected, who is generally involved, and how motivations to take part are defined and promoted – e.g. through available documentation.

During a second phase, we collaboratively mapped the preliminary analysis to the main dimensions of the environmental stewardship framework (see Figure 1). As the contexts and technologies within them differ greatly, the data supporting the analysis is also varied. For Litterati, we have also examined secondary data available on the platform's website, including videos and written documents. Our primary goal has been to understand how the platform and the waste data generated are supposed to work, and what type of narratives promote the use of this technology. In the Plogga case, we have drawn on information available on the website, including shared documents. To better understand key aspects of the initiative (e.g., the role of ambassadors), we have reached out to the founder of the association and some of its board members who have clarified our questions through emails and face-to-face conversations. For the samfällighetsförening, the analysis is based on informal conversations with residents, and on observations of the activities, and interactions in the Facebook group.

Although our analysis illustrates all the dimensions included in the framework, we acknowledge the partial worldview presented in the data, and do not make claims about its comprehensiveness. We use this data to illustrate the potential of the analytic framework, while calling for empirical studies that investigate the situated articulation of stewardship along the outlined dimensions.

4.1 Reflections on ethics and positionality

This research did not require formal ethical approval under the local context of ethical practice for research involving humans. Nonetheless, the data collection throughout has been guided by values shared with the stewardship model of relationality, ethics, and care. We have sought to connect and understand individual actions, including utterances, designed artefacts, and social processes, in the ecology of relations in which they were produced. This involves paying attention not to the 'oughtness' of those actions, but to the ways in which they are produced and performed. For instance, when residents in the case of the samfällighetsförening might place responsibility on other actors for improper waste management, we are not concerned with the correctness of the statement, but with how such a statement can be made and understood within the ecology of waste management. We have sought to position ourselves within that relationality, and understand our own power to reproduce (or not) certain types of data.

Our focus has been sited by bounded systems and organisations. However, although they play a role in local waste management,

we have not, for the purposes of this paper, directly interviewed those handling waste for third-party contractors at landfill sites, or responsible for macro-managing waste (e.g., city managers). We have excluded directly quoting participants, as the cross-case study decontextualises the meaning for their interactions with us. Data collection, as in the cases of conversations with the Plogga co-founders and participation in the samfällighetsförening, was mutually beneficial – e.g., creating knowledge about Plogga and funding opportunities with the organisation, and developing responsibility and knowledge within the samfällighetsförening. In all cases, we were open about our relationships to the research context, the goals of the research, and the use of any data collected. None of the authors had previously taken part in Plogga or used Litterati. In the case of the samfällighetsförening, the first author's direct experience as a member provided preliminary insights of key problems and tensions around waste in this setting, and of several attempts made to address them. This knowledge was central to frame more in-depth conversations with residents, and one member of the samfällighetsförening's board. Being a member of one of the bostadsförening, the first author had access to the Facebook group we discuss in this paper. All the residents we talked to were aware of the first author's involvement in a research project, and that the conversations were instrumental to this work.

5 ANALYSIS

Below, we examine the key stewardship actions that our cases foreground. We, first, unravel the role of the main actors involved, the capacities to act they draw on, and the motivations underlying their actions. We conclude the analysis by illustrating the outcomes stemming from these different actions concerned with waste removal. The structure of the analysis is motivated by a concern to examine the three cases, and to systematically compare them.

5.1 Local stewardship actions for waste management

This first section shows how waste-centred stewardship actions can be, more or less, loosely planned and coordinated, and interwoven with other activities people engage with. *Plogging* is usually carried out as a group activity, as people meet and 'go plogging' in particular urban or non-urban areas – spanning from local neighbourhoods to nature reserves. Plogging combines environmental concerns - i.e., mitigating the negative impact of wrongly disposed of waste - with health concerns, and interests in recreational sports. Care for the environment and self-care are, thus, interwoven through plogging, which makes this form of engagement a stewardship action. On an individual level, plogging is simple to understand and practice, in that it does not require specific skills or equipment. While the Plogga association centrally coordinates plogging events, it is possible for anyone to self-organise plogging groups that might exist only for the time of a run. Long-term participation and involvement are, thus, not required unless one wishes to do so. Central to plogging is that *litter picking activities are socially structured as collective events.* As summarised in the organisation's online documentation, written to help spread the concept, plogging with others makes the activity more visible. Participants in plogga events are encouraged, yet not required, to talk to onlookers to explain their actions, and the motivations that move them. This form of social influence remains, however, a suggestion and ignoring it does not compromise the activity. Moreover, the collective dimension of plogging makes litter collection in public areas less awkward and embarrassing, as it (re)frames it from an individual – and maybe unconventional – activity to a participatory act of care.

Similarly, *Litterati* draws on people's voluntary initiative to collect waste in shared spaces. This is, however, mediated by a dedicated platform that enables everyone to document waste items by taking pictures that can, then, be uploaded and annotated with tags. Through tagging, each item is added to a data repository that stores information about the quantity and the characteristics (e.g., tin, glass, or cigarette butts) of all the collected waste items (Figure 2).

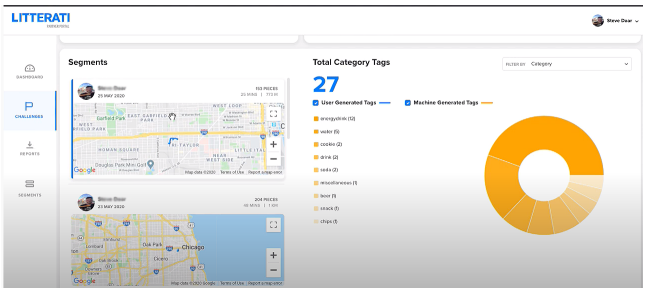

Figure 2: A report of the waste items collected by a single user in the Litterati app. On the left side, the map zooms in the area where waste has been collected. On the right, waste is categorised and quantified, based on user generated tags. From top to bottom: energy drink (12), water (5), cookie (2), drink (2), soda (2), miscellaneous (1), beer (1), snack (1), chips (1). The picture has been downloaded from https://litterati.org/tutorial-videos

Additionally, geo-location data is attached to each image, thus making available information about the type of litter found in specific areas. We characterise these sociotechnical practices to document litter as *itemisation of waste.* As we will expand in section 4.3, this way of documenting becomes a capacity building activity. For now, we emphasise that through itemisation, each waste item is added up to larger scale data collection, thus linking individual actions to a collective dimension of environmental impact. The aggregation of both quantitative (e.g., number of picked items) and qualitative data (e.g., type of items) links individual agency to collective actions and responsibilities towards waste. This point is summarised in the founder's statement[4]:

> "Individually you make a difference. Together we create an impact".

With Litterati actions of picking and documenting waste are locally bound. However the digital platform makes their outcomes, rather than their situated practices, globally visible. In contrast to Plogga, the design of the Litterati platform foregrounds sociotechnical practices like photography, (geo)tagging, documenting, and

[4]https://www.litterati.org/about

cataloguing. With this, local actions scale up not (only) through collaborative and co-sited activities, but through making the meta-data digitally available.

The *samfällighetsförening* is a more structured example of stewardship actions for handling waste, where a formal organisation manages the shared physical infrastructures, that is four recycling rooms, in multi-household buildings. The main goal of this form of stewardship is to make sure that these facilities can be easily used by local residents, that litter collection occurs regularly and in compliance with local standards and regulations. The waste work the samfällighetsförening is responsible for mostly unfolds at a macro level, and it entails connections to other infrastructures of waste management, such as waste transportation. Managing and maintaining the physical infrastructure entails negotiating and stipulating contracts with waste operators that work with litter collection. A central characteristic of this type of stewardship actions is the mediation of what is expected from the individual-local (i.e., household recycling) to what is required and possible at the collective-local (i.e., city, county). In this frame, residents are users of the local waste infrastructure, while the samfällighetsförening is responsible for providing residents with information about the recycling facilities. This means that while the first two cases promote narratives about citizens' individual and collective agencies in removing (others') waste, the role of the samfällighetsförening scopes waste management as a formal organisation's concerns to maintain common resources.

To sum up, although stewardship actions specifically aim at protecting social-ecological worlds, the manual labour of stewardship in waste management – that is, the act of picking up litter from the ground – can unfold through people's engagement in diverse activities – e.g., running, taking pictures, organising social events. Both Litterati and Plogga promote individual responsibilities from the bottom-up: cleaning local environments from other people's rubbish is a driving factor of these initiatives. The two cases draw attention to the processual aspects of protecting the environment as something we can all do, individually or in the company of others. In contrast, responsible waste management, organised through the work of a formal organisation, plays a central role in structuring macro aspects of waste disposal, but might configure people as mere users of the available infrastructure.

5.2 Actors and networks of stewards in waste management

Stewardship actions can be carried out by a variety of actors – both individual and collective – who can take up different roles, and become interconnected in networks of stewards. Outlining the relationships and attachments these actors develop with each other is critical to understand the different ways stewardship actions can emerge, and be configured.

Plogga organisers emphasise that, during plogging activities, everyone's contribution matters to reduce litter pollution and, contribute to thriving social spaces. As a registered organisation, Plogga has a board that includes its co-founders, and that plays a central role in promoting and arranging events nationally. In addition, the board actively seeks new partnerships with companies and other organisations. As visible in the Plogga's website, these efforts aim at building coalitions with other actors. Plogga relies on the work of ambassadors to expand and grow. These are people whose level of participation varies – from sporadic organisation of plogging events, to long-term commitment to hold seminars, tutor companies or public institutions on how to set up events. Ambassadors usually coordinate the practicalities of events, such as time and place, and promote central plogging values. Larger events are mostly created by the co-founders, often in connection to national or global sustainability initiatives – e.g., the global recycling day. At the time of writing, plogging has spread to over 100 countries across the world. From our conversations with key Plogga representatives, we know that most world-wide events are independently organised rather than centrally coordinated. These events are generally set up locally by organisers of running competitions, sustainability collectives, municipalities, local companies, or even hotels.

In *Litterati* actors are, first and foremost, single individuals using the app. The interface shows individual accounts, leaderboards and media, including promotional videos, that explain how to collect and document litter. Every user of Litterarti can either pick up waste items individually, or by joining a local challenge. Challenges are collective picking-litter events with specific missions (e.g., picking up a number of specific waste items in a specific area) to be accomplished within varying time frames. Participating in challenges creates an ephemeral network of individuals. Although the overall design of the platform is centred on narratives about the collective power of people, we can see little attempt to create long-term, cohesive communities, at least within the digital space of the platform. A significant prospect for Litterati to run coordinated cleanup efforts[5], and engage in long-term environmental waste stewardship comes from its collaborations with partners. These are collective actors, ranging from schools and municipalities to private companies and NGOs. As they promote cleanup initiatives and seek to attract an ever-growing number of participants, partners play a similar role to Plogga ambassadors. Here, however, the coordination of partnerships is structured through the dedicated platform.

In comparison to these two cases, the network of actors in the *samfällighetsförening* are more immediately complex, given the multiple intersecting organisations, and their different ways of participating in local processes of waste management. Firstly, the association has the main goal to manage the physical infrastructure for waste management for the five multi-apartment buildings, which are, in turn, owned and administrated by five bostadsrättsföreningar. The samfällighetsförening is run by board members, that is, residents who are periodically appointed. It can also happen that the same people are board members of both the samfällighetsförening and the bostadsrättsförening, although this is not formally required. At the time of writing, two of the board members in the samfällighetsförening are responsible to exclusively work with waste-related issues. From conversations with one of them, we know that they work with communicating best recycling practices to residents, which is mostly done by flyers placed in the recycling room. They are also concerned with spreading awareness about the additional costs associated with removing incorrectly disposed of waste, in that having bulky items removed (e.g., sofas, mattresses,

[5]https://www.litterati.org/partner-page-small-ngo

various home appliances) from the recycling rooms implies the acquisition of extra services. This information is generally communicated at member meetings, but these are often only attended by a minority of residents. Secondly, the company that built the apartment buildings and the recycling rooms is another central actor, as it is contracted by the bostadsrättsförening for administrative services, such as paying the bills for waste collection. In this specific case, and reflecting similar set ups across Sweden, residents pay a monthly fee to the bostadsrättsförening that goes via the building company. This fee covers different costs, including heating and waste collection. The company then pays the respective recipients, thus covering the collective expenses for the whole house. This marks a profound difference from cases where single households directly cover these costs – either to service providers or local municipalities. Thirdly, household members are also central actors of these waste practices. However, taking up stewardship roles that are more community-oriented seems to be problematic. We know, for instance, that a few residents do occasionally take a more active stance to clean up the recycling rooms (e.g., by washing the bins), talk to other residents to invite them to recycle properly, and bring incorrectly disposed items (e.g., electronics, small pieces of furniture) to the local, communal recycling centres. These cases are generally uncoordinated as people act on their own initiative and in their free time. They are also episodic, as long-term engagement is too demanding, and frustration and resentment can arise once recycling problems occur repeatedly after cleanups. While collecting others' litter is what Litterati and Plogga encourage people to do, this different context, with a bounded (or tiny) public [30, 78], where waste recycling is formally defined by a clearer division of work among the involved actors, makes this type of waste work more socially awkward. Residents who take on the informal role of waste stewards can be perceived as pushy, and the examples they set are not moved forward to other residents. Both the outcome (i.e., cleaner infrastructures) and impact of their actions are limited.

To summarise, both individual and collective actors are central to the three cases of stewardship in waste management, but with significant differences. Plogga and Litterati outline narratives of individual agency in acts of care for local environments. Both rely on well-defined roles to help enrol new actors, and spread litter-picking practices. The design of the Litterati platform does this through specific templates for participation (e.g., local and global challenges) that connect relevant actors under the umbrella of the digital platform, particularly the aggregated data about waste products. Both cases draw on the idea of an ever-changing –if not growing– ecology of actors that care for local waste removal, and sustainability more broadly. Relationships among actors, and attachments to issues of waste handling, propagate outwards as new people and/or organisations join these initiatives, and their environmental impact grows. In contrast, the formal organisation of waste handling in the samfällighetsförening reinforces a separation of responsibilities and roles that are not easily reconfigured.

5.3 The capacity to steward waste management

This section draws attention to the different capacities [5] – from personal resources to governance, from social to financial capital, or from cultural to physical capital – that the three cases rely on. Participation in *Plogga* is mostly voluntary, it does not involve any economic exchange, and neither does it require particular equipment – apart from bags for litter collection, and possibly a pair of gloves to protect from grease. The financial and physical resources needed to take part in events are, thus, minimal, and individual actions are inexpensive. With a small, voluntary membership fee, the Plogga association has limited economic resources to more formally set up events, or to develop any bespoke digital platform. Plogga relies on social capital – individual efforts, informal interpersonal relationships, and more formal collaborations – to spread its concept, practices, and grow. As events are run, the articulation of new collaborations can become a form of cultural capital, that is, connections to places and context-specific practices [5] that can be central to mobilise other stewardship actions. Similarly to other grassroots initiatives, Plogga uses a constellation of technologies [14, 74] which constitute part of its physical capital. Social media platforms like Facebook and Instagram are used to advertise events to the general public, and to spread awareness about mitigating the impact of waste in public areas. A website is also used to share important information about the movement, its visions, goals, and how plogging events can be organised. The website also contains information on the co-founders of Plogga, and on the past and present collaborations the organisations has been involved in. Two mobile apps – *Wastehunters* and *Go plogging* – developed independently from the Plogga association, can also be used to set up events and invite people to them.

In *Litterati* social assets such as formal and informal relationships are also central to practices of waste removal. The Litterati website contains a media repository, mostly video material of different Litterati initiatives, which is meant to show how the platform works in practice, how the data can be used, and to inspire other actors to use the platform, and work with the data. As Litterati users share their testimonies of waste removal, personal experiences of care for local places are circulated, possibly sensitising other people towards the problem. While Bennett et al.'s framework [5] characterises technology as a resource for stewardship, we see here its generative potential, and how it can, in turn, contribute to the creation of emergent capacities. The website also provides examples of how data can be used in different contexts, to further develop awareness about waste and environmental sustainability. Through the website, Litterati provides resources (human capital) for educators, including lesson plans, which can help educators fill requirements in topics – including science and nature, or sustainability.

Litterati LLC is a limited liability, for-profit company partly relying on financial capital. Sustaining Litterati's business model is seed funding from institutes, and the money that the enterprise makes from collaborations with other actors, such as corporations, schools, NGOs, and public institutes. These actors can, in fact, buy collective accounts –for a maximum of about 100 US Dollars– and use them for educational purposes. While the app is a central hub for coordinating litter picking, litter data are available on the dedicated website, where they can be compiled and displayed through dashboards. Partners have bespoke dashboards that collect, map and visualise data that are specific to them (e.g., top contributors, pieces of litter collected up to certain dates). Embedded in the design of the platform and the dashboards in the website is the vision that data can be used to mobilise other initiatives that also aim

at protecting local environments. Data can indicate attachments to specific places (cultural capital), become educational material (human capital), and support the creation of institutional capital. As noted on the website[6], data about discarded cigarette butts were used in court by a major US municipality to increase cigarette sales taxes, and use the revenue to keep the city clean.

The samfällighetsförening is defined by the shared ownership and management of land (e.g., gardens) and locales (e.g., garages, recycling rooms) connected to the apartment buildings. Its main responsibility to steward waste-related activities relies on social capital, particularly the formal network of relationships that define its main organisational goal to manage shared areas. Upholding this role connects to the physical infrastructure (physical capital) that is needed for proper recycling (i.e., recycling rooms and bins), and that the samfällighetsförening manages through formal contracts with waste operators. The type of waste being collected, and the frequency of pick-ups are, in fact, formally negotiated with local waste operators. The samfällighetsförening also plays a central, voluntary, role in providing additional recycling resources that might be needed (i.e., bins to collect batteries, light bulbs, and/or small electronics), but that are not included in the official contracts. This setup has been implemented to respond to the residents' emerging needs to dispose of these items, and the fact that many left them in the recycling rooms even if this was not allowed. However, responsibilities for emptying these additional bins remain unclear. The bins are not emptied unless board members take them to nearby recycling stations in their free time. This form of inaction persists despite the many residents who could potentially carry out these tasks, which can be read as the non-activation of this social capital rather than the lack of it. This point connects to issues related to the cultural capital of the bostadsförening, particularly with respect to what being a member entails, both in terms of responsibility and role. As members of a bostadsförening, residents do represent the bostadsförening, and have specific duties towards the organisation. Failing to recognise these responsibilities is a failure to recognise each individual's role and agency within the organisation.

When it comes to digital technology, another form of physical capacity in Bennett et al.'s framework [5], a Facebook group, administrated and maintained by the samfällighetsförening, is the main resource available for this type of waste stewardship. The group was created in August 2017, and it has currently 175 members, which is a small portion of the total number of residents in the five bostadsrättsföreningar. The Facebook group is private, but people requesting access are usually allowed, based on the assumptions that they live in one of the bostadsrättsföreningar. While the group is potentially open to any topic residents wish to bring up, most of the posts and conversations are about problems and tensions within the garbage facilities. Pictures about wrongly disposed of waste (e.g., various pieces of furniture, discarded clothes or china) are posted, together with complaints about the incident and the people responsible for it. In some extreme cases, pictures of cardboard boxes are taken, to directly point to any name and address shown on the box. Discussions about the extra costs involved in having these items removed are sometimes hard, but this information is often hidden in the threads of comments that follow posts. Since the samfällighetsförening does not have its own economic resources (financial capital), these costs are usually covered by the monthly fees that residents pay to the bostadsrättsförening (see section 5.2). Nevertheless, this complex network of relationships and economic resources is not visible to most residents. Overall, the Facebook group provides very little information to scaffold proper recycling practices, and most online actions are complaints rather than constructive suggestions of how problems could be solved. A main capacity that seems to lack here is the flow of information among the different actors. We know of an incident when a recycling room was not emptied for two weeks – as construction work was blocking the entrance for the waste collectors; neither the residents nor the bostadsrättsföreningar were aware of the reasons, while the street-level collectors failed to communicate the problem to the waste collection company they worked for.

5.4 Motivations for stewardship in waste management

While motivations to engage in waste-oriented stewardship can differ between the three cases, they show that environmental concerns are interwoven with other interests for taking part.

In *Plogga*, motivational aspects connected to clean up public areas are defined in relation to narratives about self-care and personal well-being. In the way the NGO presents itself to a broad audience, a strong emphasis is put on the environmental and health concerns that can make Plogga attractive to people. In the way Plogga is organised, motivations about long-term commitment and involvement are not required. The organisation seeks to achieve impact through the proliferation of Plogga events, rather than reoccurring participation over time, which we see as a reason for its popularity. People may join, or decide to organise an event, to try out a new form of exercise, contribute to cleaning their local environment, or to meet (like-minded) people.

In the case of *Litterati*, downloading the app and owning a smart phone are the only requirements to use the app, which constitutes a low threshold for single persons wishing to participate. On the other hand, as described in the online documentation, collective actors such as educators, might be motivated to use Litterati to reduce the workload, create an interactive and engaging exercise, and to do so alongside showing students the possibilities to collectively create change. For cities, Litterati provides two bespoke dashboards: the Resident Engagement Platform (REP), and the Municipal Assessment Platform (MAP). While there may be intrinsic motivations for city representatives to engage citizens in waste pickup, Litterati attaches REP and MAP to an overarching motivation for cities to develop smart services[7], and to meet requirements set out by the Environmental protection Agency (e.g., sustainability education, addressing sustainability issues). The adoption of specific features can, thus, be determined by overarching political objectives. The website [8] promotes the use of Litterati as a means for municipalities to engage citizens, and to monitor the corporations that are responsible and accountable for polluting urban areas.

In the case of the *samfällighetsförening*, the motivations to keep the shared areas free of waste are mostly determined extrinsically,

[6]https://www.litterati.org/stories/san-francisco-leverages-litterati-to-generate-4m

[7]https://litterati.org/smart-city-litter-and-waste

[8]https://city.litterati.org

by the role of the organisation. A main concern is the balance between costs (mostly economic) and benefits, and the extent to which recycling rooms are well maintained, both from the top, through waste operators, and the bottom-up, through proper waste recycling practices. This does not mean that board members are only moved by concerns for efficient and effective waste flow; they might also be driven by a genuine care for residents, and for upholding good neighbour relationships. As noted in 5.3, while we have noticed that a few residents occasionally take the initiative to clean up the recycling rooms, this commitment is unsurprisingly difficult to maintain. Limited time and capacity, or simply annoyance at others, might explain why these actions often fade away.

5.5 Stewardship outcomes in waste management

For *Plogga*, a direct outcome of litter picking is, at the simplest level, cleaner environments. As promoted by the organisation, self-actualisation and the physical well-being are also central aspects stemming from plogging. On the website and in other available documentation, it is common to find references to 'the broken windows theory'. While it is beyond our purposes to assess the empirical validity of this theory, here we note the emphasis it puts on the relations between environmental and social outcomes: a cleaner environment contributes to social cohesion and collective well-being. Care for both the environment and others are interwoven in the effects that stem from plogging. While this practice only mitigates litter problems, its global proliferation indicates an increased engagement with waste issue, and a growing awareness of the shared responsibilities in addressing them.

In *Litterati*, by photographing and tagging litter, waste data is created. Data is, thus, a main outcome associated with the use of the platform. Specifically embedded in the design of this platform is the idea that waste data is a multifaceted form of capital. The aggregation of data can, in fact, be used by other actors, to raise awareness, structure educational purposes, or to call for governance changes. The design of the platform, and the narratives promoting its use, are based on the very idea that outcomes of waste stewardship can be appropriated by other environmentally concerned interventions.

A main outcome of the actions taken by the *samfällighetsförening* is the flow of waste from households to communal recycling facilities, through the intervention of local waste operators, and the participation of local residents. An interesting aspect we see here is the emergence of intermediate outcomes, for instance, actions that are taken to contend with emerging problems. Residents' complaints have resulted, over the last year, in the revision of the contract with some waste companies to allow more frequent pickup of certain type waste (e.g., glass, cardboard, metal).

6 TOWARDS DIGITAL ENVIRONMENTAL STEWARDSHIP

The framework of environmental stewardship contextualises local environmental actions in its ecological relations. Where prior frameworks within sustainable HCI have been criticised for overly abstracting and simplifying sustainable actions, by focusing on individual behaviours and cognition [13, 55], the environmental stewardship framework provides a lens to attend to constituent parts of local sustainable action, while emphasising their mutual interactions. This develops understandings of what happens *on the ground* within communities where care is central [6, 7, 75, 84].

Environmental stewardship is an analytic frame, not a state of being to aim for nor a prescription of what sustainable actions are, or should be. Thinking with environmental stewardship helps answer questions such as: *'What does this action do and where does it come from?'*. In this light, the analysis has illustrated the ways stewardship interventions for waste management are enabled or constrained, rather than evaluating their qualities. In the samfällighetsförening, some people *seem* not to care about wrongly disposed of waste. However, through the framework, this aspect can be understood in terms of actors lacking capacities and opportunities to act, or failing to understand the different resources, roles, and responsibilities at stake. Frustration with inaction (e.g., not removing discarded items, failing to communicate information about proper recycling) is a form of care, but in the Facebook page it has no outlet in action.

Although oriented towards action, the stewardship framework unravels the production of action, and not just its enactments. This involves *'Seeing What Is and What Can Be'* in sustainable action [9], and how design comes to matter in the ecology of that action. We can see, through our cases, that the relational perspective and the action-orientation of a stewardship framing highlight an accumulation of resources – including relations, actors, motivations and capacities – in the production of collective actions. *We tune in to 'action' and see how it comes into being.* Attending to action reveals the ecologies of interaction, practices and resources that produce that *certain form* of action and outcome.

With its relational perspective towards action, environmental stewardship affords us, for analytic *but also* generative purposes, including the potential to identify inactions and its systemic roots (beyond behavioural motivations), and to consider interventions addressing them. As the analysis of the samfällighetsförening suggests, a *capacity gap* is part of the problem, with most residents being unaware of the economic costs involved in discarding bulky items and of the alternative physical infrastructures that could be used for proper recycling (e.g., mobile recycling tracks or nearby recycling stations, retail stores that collect old electronics). This is also a gap in the information and knowledge that could help residents, and the organisation alike, to better handle life transitions in this setting (e.g., moving to a new home, or remodelling the kitchen). While acts of care for the environment might not happen unless people feel strongly about something [18], we suggest that considering gaps in the relationships between actors, relevant capacities, and motivations, can help understand what enables, or hinders, waste-focused stewardship actions, and what specific practices are afforded or excluded. We write this at a time, when gig-work platforms like TipTapp are challenging the legislation and the role of municipalities in macro-managing waste [1], while outlining gaps in both the physical infrastructure of waste and waste governance.

Throughout the paper, we have presented environmental stewardship, illustrated its analytic relevance, and outlined how it can re-orient understandings of initiatives concerned with waste management. In what follows, and connecting to a focus on situated practices and technology design, we further unpack its relevance for HCI research. We propose *'Digital Environmental Stewardship'*

Table 1: An overview of the analysis of the three cases

	Plogga	Litterati	Samfällighet
Actors	- Individual 'ploggers' - Ambassadors - External event organisers - Partner organisations	- Single Individuals - Public institutions - Third-party partners	- Residents - Bostadsrättsföreningar - Board members - Building company - Waste operators
Actions	- Picking up others' litter - Organising and coordinating events - Physical exercising - Gaining visibility	- Documenting and tagging waste - Creating waste metadata - Developing collaborations - Advocating for governance change - Supporting various sustainability programs	- Managing physical infrastructures - Interacting with waste operators and residents - Mediating the individual-local and the collective-local - Informing about recycling practices - Facilitating waste flow
Motivations	- Low threshold to participate - No need for long-term commitment - Encountering others - Personal well-being - Attachments to places - Promoting sustainability initiatives	- Low threshold to participate - No need for long-term commitment - Commitment to cleaner environments - Adhering to local sustainability requirements - Promoting citizens' initiatives	- Balancing economic means - Alignment with formal goals - Problem-solving - Thriving social places
Capacity	- Limited economic resources - Limited physical resources - Social assets - Formal and informal relationships - Physical labour - Constellations of digital technologies	- Waste data items - Waste metadata - Dashboards and data reports - Media repository - Impact stories - Account fees - External funding	- Local waste infrastructure - Right to stipulate contracts with waste operators - Local waste governance and regulations - Sporadic individual initiatives - A Facebook group
Outcomes	- Cleaner local environment - Waste and sustainability awareness - (Re)framing litter picking - Individual well-being - Personal connections to places	- Waste data - Waste media - Cleaner environments - Waste and sustainability awareness - Personal connections to places	- Maintaining physical infrastructures - Maintaining waste flow - Shared responsibility
Role of the digital	- Advertising and organising events - Helping spread core practices - Providing documentation	- Documenting waste - Developing waste awareness - Creating data repositories	- Sharing problems and solutions - Occasional communication

as a framework to investigate the role of digital technologies in structuring stewardship interventions within specific sites of design. We introduce the concept of 'folding in actions', articulate the role of the digital in configuring environmental care, and discuss what designing with digital environmental stewardship can entail.

6.1 Folding in actions

As a first step to unravel how digital environmental stewardship can scope analyses and designs concerned with sustainability, we introduce the notion of *'folding in actions'*. We use it to emphasise that digitally-mediated stewardship actions should be framed as additive, interconnected, and transformative. As such, their potential to shape more sustainable futures can be considered through the interconnections they develop with each other, for instance, as their outcomes circulate locally, or become capacity to organise other initiatives [3, 73]. In Bennett et al.'s [5] original framework (Figure 1), stewardship actions produce various forms of outcomes, and relationships between outcomes and actions are characterised through processes of monitoring and adaptation. Within digital environmental stewardship, we consider folding in actions as stemming from the very outcomes that are generated. For instance, in Litterati, the creation and curation of waste data through the app and the online dashboards open up to further stewardship interventions, as data can be become physical capital to be used in court cases, or human capital to be used as educational material. The notion of folding in action helps investigate how outcomes circulate and are transformed into capacities for other actions. In the samfällighetsförening case, the numerous residents' complaints have resulted in an upgrade of the contracts with waste operators, but also in the provision of better information about proper recycling. Designing for 'folding in actions' entails considerations of how interventions in such settings could generate awareness about possible causes of problems and, thus, enable further actions addressing them.

Considering folding in actions as *additive* entails sociotechnical explorations oriented towards questions of *'what else'* and *'what next'*, which are inherently open towards more transformations, and actions. We can move on to the next step, because we have done something already. This, we argue, creates pathways to action, beyond mechanistic production of behavioural changes. Each route, or action, need not be digital. There is a clear necessity for waste actions, from picking up waste items to promoting an initiative (e.g., the work of Plogga ambassadors) to be 'in the world'. Resonating with other work [73], inter-connections between stewardship actions can emerge as people move between organisations, share their experiences across projects, or as interests in specific matters of concern circulate locally. In this sense, folding in actions makes

visible how networks of stewards are created, and continuously configured, around shared concerns for sustainability. This marks another difference from the original formulation of the framework that implicitly assumes the involvement of specific actors to activate stewardship. Relatedly, this notion helps see the dynamics of relationships between actors, their motivations, and capacity to act [5]. Whereas in Litterati picking up waste items can be determined by practical and affective motivations of caring for the environment, considering waste data as a capacity connects to 'higher orders' waste interventions (e.g., redefining waste governance) where municipalities are key actors. Here, capacity grows from the social capital of individual actions and the institutional capital of public actors, while propagating through different contexts for action and infrastructures. Furthermore, if actors that participate – even peripherally – in local, sustainable actions can see the 'bigger picture' of relationships, they may derive more meanings and motivations to continue. This can be particularly relevant in designing for settings, like the samfällighetsförening, where inaction is a concern.

Prior critiques in sustainable HCI have shown how interventions have typically been abstracted [13, 45, 54] - for instance, focusing on one behaviour only - or too short in duration [40]. Considering folding in actions as a constituent aspect of digital environmental stewardship allows us to consider how specific interventions might connect and propagate across contexts and over time. This is a commitment to understand the long-term, even if piecemeal, impact of design interventions for more sustainable living. Resonating with other work [27], this point emphasises the importance of considering small-scale interrelated projects in addressing global sustainability challenges, and the scale of effects [29] in inter-connecting stewardship actions; not merely by replicating specific interventions, but by considering what processes travel, and how they can mobilise different, yet related, initiatives (see, for instance [48]).

6.2 Unpacking the digital in environmental stewardship

While widely used to analyse forms of infrastructures, the conceptualisation of digital technology within existing frameworks of stewardship (see [5]) treats it as a static and given form of physical capital. However, although we might regard technology as merely a capacity (which is either available or not), we can also see it as part of the social fabric of local action; it can provide actionable means for creating new communities of stewards – not just enabling existing ones – mobilising other resources and/or actions to protect the environment. By proposing a concept of 'Digital Environmental Stewardship', we frame technology as a dynamic capacity constitutive of –and not merely given to– the different dimensions of stewardship actions. As noted, these actions can be technology-mediated, such data collation in Litterati, digitally coordinated and advertised, as is the case of Plogga, or surfacing the articulation of needs and the absence of capacity, as is the case of the samfällighetsförening. With reference to Figure 1, we see digital technology as configuring individual and collective actors (e.g., creating communities of environmental heroes as in Litterati), motivations to act (e.g., joining Plogga events), but also failing to frame the cultural capital of the samfällighetsförening (e.g., member-residents form the organisation). Digital environmental stewardship *re-centres* the role of digital technology through a set of mutually constitutive relationships between the dimensions of stewardship discussed in the analysis. In what follows, we further this point by outlining: *i)* the enabling role of technology, *ii)* its political qualities, and *iii)* the tension between the local qualities of stewardship and the impact it can generate.

Firstly, one main capacity of digital technology is to record and (re)produce actions. This is most clearly articulated in Litterati, where taking a photograph of rubbish is connected upwards to possible changes in policy and legislation. These actions might be valued as a form of personal documentation, or they might not be meaningful and engaging at all, but they are given meaning in the accumulation of data together with other people, and in the way data is compiled through the technology. In contrast, for Plogga, digital technology serves mostly to gain visibility among broad audiences, record, and disseminate content about the events that are organised. Yet, this specific use can also be understood as creating social assets [3], a means to attract people and form new partnerships. It can also be seen as a space for storytelling [57], promoting cultural capital (e.g., attachments to places), and developing narratives about each person's agency in repairing the environment. This point is relevant, as the way people interface with (urban) infrastructures is not only based on digital literacies, but also on the social imaginaries that digital technologies contribute to create (see [38, 41]).

Secondly, while stewardship actions are tethered to, and defined by, wider sociopolitical contexts, digital technology itself is political. It has the capacity to enable or inhibit opportunities to connect and act, to make visible or invisible ecological relations and issues, and, as noted elsewhere [75], to promote –or inhibit– contextual relationships of care. As a lens onto this politics, the digital component of environmental stewardship draws attention to varying *configurations of the configuration* of digital and non-digital interactions, and of the ways stewardship actions may vary across contexts and settings. These configurations might be radically different, depending on how technologies are used and appropriated across contexts, requiring closer consideration of the technological context from the outset (see 'Context' in Figure 1). In Litterati, centrally coordinating competitions and collaborations with other organisations, will still require "invisible" articulation work [77], which might be difficult to capture through design. Moreover, the creation of waste data, and the digital processes of cataloguing it, become political actions. Not only do they highlight matters of concern [49], they are abstracted to imaginaries of legal proceedings, policy, and regulation. There is a need here to examine possible reconfigurations of individual agency in engaging with further stewardship, as environmental actions 'move up' to organisations. This also calls for investigations of whether the itemisation and datafication of environmental concerns in Litterati may result in techno-deterministic narratives on the central role of software in stewardship actions. Plogga, in comparison, uses social media platforms to advertise events. Here, different actors' capacity is (re)defined by fleeting togetherness as a norm-disruptive action to pick up others' waste. The Facebook page of the samfällighetsförening is, against this, mainly an outlet for sharing problems. It is not inclusive, with only a few members compared to the number of residents, and it is not a place where

'positive' actions are initiated. Attempts to address problems (e.g., providing information on recycling) still occur outside this channel.

Thirdly, the role of the digital connects to tensions between the boundedness of the 'local' of stewardship actions and issues of the scale and site of impact. In Plogga, technology promotes a global appropriation of waste stewardship, through the proliferation of local events, rather than the replication of digital templates for participating in them. This leaves room for appropriating and adapting this form of stewardship across contexts, though it reduces a branded ownership from the Plogga organisation. In Litterati, concrete actions to pick up litter are locally bound, but the development of environmental stewardship is tied to the notion of scaling up data, from individual action to aggregated datasets, and shifting scale of responsibility, from the individual to organisations. This is particularly visible in impact studies of cities. Yet, questions remain on the global relevance of the waste data. Beyond issues of awareness raising, it is crucial to understand the extent to which such data aggregation can mobilise actions across contexts and reconfigure the actors and motivations of stewardship beyond the local. Unlike in Figure 1, we suggest that the outcomes and records of impact have capacity to not only 'feedback' to actors, but to spread out from them and the 'local'.

6.3 Designing with digital environmental stewardship

Environmental stewardship is concerned, at its core, with the protection of our world [4]. Adopting a digital environmental stewardship framework is a commitment to consider sustainability as a foundational imperative of design [9], both epistemologically and methodologically. The framework takes attention away from technological solutionism, and the atomisation of our being and acting in the world, towards the complex ecology of relationships that constitutes sustainable actions. That is, digital environmental stewardship as a framework provides us with analytic dimensions to understand what is happening when care for the environment is happening, but this 'happening' is a continual shifting configuration that is both historical and generative of future happenings.

The framework can be useful for designers, grassroots initiatives, and organisations to examine the inter-dependencies between core aspects of stewardship actions and how their transformative potential can be constituted through digital technology. Digital environmental stewardship provides a structured lens to reflect on different sociotechnical configurations of stewardship actions, explorations of how they can fold into each other, and of the role of digital technologies in enabling them. Complementing the analytical purposes illustrated in this paper, we can imagine the use of the framework to structure data collection through interviews and focus groups, or design activities aimed at the generation of both low and high-fidelity prototypes. The framework has the potential to establish a common ground on which to base discussions among different actors and stakeholders. Artefacts, such as vignettes, scenarios, personas, or mock-ups, can be designed to emphasise the relational and ecological qualities of stewardship actions, to identify where possible breakdowns and capacity gaps might occur, and where digitally mediated actions can fail, or succeed. We can think, for instance, of how capacities (e.g., laws and regulation) or stewardship outcomes (e.g., the Litterati datasets) could be used as design materials to envision more sustainable futures.

Stewardship interventions are context-specific, concerned with local practices, and the role of (pre)existing institutions. This echoes concerns to understand what already goes on locally [9], and the situated production of sustainable actions [61]. The framing challenges the idea that design projects are the "beginning" of interventions aimed at social change, and it acknowledges the questions and concerns that local communities might *already* have [73]. Drawing attention to the practical doings of care work, and turning away from moral, predefined abstractions of care [68, 70] acknowledges the diverse agencies at stake (both human and non-human) in stewardship actions, yet recognising them as equally important, both in the role to care for and to be cared for. Designing from within an ecological perspective enables reflections on how specific sociotechnical configurations of stewardship can be moved across contexts. Taking pictures of wrongly disposed of waste is at the core of Litterati. However, it would probably not be the most suitable action in the samfällighetsförening, where it could raise surveillance issues associated with revealing (to broad audiences) residents' addresses and identities. This resonates with scholarship arguing that acts and technologies of care are not always (and only) benign [11, 28], and with concerns to specify how care for the environment is done, and whom it is beneficial for. Connecting to HCI research, we see potential here to explore possible anti-design [75], that is, sociotechincal configurations that, although envisioned to support care practices, have instead the potential to disrupt or neglect acts of care. The relational orientation of the framework lends itself to careful considerations of potentially negative impact of design interventions, and to reflections on the relationships that are endorsed (or disregarded) in technology-mediated forms of stewardship.

7 CONCLUSIONS

This paper has introduced digital environmental stewardship as a framework for sustainable HCI to examine and design sociotechnical interventions concerned with care for the environment. Drawing on literature from environmental studies [5, 19, 46, 66], we have outlined key dimensions of stewardship interventions, and applied them to the analysis of three cases concerned with waste management. Responding to ongoing concerns within sustainable HCI, the framework contextualises local environmental actions in its ecological relations; this overcomes limitations that have been associated with a narrow focus on individual behaviours and cognition [13, 55], and with short-term engagement with research sites [40].

Characterising stewardship actions as emerging configurations of interconnected actors, multiple capacities to act, and varying motivations, we have shown that the framework can help discuss the systemic roots of inaction. Furthermore, we have argued that an orientation to action, embedded in an ecological and relational perspective, helps unravel how actions come to be, rather than merely evaluate them and their consequences. We suggest the notion of "folding in actions" to emphasise that, within the framework of digital environmental stewardship, actions can be understood as interconnected, additive, and potentially generative of other forms of stewardship. We see the folding in of stewardship actions

as responding to the need to create meaningful interactions towards sustainability, rather than merely solving problems through design [52]. While conceptualisations of stewardship within environmental studies regard technology as a static resource, the digital environmental stewardship framework re-centres its relevance. We discuss this in three points: the routes to actions that technologies enable, the relations of care for the environment they promote or disrupt, and the tensions between local stewardship practices and their global relevance. We argue that a framework of digital environmental stewardship can help (re)frame design and designing towards ethical concerns for the environment (e.g., from food-waste reduction to eco-tourism), and enable careful considerations of the the relations of inclusion/exclusion that technology-mediated stewardship actions can produce.

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