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Research Paper

Evaluating ecological monitoring of civic environmental stewardship in the Green-Duwamish watershed, Washington

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HIGHLIGHTS

- We characterized civic environmental stewardship in the Green-Duwamish watershed USA.
- Stewardship may be related to population density, political boundaries and resources.
- We evaluated ecological monitoring activities by stewardship programs.
- Monitoring efforts are unevenly distributed and unsystematic.
- Monitoring is driven by maintenance, funding, or a program's standard practices.

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ABSTRACT

The ecological outcomes of civic environmental stewardship are poorly understood, especially at scales larger than individual sites. In this study we characterized civic environmental stewardship programs in the Green-Duwamish watershed in King County, WA, and evaluated the extent to which stewardship outcomes were monitored. We developed a four-step process based on the Open Standards for the Practice of Conservation to structure our evaluation and to make recommendations for future monitoring of ecological outcomes of stewardship activities. Environmental stewardship, primarily in the form of restoration projects, was common throughout the lower and middle watershed. The distribution of stewardship sites was influenced by population density, political and program boundaries, and financial and technical resources. Conceptual frameworks that link conservation goals, ecological threats, management strategies, and monitoring were rare and incomplete. Collaboration among programs was an important component of stewardship in the watershed, although communication gaps were identified between geographic regions and different ecosystems. Monitoring efforts were relatively common but unevenly distributed, often unsystematic, and usually dictated by project maintenance, funding purpose, or a program's standard practices, rather than specific ecological outcomes and goals. As a result, monitoring results were rarely and inconsistently used for management. We recommend improving stewardship monitoring by clearly linking stewardship activities to specific conservation goals and objectives, developing reasonable quantitative outcome metrics that link upland and aquatic environments, and improving coordination and learning of monitoring efforts among multiple stewardship programs and actors.

1. Introduction

Monitoring the outcomes of environmental projects and programs is the basis for effective environmental management and can provide validation that a project is effective or indicate when a project is headed in the wrong direction (Stem, Margoluis, Salafsky, & Brown, 2005). It is also critical for demonstrating project impacts to stakeholders, whether they are funders, interested individuals, or regulatory agencies (Bash & Ryan, 2002; Bennear & Coglianese 2005; Stem et al., 2005). Research indicates that monitoring has the potential to improve resource management and policy decision-making (Danielsen, Burgess, Jensen, & Pirhofer-Walzl, 2010; Lee, 1999) and is an important component in generating knowledge

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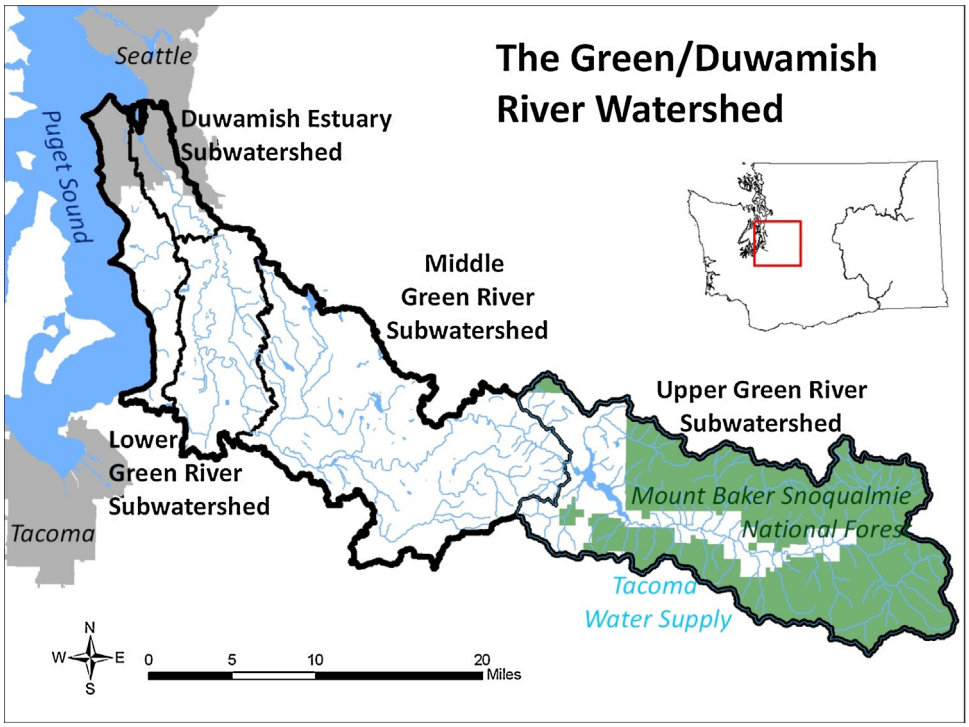

Fig. 1. The Green River-Duwamish Waterway Watershed, King County, WA, USA.

to share with other environmental practitioners (Conservation Measures Partnership, 2013). Adaptive management employs an iterative system of monitoring and experimentation to update best management practices (Holling, 1978; Walters, 1986). The goal of adaptive management is to allow managers to make informed choices in the face of uncertainty—an ongoing struggle for resource managers (Dietz, Ostrom, & Stern, 2003). Although the concept of adaptive management has become increasingly popular, evidence suggests that implementation on the ground may not match theoretical definitions of the term. As Lee (1999) points out, "adaptive management has been much more influential as an idea than as a way of doing conservation so far." Rist, Campbell, & Frost (2012) noted that few studies present a framework for evaluating a specific management problem or document application of adaptive management, and even fewer assess outcomes. In this paper we explore the question of whether and how environmental stewardship projects in the Green Duwamish watershed, USA are monitored.

Many important components of the Puget Sound ecosystem, including species diversity, forest cover, and water quality, have undergone alarming declines (Puget Sound Partnership, 2009). The Puget Sound region supports a strong culture of environmental stewardship (Wolf, Blahna, Brinkley, & Romolini, 2013) and residents and institutions throughout the northwestern portion of the state of Washington, USA, have taken action to address environmental threats. At least 588 groups, including government agencies and private organizations, conduct activities on behalf of the environment in King and Pierce Counties (Brinkley, Wolf, & Blahna, 2010). On public lands, parks, and green belts owned by King County, residents contributed an estimated 53,140 h of volunteer service in 2012 (King County Department of Natural Resources and Parks, 2013). Similarly, residents of Kent, south of Seattle on the Green River, contribute an average of 10,000 h of volunteer service annually on behalf of natural lands (Green Kent Partnership, 2011). The Green Seattle Partnership is the largest urban forest restoration effort in the nation in terms of acres targeted, with more than 100 different resident groups registered as volunteers for restoration efforts and around 80,000 volunteer hours contributed annually (Green Seattle Partnership, 2006).

Individuals, non-government organizations (NGOs), and government agencies alike conduct and facilitate civic environmental stewardship actions throughout Puget Sound, and broad-scale ecosystem restoration policies and plans identify such actions as important components in meeting restoration goals. However, the ecological outcomes of civic environmental stewardship are still poorly understood and there is little research on this topic. For example, one study examined characteristics of community groups and the effects on survival and growth of trees that they plant (Jack-Scott, Piana, Troxel, Murphy-Dunning, & Ashton, 2013). Another study examined urban tree planting programs and the importance of stewardship activities implemented by nonprofit organizations (Roman et al., 2015).

Given the significant resource investment in financial support and labor hours (both paid and volunteer), this lack of knowledge about outcomes is troublesome (Koontz & Thomas, 2006). Without such an understanding, managers of landscape-level restoration initiatives such as the Chinook Salmon Recovery Plan and the Puget Sound Action Agenda risk undervaluing the role of civic environmental stewardship or misdirecting efforts to support it (Svendsen & Campbell, 2008; Wolf et al., 2013).

In this paper, we characterize and evaluate monitoring related to civic environmental stewardship activities and programs. Specifically, we focused on exploring the state of ecological monitoring associated with sites under stewardship to determine the extent to which existing monitoring activities and circumstances could be applicable to measuring the landscape-scale ecological outcomes of stewardship. The Green-Duwamish watershed (Fig. 1) located in southern King County in the state of Washington, USA, and abutting the east-central shores of Puget Sound, was the case-study landscape.

The Open Standards framework, an adaptive management process developed by a partnership of conservation-focused organizations, guides the design, management, and measurement of impacts for conservation and restoration actions (Dietz, Brown, &

Swaminathan, 2010). The Open Standards framework is a tool for landscape-scale efforts in Puget Sound, and is being implemented as an integral part of planning, monitoring, and implementing the programs outlined in the Puget Sound Action Agenda (Hook & Knauer, 2012) as well as for Chinook salmon habitat recovery efforts (Puget Sound Recovery Implementation Technical Team, 2013).

Our primary research question was "How can land managers in the Green-Duwamish watershed measure the effectiveness of disparate civic environmental stewardship efforts in recovering ecosystem functions at various scales in the watershed?" Specific objectives were to: 1) characterize civic environmental stewardship in the Green-Duwamish watershed; and 2) evaluate the effectiveness of ecological monitoring activities by civic environmental stewardship programs in measuring and improving ecological outcomes at various scales.

The definition of the concept of civic environmental stewardship is adapted from Romolini, Brinkley and Wolf (2012): physical activities on behalf of the environment, conducted by volunteers, on public or quasi-public lands. This definition of civic environmental stewardship does not capture the full range of environmental stewardship actions, but narrowed our focus to actions that were motivated by two particular circumstances: 1) actions on public and private lands that are managed in the public interest with clear, societally-acceptable ecological goals; and 2) actions motivated largely by non-monetary considerations. In addition, this definition of civic environmental stewardship constrained our focus to actions with measurable ecological outcomes – as opposed to activities such as education or policy advocacy, which may eventually have significant environmental outcomes but for which the primary outputs are social.

1.1. The Green-Duwamish watershed

The Green-Duwamish watershed provides a valuable case study for research (Fig. 1). The river is 93 miles long and the watershed is large enough (668 square miles) to capture a diversity of habitats in which stewardship activities may be similarly diverse, but small enough to be manageable as a single unit for ecosystem restoration purposes (Margerum & Whitall, 2004). The watershed's relatively compact size leads to steep gradients, both ecologically (from alpine habitats to estuary) and in terms of land uses (from uninhabited wilderness to dense urban development). The watershed supports five species of threatened anadromous fish species and the upper watershed is the primary water supply for the city of Tacoma.

The watershed is home to over 630,000 residents, a broad diversity of socioeconomic conditions, and economic centers such as the Port of Seattle that are critical to the region's social and economic wellbeing (Duwamish River Cleanup Coalition, 2009). At the same time, many residents of the watershed, particularly those in the highly urbanized, low-income communities in the Duwamish Valley, are disproportionately at risk for negative health impacts from environmental degradation (Daniell, Gould, Cummings, Childers, & Lenhart, 2013; Duwamish River Cleanup Coalition, 2009). Some sediment in the Duwamish sub-watershed is so toxic that the Environmental Protection Agency has designated the Duwamish Waterway as a Superfund site.

The watershed provides an estimated $446 million to $3.3 billion dollars in ecosystem services, but these services can only be generated if the watershed's natural ecosystem processes continue to function at an adequate level (Christin, Stanton, & Flores, 2014). Urban development, habitat conversion for agriculture and timber production, severe hydrological modifications, and the spread of invasive species have greatly reduced the quantity and function of the watershed's natural ecosystems. While many fragments of intact natural habitats remain, much of the watershed has been transformed (WRIA 9 Steering Committee, 2005). By one estimate, the watershed lost between $1.7 and $48.1 million in ecosystem service values between 2001 and 2011 (Christin et al., 2014).

The watershed is recognized by numerous government institutions as a single unit (referred to as Water Resource Inventory Area 9) for the restoration of habitat for Chinook salmon and bull trout. Furthermore, the Green-Duwamish watershed was designated an Urban Waters Federal Partnership site in 2013. Goals of the Partnership include improving water quality and conservation, reconnecting Americans to their waterways, and collecting the data necessary to demonstrate these goals. The diversity and complexity of ecological and social conditions within a relatively small, ecologically and socially connected area offers opportunities to study numerous aspects of social-ecological phenomena such as civic environmental stewardship (Pickett et al., 2008).

2. Methods

Our study focused on the characteristics, patterns, and dynamics of civic environmental stewardship, and monitoring efforts associated with stewardship, in the Green-Duwamish watershed. Data were collected through semi-structured, key-informant interviews with civic environmental stewardship practitioners throughout the watershed, supplemented by document review. The interview pool was compiled using a recent census of environmental programs throughout King and Pierce Counties, supplemented with referrals during the interview process (Brinkley et al., 2010). Our sample was composed of distinct environmental stewardship programs that work within the Green-Duwamish watershed and participate in ecological monitoring.

Interviews were conducted with 14 individuals representing 16 distinct programs selected from the pool. The programs represented were selected such that there was representation from each of three broad programmatic categories: 1) coalition leaders, or programs that function as critical organizational nodes for coordinating and facilitating environmental stewardship efforts; 2) active participants within larger coalitions that cite civic environmental stewardship as a major focus; and 3) programs that conduct civic environmental stewardship actions without any close coordination with a broader coalition.

For each of the 16 programs, potential interviewees were identified based on Internet research, prior knowledge, and referrals from other interviewees, and included individuals who were knowledgeable about 1) civic environmental stewardship activities in the Green-Duwamish watershed; and 2) ecological monitoring at or near the sites of stewardship actions. Half of the interviewees were from non-government organizations, representing eight different programs within six different organizations. These included four programs with a core goal of facilitating stewardship across multiple sites within a landscape, two programs with stewardship as a goal within a larger context of environmental and community advocacy, and two programs focused on providing scientific and strategic guidance for coordinated stewardship efforts. Half of the interviewees were from municipal governments, representing eight different programs within six different agencies. Of these, four programs focused specifically on land management, three programs focused primarily on natural resource conservation, and one program was dedicated to community development.

The interviews explored three major lines of inquiry: 1) characterizing the programs' contribution to civic environmental stewardship actions in the watershed; 2) characterizing the ecological monitoring activities being conducted at and near stewardship sites and 3) evaluating whether and how data from these sites are used and shared with others (see online Appendix). Interviews were recorded and transcribed for analysis.

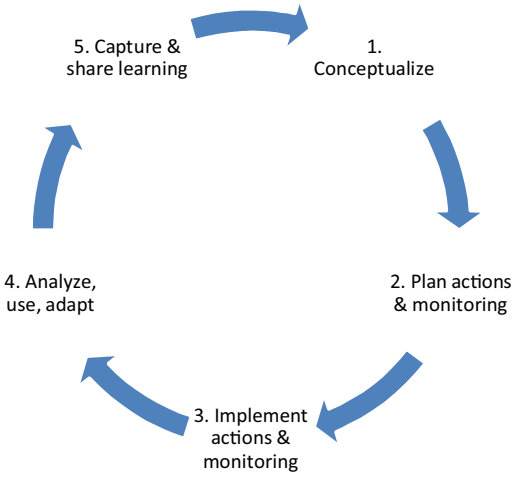

Fig. 2. Open Standards project cycle.

2.1. Data analysis

Interview transcripts were coded and analyzed using the qualitative data analysis software package nVivo. First, an *a priori* provisional coding scheme was applied to interview transcripts. During provisional coding, responses were categorized according to the initial topics of interest for this research, including characteristics of stewardship actions, characteristics of monitoring activities, and evaluation of monitoring activities. Responses in each provisional category were then further analyzed through an iterative process of additional coding, which illuminated themes and emergent patterns.

The Open Standards for the Practice of Conservation (Conservation Measures Partnership, 2013) framework was used as a guide for evaluating monitoring activities associated with stewardship. Based on the open standard project cycle (Fig. 2), we identified four project characteristics that we used as a basis for evaluating stewardship monitoring activities in the Green-Duwamish:

1. Conceptual models: The extent to which stewardship actions are planned based on specific conservation targets, goals, threats, and strategies [based on steps 1 (conceptualizing) and 2 (planning) of the cycle].
2. Monitoring implementation: Whether and how the outputs and outcomes of stewardship activities are monitored, including a review of indicators chosen to measure progress toward goals, monitoring methods, and the audiences identified for monitoring data [based on steps 2 (planning) and 3 (implementing and monitoring) of the cycle].
3. Analysis and use of monitoring data: The extent to which monitoring data are actually used, particularly for adapting stewardship actions to improve their outcomes [based on step 4 (analyzing, using, and adapting) of the cycle].
4. Capturing and sharing learning: The extent to which stewardship programs identify shared goals, conduct compatible measurements, and share the results of monitoring and analysis [based on step 5 (sharing) of the cycle].

While the concept of "scaling up" is not explicitly included in the Open Standards, the principle of adaptive management requires monitoring efforts to be flexible to different project or analysis scales (Peterson & Parker, 1998). Thus, for each project characteristic above, we also noted whether or not project elements such as indicator measurements or project objectives could theoretically be synthesized to scale up monitoring results to the landscape level. Aspects of monitoring activity that would be conducive to scaling up include: targets, goals, and objectives in common between programs, consistent and transparent monitoring methods, and effective information-sharing within collaborative networks.

Table 1
Stewardship activities and percentage of sampled programs conducting each activity.

Category	Activity
Ecological Restoration (94%)	• Removing Invasive Plant Species • Native Plan Installation • Site Maintenance (mulching, soil amendment, watering)
Ecological Monitoring (81%)	• Various Data Collection
Site Engineering (38%)	• Improving Fish Passage • Large Wood Installation • Gravel Replenishment
Restoration Forestry (25%)	• Selective Tree Removal

3. Results

3.1. Civic environmental stewardship in the Green-Duwamish watershed

Environmental stewardship activities in the Green-Duwamish watershed were characterized according to themes identified during the interview data coding and analysis process.

3.1.1. Stewardship activities

The most common type of stewardship activity discussed by interviewees (Table 1) was ecological restoration, specifically removing invasive plant species, native plant installation, and site maintenance. Other activities included *ecological monitoring* on sites in restoration and in other natural areas; *site engineering*, especially in aquatic areas; and *restoration forestry*, or selectively removing trees from a forest stand in order to change that stand's successional trajectory.

Activities with primarily ecological goals, but no direct measured ecological outputs, included land acquisition, the recruiting and training of volunteers and stewards, public outreach on environmental issues, political advocacy, and participation in environmental governance. Activities with primarily social goals included trail building and maintenance, community-building activities, connecting people with the natural world, gathering community input on environmental plans, and leadership development.

3.1.2. Stewardship activity site locations

Interviewees mentioned more than 50 distinct sites for environmental stewardship, 15 of which were mentioned by multiple interviewees. While the majority of the sites identified were on public lands, interviewees did mention some stewardship sites on private lands as well, including volunteer-driven activities. The density of stewardship sites appeared to be roughly proportional to population density in the watershed. That is, the locations of the majority of stewardship activities were in the densely populated Duwamish and Lower Green sub-watersheds. Site distribution also appeared to be influenced by political and program boundaries; stewardship sites appeared to be more abundant in the two cities that participated in the Green Cities program, Seattle and Kent. The Green Cities program is a network of partnerships between the non-governmental organization Forterra (www.forterra.org), city governments, and other local stewardship organizations, and

in addition to Seattle and Kent, also includes the cities of Tacoma, Kirkland, Redmond, and Everett.

3.1.3. Types of participants

From interview data, three general types of individual participants in stewardship actions were identified: 1) occasional volunteers, 2) volunteer stewards, and 3) paid crewmembers. Volunteer stewards assumed clear responsibility for restoration work on their sites, and generally showed a high level of commitment compared to occasional volunteers. Stewardship actions conducted by paid crews did not fit into the definition of civic environmental stewardship that initially framed this research, but it became clear as interviews progressed that from the perspective of exploring the monitoring of ecological outcomes of stewardship, ignoring the contributions of paid crews would be extremely difficult. Nearly every interviewee mentioned that their programs relied, to varying extents, on paid crews to conduct stewardship actions. In some cases, paid crews were assigned to different sites than volunteers, but in many other cases, paid crews were assigned specific activities on sites that volunteers contributed to as well.

3.2. Conceptual models

The Open Standards framework describes conceptual models as illustrations of "the main cause and effect relationships that... exist within the project area" (Conservation Measures Partnership 2013, pp. 14–15). Major project elements of a conceptual model include conservation targets; environmental threats to those targets; goals; and strategies for reaching those goals. Interviewees were asked about their program's conservation targets and stewardship goals, the perceived threats to meeting stewardship goals, and the extent to which the goals were connected to specific stewardship actions. However, stewardship actions are not the same as stewardship strategies, so specific actions are illustrated with the use of results chains, connecting actions to desired outcomes. In this way, elements of a conceptual model were inferred from the interview data.

3.2.1. Conservation targets and stewardship goals

Goals are defined in the Open Standards framework as statements of the desired future impacts of a project, such as the future status of a conservation target. An expansive list of conservation targets (e.g., elements of biodiversity that a conservation project is designed to affect) and stewardship goals were developed from interview data analysis (Table 2). The targets fell into four general categories: 1) holistic or place-based targets, 2) species-related targets, 3) biophysical targets, and 4) ecosystem services targets. Interviewees also mentioned a number of targets that were primarily social in nature. The role of these social targets in monitoring the impacts of stewardship was not investigated in this study.

3.2.2. Conservation threats and stewardship actions

The identification of factors that affect a conservation target, including direct and indirect threats, is an important element of the Open Standards framework (Table 3). Invasive species were the most common threat, mentioned by all interview subjects. Other threats that could be addressed through stewardship actions included degraded water quality and aquatic habitat loss. However, many of the threats mentioned in interviews, such as development and climate change, are beyond the scope of civic environmental stewardship.

Interviewees were also asked to elaborate, when possible, their assumptions of the logical sequence of events that would link their stewardship actions or strategies to the eventual achievement of these goals. About 56% of interviewees laid out specific causal progressions of results in their responses, indicating that volunteer stewardship actions were in some cases planned with specific conservation targets in mind.

Table 2
Conservation targets and stewardship goals identified in interviews.

Category	Conservation Targets	Stewardship Goals
Holistic or place-based	• Landscape restoration • Forest habitat health (including urban forests) • Aquatic habitat health (including wetlands & riparian areas) • Wildlife habitat health	• Land in active restoration • Diversity of habitats • Habitat connectivity • Wildlife habitat health • Forest composition (target forest types) • Reduced invasive vegetation
Species-focused	• Salmon population parameters (especially habitat) • Animal communities • Biodiversity	• Habitat use by salmon • Habitat use by wildlife • Vegetation diversity • Native vegetation health
Biophysical	• Water quality • Air quality • Natural river movement	• Water temperature • Dissolved oxygen in water • River-to-floodplain connectivity • River sinuosity
Ecosystem services	• Carbon sequestration • Stormwater mitigation • Air quality	• (none identified)

Table 3
Threats to conservation targets identified in interviews.

Threat category	Specific threats
Agriculture & aquaculture	• Agriculture • Livestock • Hatchery practices
Natural system modifications	• Logging • Illegal logging • Water flow modification leading to habitat loss • Shoreline modification leading to habitat loss • Loss of riparian vegetation • Degraded water quality • Unsustainable successional trajectory
Biological resource use	• Salmon harvest
Recreational use	
Development	• Residential • Industrial
Pollution	• Litter • Water pollution
Invasive species	
Water withdrawals & diversions	• Dams
Climate change	

3.2.3. Comparative evaluation of conceptual models

Common themes were identified among the conceptual model elements identified from interviews. The most common element, mentioned by all, was the identification of invasive species as

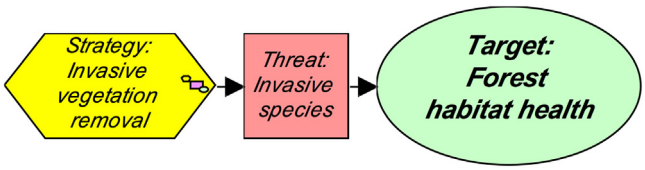

Fig. 3. Simplified conceptual model, generated in Miradi, related to forest habitat health.

a major threat on which to focus stewardship actions. Another common element, mentioned by about 63% of interviewees, was increasing habitat connectivity. One significant theme in which conceptual models differed was the breadth and complexity of the targets, goals, and strategies identified to meet these goals.

Using a software program called Miradi, developed by the coalition of organizations responsible for the development of the Open Standards framework (Foundations of Success and Beneficent Technology, Inc., 2013), we created illustrative conceptual models for two commonly-identified conservation targets: forest habitat health and salmon habitat health (Figs. 3 and 4).

3.3. Monitoring implementation

According to the Open Standards framework, conceptual models guide the development and implementation of a monitoring plan. Elements of a monitoring plan include the intended audiences to which monitoring results will be reported, ecological indicators to be monitored, and data collection methods.

3.3.1. Implementing monitoring activities

No interviewees described a monitoring plan that was fully conceptualized according to the Open Standards framework, although some of the formal coalitions working in the watershed included selected elements in their plan. All interviewees mentioned at least some monitoring activities on stewardship sites (although not all programs conducted monitoring themselves) and the extent of monitoring varied widely. Furthermore, the quality of the monitoring data was reported to be highly variable, and the extent to which monitored sites were representative of ecological outcomes of stewardship on the watershed was unclear.

Interviewees described a variety of approaches for implementing monitoring. While about 44% of programs relied primarily on volunteers to conduct monitoring, about 63% reported using paid staff or crews to collect monitoring data, sometimes on the same sites that volunteers were monitoring. The employment of paid monitoring crews, as well as academic researchers, was particularly common in the aquatic environment, in part given the high data standards required to meet aquatic environmental regulations.

3.3.2. Factors influencing monitoring implementation

Interviewees cited a number of motivations for conducting monitoring, both internal and external. Seventy-five percent of interviewees identified policies within their programs that called for a certain amount of monitoring. Additional influences were to meet terms set by a partnership or broader coalition, along with regulatory requirements. This was particularly relevant for government agencies, and appeared to be most frequently associated with projects in the aquatic environment. About 13% of interviewees mentioned the need to demonstrate to volunteers that the stewardship work they were doing was having a positive environmental impact, and demonstrating success to funders was mentioned by 25% of interviewees.

Two consistent themes emerged with respect to obstacles to monitoring the results of stewardship actions. Most commonly mentioned, by all interviewees who discussed monitoring, was the lack of financial, technical, and labor resources. A second theme was that programs often appeared to lack an institutional culture that encouraged monitoring. About 31% of interviewees stated that monitoring was often considered secondary to physical restoration activities, maintaining a base of volunteers, or other activities related to stewardship.

3.3.3. Audiences identified for monitoring

The Open Standards framework recognizes that programs may focus on measuring different project attributes depending on the intended audiences for the data. Interviewees most frequently indicated that measurements were collected for internal use within a program, or to share with other members of a coalition. Twenty-five percent of interviewees also mentioned funders as an audience for monitoring data. Finally, half of the interviewees mentioned involvement in collecting data to be submitted to regulatory agencies.

3.3.4. Indicators and other ecological attributes monitored

Interviewees also mentioned recording direct project activity attributes that quantified project implementation, such as the number of trees planted on a site. Many interviewees also mentioned specific project activity attributes that were tracked over time, such as plant survival from year to year, although this type of monitoring was not as common. Nearly all interviewees discussed qualitative monitoring (e.g., visual observation, anecdotal accounts) of stewardship sites and about half indicated that site managers tended to rely *primarily* on qualitative monitoring. Many interviewees saw significant value in qualitative assessment, especially if the alternative is to conduct no monitoring at all. At the same time, other interviewees expressed a desire to move away from qualitative assessments to systematic monitoring of quantifiable indicators.

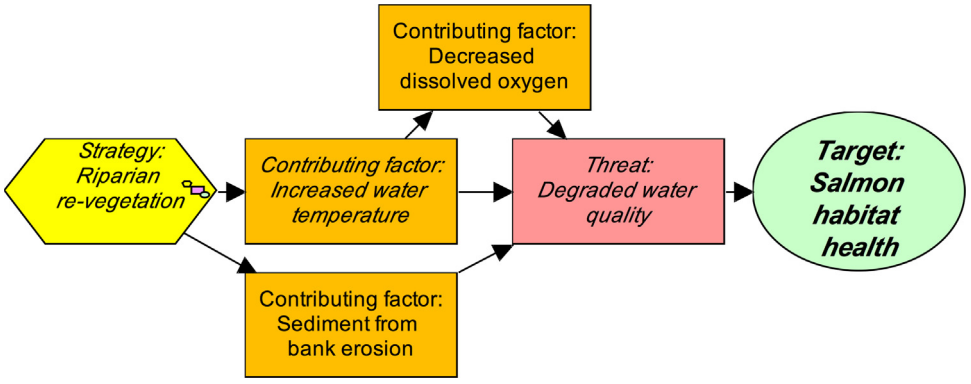

Fig. 4. Conceptual model, generated in Miradi, related to salmon habitat health.

A few interviewees were able to link the ecological attributes monitored with their projects' specific goals and objectives. However, other interviewees were concerned that the attributes chosen for monitoring were not always appropriate as indicators for progress toward their goals; rather, they were collected based on a standardized protocol, or based on the rationale that it is better to collect too much information than not enough.

3.3.5. Monitoring methods

Specific monitoring methods used depended largely on who conducted monitoring activities. Programs that relied on volunteers to conduct monitoring had, by necessity, monitoring protocols simple enough for volunteers with only basic training to implement effectively. On the other hand, some programs relied on paid crews or academic researchers to conduct data collection or rigorous experiments on stewardship sites. While interviewees mentioned a number of instances in which data were collected with scientific rigor, all interviewees acknowledged that these were special cases. Most interviewees acknowledged that scientific rigor might not be a realistic goal for monitoring in many cases.

3.4. Analysis and use of monitoring data

Analysis and use of monitoring data appeared to be a major challenge for most programs. Challenges arose at each step of the analysis process, from storing and preparing data, to analysis, to application of results. Data were difficult to synthesize and store, particularly over long time periods or between multiple programs within a partnership. Data analysis presented similar challenges for many programs, primarily due to a lack of financial or technical resources.

The Open Standards framework emphasizes using monitoring data to inform an adaptive management process, in which project elements are adjusted iteratively based on monitoring results. Interview responses indicated that the results from monitoring efforts were used inconsistently, at best, for making management decisions. Furthermore, in only one case did an interviewee mention circumstances in which the results of ecological monitoring were applied to assess a program's conceptual model or strategic plan with respect to stewardship. At the level of site-specific plans and protocols, the results from other similar sites often informed planning for future sites, and no examples were found of program-level or landscape-level adjustments in response to monitoring results.

3.5. Capturing and sharing learning

The Open Standards process emphasizes the importance of documenting and sharing the lessons learned during a project cycle, both within and outside of programs, as well as more generally creating a learning environment within programs and collaborative networks. While interviewees did not describe shared learning explicitly, the extent to which some form of knowledge-sharing occurs can be inferred from the amount of collaboration and interconnection between stewardship programs throughout the watershed.

3.5.1. Collaboration and network connections

Interviewees identified a number of formal coalitions in the watershed, most notably, but not limited to, the Green Cities partnerships in Seattle and Kent. Most of the formal coalitions have a major focus on facilitating volunteer stewardship, although one (the Watershed Ecosystem Forum) facilitates significant environmental stewardship but does not have a specific focus on volunteer activities. While the collaborative efforts in the watershed provided venues for the connection of numerous programs that may not otherwise interact, there were two notable gaps in the types of connections identified in interviews. First, there were only sparse connections between programs whose primary focus was stewardship actions in upland habitats and programs that primarily focused on aquatic habitat. Although many interviewees recognized the interconnectedness of these two ecosystem types within the watershed, most interviewees acknowledged little collaboration. The second notable gap was a relative lack of collaboration between programs working in the Duwamish and Lower Green sub-watersheds and those working in the Middle and Upper Green.

3.5.2. Sharing learning

While some programs, especially those working within formal coalitions, participated to some extent in sharing results and information, many interviewees indicated that their programs did not emphasize sharing results. In fact, some interviewees stated that reporting on results was uncommon even within a single program. There was no indication that any programs had a policy of keeping data and results private; rather, it appeared that the challenges discussed above with data analysis and use resulted in a paucity of substantive results to share with others.

Some interviewees mentioned further challenges with sharing the results of monitoring activities: the lack of standardization in monitoring protocols; the wide variety of attributes monitored; and differences in project goals – each made results difficult to synthesize or learn from for projects elsewhere in the watershed. Finally, the gaps within the network of stewardship programs discussed above were also evident in the context of sharing the results of monitoring activities.

4. Discussion

4.1. Characterizing civic environmental stewardship

Environmental stewardship is common throughout the lower and middle watershed. We identified primary stewardship activities with ecological outputs, specifically, ecological restoration. However, interviewees also cited numerous other examples of environmental stewardship, including public outreach and education, political advocacy, and community-building around shared natural resources. The distribution of stewardship sites appeared to be influenced by population density, political and program boundaries, and the financial and technical resources of each program. This was not surprising, given the need for a substantial pool of potential volunteers who are willing and able to frequently visit sites under stewardship. At the same time, recent research elsewhere in King County has indicated that in some cases, volunteers travel long distances to participate in stewardship events, which would imply that proximity to population centers is not always a prerequisite for volunteer stewardship activities (Daniels, Robbins, Brinkley, Wolf, & Chase, 2014).

With respect to the density of stewardship sites, cities that participated in the Green Cities network appeared to have more stewardship actions occurring within their borders than nearby locations. However, this relationship was not formally tested, and stewardship actions were occurring in adjacent cities as well, often in collaboration with members of Green Cities partnerships such as the non-government organization Forterra.

4.2. Evaluating ecological monitoring

Ecological monitoring activities in the watershed were unevenly distributed, often unsystematic, and inconsistently used for management. Although all interviewees mentioned some monitoring activities, many of the activities were qualitative and designed primarily to monitor project maintenance and survival of vegetation,

rather than ecological outcomes. While qualitative assessments of project success can be very useful for management at the site level, quantitative measures are necessary for application to broader scales. Furthermore, numerous interviewees expressed concern over the consistency and quality of data collection efforts. Some of this concern was based in the challenge of engaging non-scientists in collecting credible scientific data. Citizen science has been shown to be useful for management decisions (Cohn 2008; Dickinson, Zuckerberg, & Bonter, 2010), but its effective use relies on careful data management and quality control, as well as careful identification of monitoring protocols that can be implemented with minimal training (Litle, Wainstein, & Dalton, 2009).

We identified a number of comprehensive, conceptually credible monitoring plans in place for stewardship actions in the watershed. In spite of this, it appeared that the majority of monitoring actions were being undertaken without a strategic action and monitoring plan linked to specific ecological goals and objectives. Sites were often monitored in response to non-specific program guidelines or requirements from regulatory or funding bodies rather than according to site-specific or programmatic monitoring plans. The planning step of the Open Standards project cycle provides tools to aid in monitoring plan development, and we have illustrated sample conceptual models from some of the more well-developed plans as described by interviewees (Figs. 3 and 4). However, few interviewees provided clear linkages between environmental threats, stewardship goals, conservation strategies, and specific outcomes that could be used as a basis for monitoring.

The process of coordinating monitoring efforts within stewardship networks presents challenges. The primary obstacles to coordination are the high transaction costs of developing and implementing a data repository, and the relatively low priority that many programs assigned to monitoring and data analysis. The presence of transaction costs in collaboration is consistent with other research, which has noted that the cost of initiating and developing connections with other programs can hinder collaboration (Margerum & Whitall 2004; Schneider, Scholz, Lubell, Mindruta, & Edwardson, 2003).

The gaps between upland and aquatic environments and between geographic areas of the watershed add significant challenges to collaboration and information dissemination. This may be due to the differences in identified threats facing upland and aquatic environments versus densely-populated lower subwatersheds, as well as differences in the relationships of local communities to natural lands and resources. Fostering interactions among groups focusing on each of these areas could benefit stewardship work and ecological health throughout the watershed.

4.3. Managing at the landscape scale

Our findings suggest that more effective monitoring of landscape-scale ecological impacts would include 1) identification of ecological goals and indicators to measure progress toward these goals, 2) systematic implementation of coordinated monitoring protocols and monitoring sites throughout the watershed, and 3) coordination of monitoring and evaluation efforts among multiple programs. The careful choice of ecological goals, and a limited number of ecological indicators to measure progress toward these goals, is important. We found significant overlap between programs in terms of basic ecological attributes monitored, including percentage of native and invasive vegetation cover, native plant survival over time, and for aquatic environments, fish use over time. The financial and technical resource limitations identified in the watershed underscore the need to select a few key strategic indicators in order to make monitoring as cost-effective as possible. Remote-sensing methods and geospatial analysis are potentially useful tools for measuring ecological impacts at the landscape scale (Wolf et al., 2013).

Scaling up site-level monitoring efforts to the landscape scale requires collaboration among multiple programs to establish a unified monitoring framework (Atkinson et al., 2004). Monitoring at the watershed scale to measure the impacts of stewardship will require systematic planning and implementation of monitoring methods and monitoring sites. To effectively tap into the existing capacity for site-level monitoring in the watershed, close coordination within stewardship program networks is necessary. Given the current obstacles to collaboration, centralized leadership in determining ecological goals and additional resources to lower the transaction costs of collaboration may be useful. Collaborative efforts at the landscape scale may most appropriately fall within the purview of a government agency or a partnership among agencies. For collaborative environmental actions such as landscape-scale monitoring, government agencies are well positioned to provide a structure for collaboration (Koontz et al., 2004), and to lower the transaction costs of collaboration for non-governmental organizations (Schneider et al., 2003). Furthermore, compared to NGOs, government agencies are more likely to have access to the resources necessary to measure ecological outcomes at the landscape scale, including funding, technical expertise, and infrastructure, (Thomas & Koontz 2011).

Landscape-scale, government-led collaboration is present in the Green-Duwamish watershed, in the form of salmon habitat recovery efforts led by WRIA9's Watershed Ecosystem Forum. Furthermore, the watershed's recent designation as an Urban Waters Federal Partnership site has the potential to facilitate government-led environmental actions in the future. The goal of the Partnership is to break down agency silos and encourage collaboration between federal and non-federal players that are active in water quality and conservation efforts in the watershed. The Green-Duwamish is one of 19 Partnership sites nationally, and our findings can contribute toward development of a more generalizable stewardship monitoring protocol. In addition, the Open Standards-based evaluation process used in our study could be adapted and implemented to systematically review and evaluate stewardship activities in other complex watersheds.

5. Conclusion

The current status of ecological monitoring of civic environmental stewardship programs in the Green-Duwamish watershed indicates that more systematic and coordinated efforts toward understanding the ecological impacts of stewardship are needed. In addition, landscape-scale ecological monitoring is necessary but not sufficient for measuring the full impacts of environmental stewardship. Our focus on the physical activities conducted by volunteers on public and quasi-public lands presents an incomplete picture, as we did not capture the myriad non-physical environmental stewardship activities (environmental education, outreach and training, and political advocacy) that are happening in the watershed. A comprehensive understanding of both ecological and social impacts of environmental stewardship will be useful for prioritizing projects and funding, planning for ecosystem recovery, and furthering social welfare goals. Our study is a first step towards understanding the complex interactions involved in civic environmental stewardship that are at play and need to be understood for effective management.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.landurbplan.2016.09.017.

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