Remediation to Restoration to Revitalization: Engaging Communities to Support Ecosystem-Based Management and Improve Human Wellbeing at Clean-up Sites

Kathleen C. Williams and Joel C. Hoffman

Abstract Remediation to Restoration to Revitalization (R2R2R) is a framework to identify ecological and policy-based relationships between large-scale aquatic sediment remediation projects, subsequent habitat restoration projects, and waterfront revitalization. A defining feature of R2R2R is that it possesses three essential feedback loops: a translational ecology feedback loop, an adaptive management feedback loop, and a project management feedback loop. The R2R2R framework builds on Ecosystem-Based Management (EBM) theory by addressing the role of humans through these feedback loops, and by recognizing the ability of communities to learn and make choices that improve the environment through translational science. In this framework, translating ecological changes from remediation and restoration projects to public benefits (e.g., swimmable water, potential for urban greenspace) using the concept of ecosystem services is critical to support decision-making. In practice, community perceptions and uses of the remediated and restored ecosystem or habitat are central to EBM. We use the Great Lakes Area of Concern program to illustrate how R2R2R exemplifies EBM for large, complex sediment remediation and aquatic habitat restoration projects.

Lessons Learned

- The Remediation to Restoration to Revitalization (R2R2R) framework is integrative of diverse interests through ongoing opportunities for engagement and a synthesis of input to inform research and project alternatives
- Consideration of translational ecology and adaptive management, in addition to the project, create distinct opportunities for engagement with the community, stakeholders, and project implementers

K. C. Williams · J. C. Hoffman (✉)

Great Lakes Toxicology and Ecology Division, United States Environmental Protection Agency, Office of Research and Development, Center for Computational Toxicology and Exposure, Duluth, MN, USA

e-mail: hoffman.joel@epa.gov

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- Health Impact Assessment can create science-based, community-relevant, and decision context relevant recommendations

Needs to Advance EBM

- Identify relationships between a positive change in environmental stressors, such as sediment contamination and habitat degradation, and improvements in human health or quality of life
- Case studies inclusive of a broad range of environmental management contexts that contribute to our social capacity for inclusive, equitable decision-making in social-ecological systems

1 Introduction: The R2R2R Framework

Remediation to Restoration to Revitalization (R2R2R) is a framework to identify ecological and policy-based relationships between large-scale sediment remediation projects, subsequent habitat restoration projects, and community revitalization. Ecological outcomes of remediation and restoration may be defined in terms of either ecological quality (e.g., a sediment quality target) or quantity (e.g., acres of wetland restored; Krantzberg 2003). Revitalization outcomes promote human-wellbeing, including social equity, while protecting or improving natural capital (Angradi et al. 2019). However, as a social-ecological system, the connections and feedbacks between remediation, restoration, and revitalization are not well-understood. In the Great Lakes region, remediation and restoration projects along urban waterfronts changed people's interactions with urban, aquatic ecosystems. For example, after projects were complete, increased use of trails and waterways, and changes in economic activity and land uses, improved people's quality of life (Krantzberg 2012; Hartig et al. 2019; Williams and Hoffman in review). However, a framework to identify the connection and feedbacks that led to the change in quality of life has not been available to researchers or managers. This impedes achieving a broader goal of maximizing ecological outcomes and social benefits to human well-being. Therefore, our goal was to develop this framework, recognizing that it should incorporate principles of Ecosystem-Based Management (EBM).

We developed R2R2R in the context of the Great Lakes Area of Concern (AOC) Program. The U.S.-Canada Great Lakes Water Quality Agreement (Annex 1, 2012) defines Areas of Concern as "geographic areas that fail to meet the general or specific objectives of the agreement where such failure has caused or is likely to cause impairment of beneficial use of the area's ability to support aquatic life." When the program was initiated in 1987, 43 AOCs were identified, 31 of which were entirely or partly in U.S. waters. Most AOCs are located near population centers, are within the Great Lakes coastal zone, and are degraded by legacy contaminants including heavy metals and persistent organic pollutants (Hartig et al. 2019). The program recognizes 14 distinct beneficial use impairments (BUIs). Nearly all AOCs have multiple impaired beneficial uses, which arise from multiple causes including sediment and water contamination, habitat loss, excess nutrients and sediment

inputs, and improperly functioning storm or sewer systems (Hartig and Zarull 1992). It is common for Superfund sites to be located within an AOC, and for brownfields to be located nearby. The AOC program's goal is to remove BUIs through contaminated sediment remediation, aquatic habitat restoration, or both. In AOC communities, revitalization is primarily targeted towards urban waterfronts, and is inclusive of policies or actions on waterfronts or in adjacent aquatic areas.

Our objective is to describe the R2R2R framework and demonstrate how it builds upon EBM theory. We anticipate the R2R2R framework can be applied broadly to the problem of remediation, for example in brownfields or Superfund programs (Lipps et al. 2017) and recognize that important details of implementation will depend on each program's requirements and legal authorities. For example, under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as Superfund), the definition of natural resources and the criterion for future use (e.g., residential) will influence remediation, restoration, and revitalization decisions (Burger 2008). For the purposes of this chapter, we will speak of R2R2R in general terms, and provide examples specific to the Great Lakes AOC program. We conclude with a case study which illustrates that integrating social and ecological knowledge is possible by integrating a formal decision-support system (Health Impact Assessment) designed to consider diverse knowledge and values into the R2R2R framework.

2 R2R2R Framework as a Decision-Support System

The R2R2R framework describes a process for achieving management goals and project objectives within a social-ecological system (Fig. 1). Generally, R2R2R sites involve substantial engineering to address ecological stressors causing identified ecological impairments. Community members, stakeholders, and agencies choose the acceptable ecological or human risk at the remediation site, the type and quantity of habitats to be restored (within biological constraints), and the future uses and activities that will occur at the site (Krantzberg 2003). Because it is an engineered project within a community, the ecosystem undergoing remediation and restoration is embedded within a social system which may be organized by neighborhoods, user groups, municipalities, and state, federal, and tribal agencies. It is a flexible, adaptive system that is built upon, and responsive to, diverse community members and organizations. As such, R2R2R can also be described as an adaptive co-management system (Folke et al. 2002). As with adaptive co-management, R2R2R focuses on specific places (AOCs) and environmental stressors (BUIs), and emphasizes learning through management actions, adaptively evolving management activities and governance (Dietz et al. 2003; Olsson et al. 2004).

A defining feature of R2R2R is its three feedback loops: a translational ecology (TE) feedback loop, an adaptive management (AM) feedback loop, and a project management (PM) feedback loop (Fig. 1). As illustrated, the R2R2R framework is cyclical and iterative, and thereby explicitly recognizes ecological and social

complexity and interactions. For example, the cycle could begin with a plan for revitalization, which in turn may spark community, stakeholder, or decision-maker interest in remediation and restoration. These feedback loops are linked. For example, the TE and AM feedback loops intersect during community engagement as the community helps to define the project ecological and social goals.

In translational ecology (TE), scientists and community members collectively identify ecological and social goals, and address problems related to both environment and society (Enquist et al. 2017). Translation is built on knowledge exchange between scientists and stakeholders, and thereby promotes mutual learning. This approach is shared with EBM (Slocombe 1998) and is inherent to the design the Great Lakes AOC program (Krantzberg 2012). The R2R2R framework requires an iterative, participatory TE process that is dynamic and adaptive because the underlying ecological system is complex and the social system includes agencies, non-government organizations, and socio-economically diverse communities. For AOCs, R2R2R is inherently translational; when their original Remedial Action Plans (RAPs) were created in the late-1980s, state agencies were advised by scientists, local governments, and community members (Botts and Muldoon 2005; Hartig and Zarull 1992). The TE feedback loop ideally continues through four discrete stages of the R2R2R process (policies and goals, and remediation, restoration, and revitalization projects; Fig. 1). Scientists engage with community members and stakeholders to gather knowledge and co-produce scientific data, which are translated into potential ecosystem goods and services (EGS), with associated benefits or losses (trade-offs) identified based on project alternatives (e.g. Martin et al. 2018; DeWitt et al. 2020). This information is provided to decision-makers, and their decision in turn affects researchers and community members (Daily et al. 2009; Wall et al. 2017). In TE, a wide range of stakeholders and community members are included. To address related environmental justice concerns, extra effort may be required to engage under-represented and vulnerable populations that are directly or indirectly affected by the contaminated site (Geller et al. 2016).

In the adaptive management (AM) feedback loop, periodic evaluations based on project-effectiveness metrics determine whether the project is meeting identified targets relative to either goals (program or policy scale) or objectives (project scale; Slocombe 1998). If those goals are not met, decision-makers must modify the project to address identified shortcomings, and the cycle of evaluation and modification continues (e.g., McLain and Lee 1996). If decision-relevant endpoints are chosen that convey value to the public regarding the ecosystem services gained or lost through the remedy (e.g., water of sufficient quality to use, fish of sufficient quality to safely consume) or restoration (e.g., wetlands of sufficient quality to support ecologically sensitive, charismatic species), metrics can potentially be used for both public communication and in a translation ecological context (Allan et al. 2015; Angradi et al. 2016; Olander et al. 2017; Wall et al. 2017). Ideally, within the AOC program, AM for remediation and restoration projects begins with discrete management actions to support project implementation, followed by project implementation, monitoring, and evaluation, and ultimately (if impairments are successfully removed) AOC delisting. In between the time when all identified management

actions are complete and delisting, there is opportunity for the AOC community (including state agencies, citizen advisory committee, and potentially stakeholders and community members) to address additional remediation and restoration needs as necessary.

Remediation goals are developed by evaluating the risk or impact to the ecosystem from chemical exposure, which can be accomplished formally through ecological risk assessment or through other evaluations to determine ecosystem impairments (Burger 2008). Remedy effectiveness is an approach to determine whether remediation goals are met, wherein physical, chemical, and biological lines of evidence (LOE) are measured prior to, potentially during, and after remediation (e.g., Meier et al. 2015). Multiple LOE such as sediment or porewater contaminant concentration, toxicity tests, contaminant bioaccumulation, indices of biotic integrity, or bioassays are measured to evaluate the ecosystem response. Ideally, at least some LOE have associated targets (i.e., a desired value post-remediation).

Restoration effectiveness is an emerging concept within the R2R2R framework. We assume here that the remediation project has at least some ecosystem restoration goals. The purpose of restoration is to address ecological stressors and in the context of the AOC program, which is focused on riverine, coastal, and riparian habitats, these stressors include aquatic habitat loss or degradation, sedimentation or erosion, and invasive species (Hartig and Zarull 1992). In R2R2R, identified ecological goals include multiple species and habitats, and may address supporting ecological functions (e.g., nutrient cycling or fish spawning habitat). The topic of developing habitat restoration targets has been addressed at-length (e.g., Ruiz-Jaen and Aide 2005; Palmer et al. 2005). Some targets, such as water quality criteria, must specifically address program needs. Other targets which are ecologically relevant (i.e., an index of biotic integrity or metric of stress) and devised for various levels of biological organization (species to ecological community) may support AM decisions.

Revitalization effectiveness is a relatively new concept in Great Lakes AOCs. Remediation has economic benefits, which have been measured in AOCs by hedonics and economic impact analysis (e.g., Isely et al. 2018). For R2R2R, revitalization is best understood as a positive change in community wellbeing (Krantzberg 2003). Community-level social and economic changes can occur in concert with remediation and restoration efforts (Krantzberg 2012). For example, AOC practitioners associate remediation with positive social changes, including increased recreational use of the waterfront and changes in land use or waterfront business (Williams and Hoffman in review). While environmental, economic, social, and governance metrics have been proposed (Angradi et al. 2019), few formal studies exist that demonstrate broad-based changes in community wellbeing or quality of life (Krantzberg 2012).

The PM feedback loop recognizes that the community and scientists may identify project-specific goals that require certain ecological targets to be met at the preceding step. Often, risk assessment, remediation, and restoration are conducted separately and independently; however, integration can achieve efficiencies in terms of time and energy (Burger 2008). In the R2R2R framework, we postulate that integration can yield a greater ecological and social impact than would be achieved by

conducting remediation, restoration, and revitalization projects separately. However, we are not aware of studies evaluating the relative success of integrating these elements.

3 R2R2R and Ecosystem-Based Management

As a framework, R2R2R shares foundational elements with Ecosystem-Based Management (EBM; Grumbine 1994; Arkema et al. 2006; Ruckelshaus et al. 2008). These qualities include that it is normative (reflects specific values), principled (aims to improve public good), integrative of different interests by synthesizing a wide range of information and knowledge garnered through engagement and participation, accommodating of complexity and change through feedback loops, is explainable to a wide group of people through the translational ecology loop, and is adaptive (Box 1; Slocombe 1998). In R2R2R, project workflow is relational and directional, such that the outcomes of the last stage (revitalization) are linked to both the initial conditions and success of prior stages (remediation and restoration). As such, ideally, discussions regarding all three stages and the associated projects.

Box 1 Principles of the Remediation to Restoration to Revitalization Framework

Ecological integrity and sustainability

To restore ecological integrity, the program adheres to a sustainable relationship between humans and ecosystems recognizing that the capacity of ecosystems to support life has been substantially diminished because of human actions (i.e., ecological impairments). An important outcome is the creation or restoration of the cultural, spiritual, or experiential relationship between people and the river.

Spatial planning

The spatial distribution of people, resources, and ecosystems is critical to R2R2R. Remediation and restoration are spatially-specific activities that occur within a landscape mosaic of human and ecological communities. Sediment contamination and aquatic habitat loss or degradation are spatially discrete and heterogeneously distributed, though stressors may occur at larger spatial scales. The built environment is amenable to spatial planning.

Effectiveness metrics

Effectiveness metrics inform whether remediation, restoration, and revitalization project objectives are met. Adaptive management can occur in ecological and social domains, and therefore metrics and pre- and post-project monitoring should occur in both domains.

(continued)

Box 1 (continued)*Remediation, restoration, and revitalization adaptively linked*

Objectives and outcomes of remediation, restoration, and revitalization projects flow from one project to another, and thus success is interlinked. While remediation and restoration objectives are often established by government agencies, because revitalization objectives are community-based, community values and use objectives can inform remediation and restoration objectives.

Agency of people

Where science and policy knowledge are produced together, the process undertaken to engage stakeholders and the public matters. In the context of decision-support (e.g., health impact assessment), collaborative group processes facilitate mutual learning. Trust and legitimacy, which are founded on facilitation and knowledge sharing, are important for project success.

Social system integral to the framework

The translational feedback loop integrates community values and knowledge with scientific knowledge to inform project objectives, which in turn aims to improve provisioning of ecosystem services for community wellbeing. Recommendations to achieve ecological and social goals arise from community members, stakeholders, and scientists, and are responsive to policy goals (e.g., removal of ecological impairments).

Participatory process that integrates different kinds of knowledge

Translational ecology is used to integrate scientific, local, and traditional ecological knowledge using participatory processes that adhere to principles of democracy, collaboration, communication, and equity. The participatory process is organized as a cooperation among individuals, nongovernment organizations, municipalities, and state, federal, and tribal agencies working at neighborhood, city, reservation, and state scales.

In R2R2R, as with EBM, ecosystem services provisioning is fundamental to sustainability over time (Levin and Lubchenco 2008). Ecosystem goods and services (EGS) are outputs of nature that contribute to human wellbeing when consumed, used, or enjoyed (Bruins et al. 2017). Coastal wetlands and river mouth estuaries (Larson et al. 2013), the most common habitat impacted in AOCs, provide a diverse array of ecosystem services (Sierszen et al. 2012). Beneficial use impairments in AOCs such as fish consumption advisories, beach closings, or dredging restrictions represent ecosystem services loss. Moreover, EGS respond directly to alteration of the biophysical state of the AOC (Yee et al. 2020), provide a consistent and comprehensive set of benefits for consideration, and can be mapped or quantified to illustrate trade-offs to the public (Angradi et al. 2016).

It is important to recognize in Fig. 1 the relationships between ecological integrity and ecosystem services on the ecosystem side, and wellbeing and equity on the social system side (Schoeman et al. 2014; Piet et al. 2020). An accounting of

ecosystem services can provide measures of community benefits that may not be easily recognized (Olander et al. 2017). By embedding EGS as the connection to wellbeing and equity, we recognize trade-offs are central to decision-making (Angradi et al. 2016; Martin et al. 2018). As such, recommendations can be made to ensure that impacts do not disproportionately affect under-represented, disadvantaged, and vulnerable groups. Here again, we need decision support processes that integrate different kinds of knowledge, including traditional ecological knowledge (Berkes et al. 2000), recognize the importance of social inclusiveness, and provide recommendations to improve equity.

It is also important to recognize that the restored ecosystem and community are embedded within larger systems, such as a watershed and state, respectively. This external relationship may present concerns related to resiliency, reversibility, source control, long-term stewardship, or other factors that arise from outside the control of the project area or community and which need to be addressed as part of the solution (Adger et al. 2005; Levin and Lubchenco 2008; Palumbi et al. 2008). The Great Lakes AOC program can address AOC-specific structural goals (habitat amount, cultural features) and organizational goals (ecological productivity or connectivity, human use and development), but can only contribute to process goals (biodiversity and evolutionary complexity, quality of life; Slocombe 1998), which are driven by large-scale stressors (e.g., Allan et al. 2015).

One of the animating questions in EBM, and in R2R2R, is *who* will do this work? Substantial challenges exist with respect to our understanding of social-ecological systems for implementing integrated solutions. For example, social dimensions of social-ecological systems remain poorly defined (Brown 2009, 2014), and when considered are limited to studies of scale, governance, and institutions (Brown 2014; Turner 2014). Moreover, the focus on “the functionality of institutions and ... normative issues as outcomes,” instead of as integral parts of the system (Cote and Nightingale 2012) minimizes the attention given to relations of power, diverging interests, and social identities (Brown 2014; Turner 2014) that often challenge the creation of sustainable solutions. In R2R2R practice, we therefore ask, “what is the role of scientists, decision-makers and managers, public advisor groups, and citizens?” Are roles clarified, aligned, and sufficiently supported for R2R2R to be successful? How do we address ongoing conflict between government processes that traditionally rely on technological knowledge versus community processes that rely on integrated knowledge? Current environmental management practice often treats these different interests as competing, but an agonist approach (Mouffe 1999) suggests that finding ways to treat these different types of knowledge as equal can be productive (Cote and Nightingale 2012). To address the underlying drivers of environmental degradation, we need to engage community morals and values, as well as promote shared benefits of revitalization (Groenfeldt and Schmidt 2013; Daigneau 2015). This is where TE principles (collaboration, engagement, commitment, communication, process, and decision-framing) are critical to connect research and practice (Lawson et al. 2017; Wall et al. 2017).

R2R2R can address potential shortcomings with respect to community engagement that can occur in EBM (Krantzberg 2003). It does so by stipulating community

engagement and translational science to occur at each part of the process, recognizing that different community groups may be engaged with and impacted by each part of the process differently. We postulate that for R2R2R to be successful, there must be a translational component that facilitates learning given that remediation and restoration projects generally rely on scientific or technological knowledge (Cote and Nightingale 2012; Partidario and Sheate 2013). To do so requires a decision-support process that follows TE principles and is based on constructivist learning theory, such as impact assessment (e.g., health impact assessment; Partidario and Sheate 2013) or structured decision-making (Sharpe et al. 2020). For implementation, R2R2R requires concepts and strategies from social science that aim to span the boundary between scientific knowledge and decision-making (Mollinga 2010; Williams 2015). Next, we demonstrate how using a constructivist approach can yield a broad range of potential political solutions and recommendations through community engagement (Cote and Nightingale 2012; Evans 2011). The following case study explores how this engagement may produce an integrated solution.

4 Implementing R2R2R Case Study

The U.S. Environmental Protection Agency designated the St. Louis River Area of Concern (AOC) in 1987 owing to historical degradation including discharge of untreated wastewater and debris from industrial and municipal facilities (MPCA and WDNR 1992). The AOC includes the lower 63 km of the St. Louis River. The port cities of Duluth, Minnesota and Superior, Wisconsin are situated at the river's mouth where it flows into Lake Superior. With respect to sediment contamination, chemicals of concern include polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins (PCDDs, or dioxins), polychlorinated dibenzofurans (PCDFs, or furans), polyaromatic hydrocarbons (PAHs), and heavy metals, all of which are present at multiple locations in the AOC (Crane et al. 2005). State (Minnesota, Wisconsin) and tribal (Fond du Lac Band of Lake Superior Chippewa) agencies coordinate sediment remediation and habitat restoration projects. In Duluth, the neighborhoods adjacent to the river were once home to numerous saw mills, coal tar processing facilities, and steel mills, but today are suffering from poverty and poor health outcomes (Williams et al. 2019).

With sediment remediation underway, the City of Duluth is revitalizing the "St. Louis River Corridor" through the development of active recreation opportunities including trails, regional parks, and improved access to the river in these same neighborhoods (City of Duluth 2018). The AOC and community revitalization processes intersect at the Kingsbury Bay and Grassy Point habitat restoration project. Kingsbury Bay is adjacent to a city park and campground that is also a historical Native American camp, along which a riverfront trail will be improved. Grassy Point is city-owned green space along the riverfront; it is a wetland complex and has an unimproved boat launch and a wetland boardwalk with a fishing pier that are in

disrepair. Kingsbury Bay is impacted by long-term excess sedimentation that resulted in aquatic habitat loss. Grassy Point was the location of two former saw mills, resulting in sediment contamination from both wood wastes and dioxins. The two sites are about 2 km apart, and the combined project covers about 1 km² of river and involves dredging 268,000 m³ of sediment. The restoration will beneficially use sediment dredged from Kingsbury Bay to build habitat at Grassy Point Park, while remediation work as Grassy Point includes wood waste removal and covering contaminated sediments. The project will improve river access in economically-disadvantaged neighborhoods with poor access (USEPA 2019). Project objectives include adding a river trail, a swimming beach, canoe and kayak landings, boardwalks, fishing piers, and interpretative signage. The project area also has potential for supporting plants including wild rice that are culturally important to indigenous people.

Recognizing the complexity of design decisions, project implication for the health of adjoining neighborhoods, and a diversity of community members and stakeholders, we conducted a health impact assessment (HIA) to create evidence-based recommendations to inform the Minnesota Department of Natural Resources project design (i.e., sediment remediation and aquatic habitat restoration) and the City of Duluth park planning (i.e., site access and amenities). Health impact assessment (HIA) is a systematic process that uses a variety of data sources and community and stakeholder consultation to ascertain potential health impacts of a policy change or decision, and to make recommendations that mitigate negative health impacts or enhance positive health impacts (National Research Council 2011). Health impact assessment is built upon democratic participation, health equity, and a comprehensive approach to health (i.e., community wellbeing; Quigley et al. 2006). Further, HIA assumes the community is a stakeholder (Human Impact Partners 2011), which is important given a lack of consensus regarding long-term plans for redevelopment along the river (Johnston et al. 2017).

The inclusion of community input early in the process ensures community values are considered at a point when values can influence recommendations provided as part of the HIA (Iroz-Elardo 2014). In the Kingsbury Bay-Grassy Point habitat restoration project, we started the process with two introductory meetings for stakeholders, one for the general public and one for group representatives (i.e., city planners, non-government organizations, and natural resource managers). The meetings were nearly identical and included an introduction to HIA, an overview of the project, and opportunities for discussion and input. To ensure opportunities for meaningful inclusion, we captured different types of knowledge and experience. Participants in both meetings were invited to share their experiences with the two sites by placement of sticky notes on project maps, and to explain how the changes would impact their daily lives or experiences (Boschmann and Cubbon 2014; Johnston et al. 1995). The submitted comments reflected a variety of personal and professional experiences and conveyed individual perspectives regarding sense of place and identity. Comments included concern about park maintenance, safety,

access, traffic, invasive species management, disturbance of an adjacent Superfund site, and identified opportunities for social gathering, birding, fishing, and boating.

Health impact assessment is designed to mediate power relations through an inclusionary and iterative process. In the Kingsbury Bay-Grassy Point habitat restoration project HIA, all submitted comments were analyzed to identify the social and environmental determinants of health and wellbeing valued by community members and stakeholders (Marmet et al. 2008). This community-based information was used to construct health pathways, which identify how project elements are likely to effect health outcomes. We identified impacted ecosystem services to relate the proposed biophysical changes at the site to public-friendly endpoints such as swimmable water or edible fish, and then to health benefits. Transparency was ensured throughout the process through ongoing communication and opportunities for input. Detailed meeting notes that include all comments, questions, and participants were distributed after each meeting, and community members and stakeholders could make suggestions or corrections to any set of notes produced. Community members and stakeholders were invited to participate in technical and community committees that advise the HIA through each step.

In total, the HIA yielded 77 unique recommendations to improve project health outcomes. Recommendations addressed trail safety, environmental quality, cultural resources, and social places for gathering. Recommendations also addressed the ecological quality of the project, including to protect existing high-quality wetlands and to implement invasive species controls. Importantly, the process was widely endorsed by community members, stakeholders and decision-makers as positive and constructive. We found that HIA is helpful in the AOC context because it provides a means to explore how sediment remediation, habitat restoration, and park management are interrelated, and how this will collectively impact community health as defined by community members and stakeholders. In this case study, the HIA informed both final landscape design for habitat restoration and will be included in future park master planning.

Broadly, HIA integrates with the three loops of R2R2R, and therefore may be widely useful. In this case study, HIA served as a formal approach to decision support that facilitated translational science. Other decision support approaches might also be used to support TE (e.g., Sharpe et al. 2020). The TE loop included the community through engagement and data co-production; community knowledge was foundational to the science-based pathways for impact analysis. The AM loop related HIA recommendations to restoration projects and city park plans, which changed in response to research and collective discussions about the value of Kingsbury Bay and Grassy Point Park. Finally, the PM loop linked revitalization outcomes such as safe swimming beaches and birdwatching opportunities to ecosystem services that were necessary to restore through remediation and restoration.

5 Conclusions

It has long been recognized that successful implementation of an ecosystem approach to integrate environmental and social decision-making requires attention to both the substance and process of the approach (Slocombe 1993; McLain and Lee 1996). The R2R2R framework builds on EBM theory by addressing the role of humans (e.g., natural resource agencies, community members) through multiple feedback loops, and recognizing their ability to learn and make choices that improve the environment through translational science. We demonstrate that integrating social and ecological knowledge is possible by utilizing the R2R2R framework with a specific process (HIA) designed to consider diverse knowledge and values. Ecosystem-Based Management is difficult because the benefits humans and society derive from ecosystem processes cannot be viewed as objectively existing “out there,” but as entangled in social and political processes (Ernstson 2013). The R2R2R framework provides interlinking loops of translational ecology, adaptive management, and project management as a system for integrating these diverse processes. As a community of practice, R2R2R is relatively new, and we anticipate that ongoing remediation and restoration efforts in the Great Lakes and elsewhere will contribute to our social capacity for inclusive, equitable decision-making in social-ecological systems.

Disclaimer This chapter has been subjected to Agency review and has been approved for publication. The views expressed in this paper are those of the author(s) and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.

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