



# Environmental education outcomes for conservation: A systematic review

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## ABSTRACT

Effective environmental education represents more than a unidirectional transfer of information: rather, this suite of tools develops and enhances environmental attitudes, values, and knowledge, as well as builds skills that prepare individuals and communities to collaboratively undertake positive environmental action. Environmental education also facilitates connections between actionable research findings and on-the-ground practices, creating synergistic spaces where stakeholders collaborate to address dynamic environmental issues over time. Because of this commitment to application and iteration, environmental education can result in direct benefits to the environment and address conservation issues concretely. Yet, the path to achieving those tangible impacts can be winding, with robust data documenting changes challenging to produce. To better understand the research-implementation spaces where those environmental education outcomes occur, are measured, and are reported, we undertook a systematic review of research on environmental education's contributions to conservation and environmental quality outcomes. Given the variation in research designs and data, we used a mixed-methods approach to the review; analysis of the 105 resulting studies documented strongly positive environmental education outcomes overall and highlighted productive research-implementation spaces. Chi-square analyses revealed that programs reporting direct outcomes, compared with those reporting indirect outcomes, differed on primary topic addressed. A narrative analysis indicated that environmental education programs documenting direct impacts included: a focus on localized issues or locally relevant dimensions of broader issues; collaboration with scientists, resource managers, and/or community organizations; integrated action elements; and intentional measurement/reporting structures. Those themes suggest program development and documentation ideas as well as further opportunities for productive research-implementation spaces.

## 1. Introduction

In the Anthropocene era (Steffen et al., 2007), Earth's systems are experiencing intense pressure on biological, chemical, and geological cycles, resulting from human-induced resource use and overuse at a magnitude never-before experienced (Barnosky and Hadly, 2016). People are pressing against planetary boundaries in ways that may permanently alter systems critical for sustaining life on Earth (Rockström et al., 2009a; Steffen et al., 2015). Conducting relevant, high-quality scientific research and sharing the findings with decision-makers is not enough to solve complex environmental and conservation issues (Knight et al., 2019; Lemos et al., 2018; Toomey et al., 2017). Rather, we need synergistic spaces where research findings are interpreted and applied in on-the-ground contexts in ways that acknowledge and meld with social, political, and economic milieus (Toomey et al.,

2017).

Environmental education is a conservation strategy that creates such synergistic spaces, facilitating opportunities for scientists, decision-makers, community members, and other stakeholders to converge. Environmental education foregrounds local knowledge, experience, values, and practices, often in place-based settings; in this way, it encourages numerous groups, including those that may be marginalized, to interface productively with research (Toomey et al., 2017). By definition, environmental education encompasses approaches, tools, and programs that develop and support environmentally related attitudes, values, awareness, knowledge, and skills that prepare people to take informed action on behalf of the environment (Monroe and Krasny, 2016; UNESCO, 1978). It focuses on outcomes at various scales, including at the individual level (e.g., an individual's environmental attitudes or behavior), societal level (e.g., community capacity-building),

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and ecosystem level (e.g., number of an endangered species). Based on a growing body of research foregrounding behavioral complexity, environmental education has moved away from suggesting a linear path from environmental attitudes to knowledge to action, now emphasizing a dynamic, complex ecosystem of relationships that influence behavior rather than earlier ideas derived from an information-deficit perspective (Marcinkowski and Reid, 2019; West, 2015).

Drawing on and leveraging the field's interdisciplinarity nature, environmental educators incorporate principles from behavioral psychology, health education, marketing, learning sciences, and sociology, among others (Heimlich and Ardoin, 2008; Jacobson et al., 2015). This diversity of perspectives and theoretical frames guide what researchers envision as effective practices in the field. Those practices include, particularly: having direct, place-based experiences; being part of a community that develops shared prosocial and environmental norms; learning about and developing a connection to the local environment; building and honing action-related skills; and having opportunities to take action on meaningful issues (Monroe and Krasny, 2016; Niemiec et al., 2016).

Over the past several decades, policymakers, funders, nonprofit leaders, and others have consistently called for evidence of the ways in which environmental education brings about tangible improvements in environmental quality and helps achieve conservation outcomes (Johnson, 2013; Krasny, 2009). Researchers and practitioners have echoed the call to investigate links between environmental education and direct environmental outcomes, such as improved air quality, invasive species eradication, or an increase in the population of targeted threatened species. Simultaneously, stakeholders have called for more nuanced understanding of the processes and mechanisms supporting such contributions (Heimlich, 2010; Johnson et al., 2012), while acknowledging challenges inherent in measuring and describing the nature of such multifaceted, nonlinear, systems-embedded relationships (Ardoin et al., 2013; Short, 2009; Toomey et al., 2017).

Identifying and specifying the ways in which environmental education leads not only to conservation actions and behaviors, but especially to tangible environmental improvements, necessitates many steps. Environmental education addresses wicked problems (Knight et al., 2019; Toomey et al., 2017), such as climate change and biodiversity loss, which are mired in the complexities inherent in socio-ecological systems. Understanding and contextualizing the success of an environmental education program often involves measuring short- and intermediary-term outcomes (e.g., environmental concern, self-efficacy, critical thinking), followed by tracking outcomes that require more time to develop and manifest (Ardoin et al., 2015). Pinpointing the influence of environmental education programs can be further complicated by the fact that such programs are frequently nested within larger conservation or education initiatives (Ardoin and Heimlich, 2013; Trehella et al., 2005). Quality environmental education involves many partners and stakeholders who collaborate in a research-implementation space where science, decision making, and local culture and environment intersect (Toomey et al., 2017); environmental education evaluation and assessment often struggle in these productive, yet complex, spaces.

Researchers have examined outcomes of environmental education in a variety of contexts, with varied audiences. In a review of 206 residential environmental education programs, Ardoin et al. (2015) found that intended outcomes included environmental awareness, attitudes, skills, and behaviors, including citizen participation. Stern et al.'s (2014) review of 66 studies evaluating youth environmental education programs found positive correlations with the outcomes of knowledge, awareness, skills, attitudes, intentions, behavior, and enjoyment. Ardoin et al. (2018) reviewed 119 studies of K-12 environmental education programs and reported 121 discrete outcomes grouped categorically into domains of knowledge, dispositions, competencies, behavior, and personal characteristics. In their systematic review of climate change education, Monroe et al. (2017) described programs

measuring knowledge, attitudes, and behavior. Thomas et al.'s (2018) review of 79 evaluations of conservation education programs reported cognitive, behavioral, social, and ecological outcomes. Thomas et al. (2018) also discussed a need for improved links among the environmental issues that programs addressed, metrics of program effectiveness, and actual outcomes measured and reported. Taken together, these reviews suggest a range of intended outcomes for environmental education, yet they also indicate that few programs explicitly articulate an environmental quality or conservation improvement goal. Environmental education programs often are designed to impact knowledge, attitudes, and behaviors; consequently, researchers measure changes in those areas, rather than documenting direct ecological impacts.

Thus, questions persist about the extent to which, and through what pathways, environmental education can improve environmental quality. To address these questions, we pursued a systematic review of environmental education's role in developing, supporting, and sustaining individuals' and communities' environmental actions that have direct, positive impacts on environmental quality and conservation outcomes. Initially, we asked: In what ways are researchers and practitioners measuring conservation/environmental quality outcomes of environmental education? We then pursued a related question: What trends occur in studies that report on outcomes of projects or initiatives with directly observed impacts of environmental behaviors on environmental quality improvement? We worked to coalesce, synthesize, and analyze the literature. In the results and discussion, we present findings for conservation researchers and practitioners interested in using environmental education as one tool to navigate the research-implementation space (Toomey et al., 2017).

## 2. Methods

Anticipating a mix of qualitative, quantitative, and mixed-methods studies, and given the dual nature of our research questions (i.e., the first question is primarily quantitative in nature, the second more qualitative), we pursued a mixed-methods systematic review process (Heyvaert et al., 2017). This type of synthesis can accommodate results from different research designs; it involves flexible analytical tools that can be adapted to fit the data and research questions. Systematic reviews can help navigate research-implementation spaces as they encourage reflection and, by considering an array of evidence, respect a multiplicity of methods and epistemologies (Toomey et al., 2017).

### 2.1. Searching the literature

We followed established procedures for systematic reviews of scholarly literature (Cooper, 2010; Gough et al., 2017), as well as for conservation literature specifically (Pullin and Stewart, 2006). First, we identified the appropriate search terms to capture empirical research examining environmental education and conservation/environmental quality outcomes. We conducted > 20 systematic exploratory searches using combinations of search terms. After reviewing over 1000 abstracts, we selected the following terms to identify environmental education-related research: environmental education, conservation education, education for sustainability, sustainability education, and education for sustainable development.

Our exploratory searches indicated that broad terms, such as "conservation," or even "conservation outcomes," neither sufficiently nor efficiently captured relevant literature; rather, more specific search terms were necessary. To avoid the bias of self-generating a list of issue-specific outcome terms, we selected terms based on Rockström et al., 2009a, 2009b planetary boundaries, a highly cited, policy-relevant synthesis of pressing environmental issues. Guided by those categorizations, we used the following list of environmentally related search terms: climate change, global warming, biodiversity, biological diversity, species richness, species diversity, species loss, nitrogen, agriculture, phosphorus, ozone, chlorofluorocarbons, ocean, freshwater,

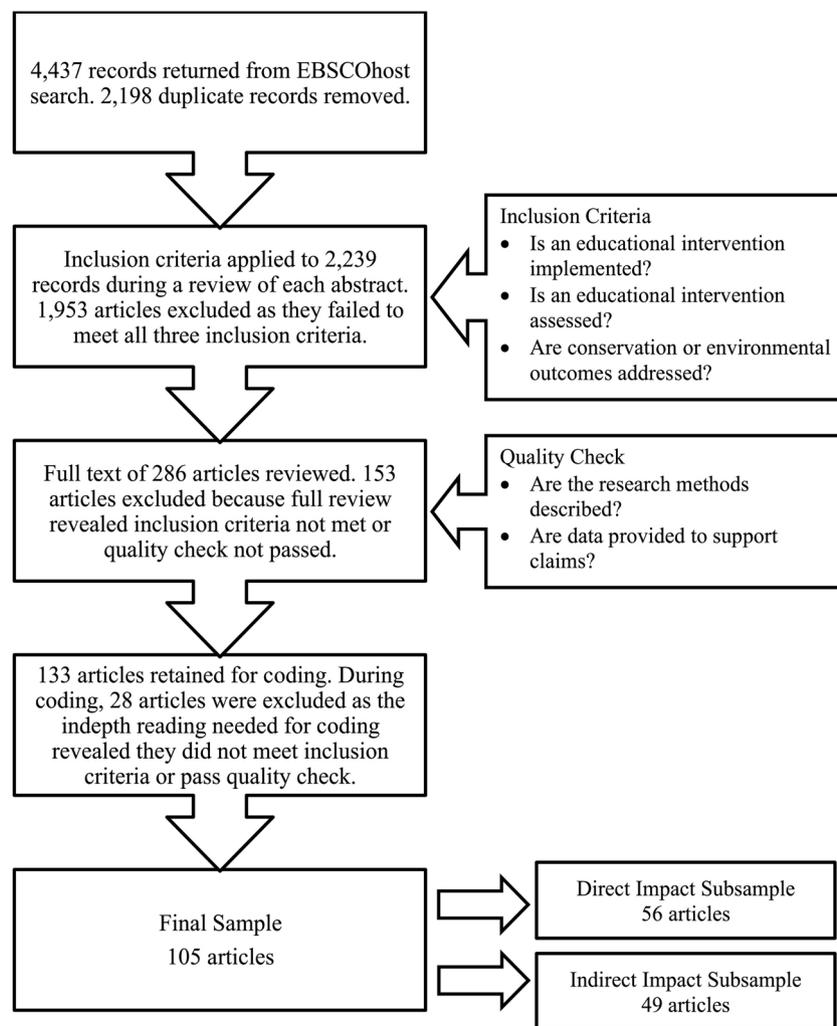


Fig. 1. Search process flowchart with decision tree.

water quality, water supply, water quantity, watershed, land use, forests, urban development, urbanization, pollution, air quality, and aerosol.

For the final search, we combined the two sets of terms (environmental education and selected synonyms + conservation and environmental issue terms, derived from Rockström et al.'s categorizations). We ran the combined search in seven EBSCOhost databases (Academic Search Premier, Africa-Wide Information, British Education Index, Education Full Text, Environment Index, ERIC, and GreenFILE) previously identified as relevant to work in the environmental, conservation, and/or education fields (Ardoin et al., 2018). We obtained 4437 citation records after limiting our search to peer-reviewed literature published in English between 1997 and 2016. This timeframe was selected as a manageable 20-year period that captured a combination of recent research as well as older research that has remained relevant. We removed duplicates within the EBSCOhost search engine and imported 2583 records into the Zotero bibliographic management program. We manually identified an additional 339 duplicate records, leaving 2239 records to review (see Fig. 1).

## 2.2. Vetting results for relevancy and quality

Next, we reviewed each of the 2239 abstracts for relevancy using a decision tree based on three inclusion criteria. In the sample, we retained studies that: (1) implemented an environmental education intervention, (2) assessed the intervention, and (3) described inclusion of

conservation-related outcomes. To test the decision tree, we randomly selected 50 records to review in a preliminary round. Three review team members read each abstract for the 50 citations and applied the decision tree principles (see Inclusion Criteria and Quality Check boxes in Fig. 1). Reviewers agreed on the inclusion principles for 44 out of the 50 citations (88% agreement, Krippendorff's alpha = 0.817). Based on an acceptable level of agreement (alpha > 0.80; Krippendorff, 2004), we commenced vetting all 2239 records with at least one member of the research team reading each abstract to determine whether to include a study for further review.

In the first review round, 1953 articles failed to meet the decision tree criteria; we excluded those studies from further review. Common reasons for exclusion were that the study did not implement or assess an environmental education program, was not published in a peer-reviewed journal, or did not report on primary research (e.g., was a book review or literature review). For the remaining 286 articles, we located full-text versions and team members read each article to see whether, upon full review, the studies met the decision tree criteria. At this time, we performed a basic quality check, ensuring that included studies sufficiently described their methods and provided data to support their findings. We verified that each study contained a section of text that identified the methods or methodology used to design and implement the study. We also confirmed that each study presented some form of empirical data. After full review, we excluded 153 articles, leaving 133 in the sample. During coding, we deemed that an additional 28 articles did not meet our inclusion criteria; our final sample included 105

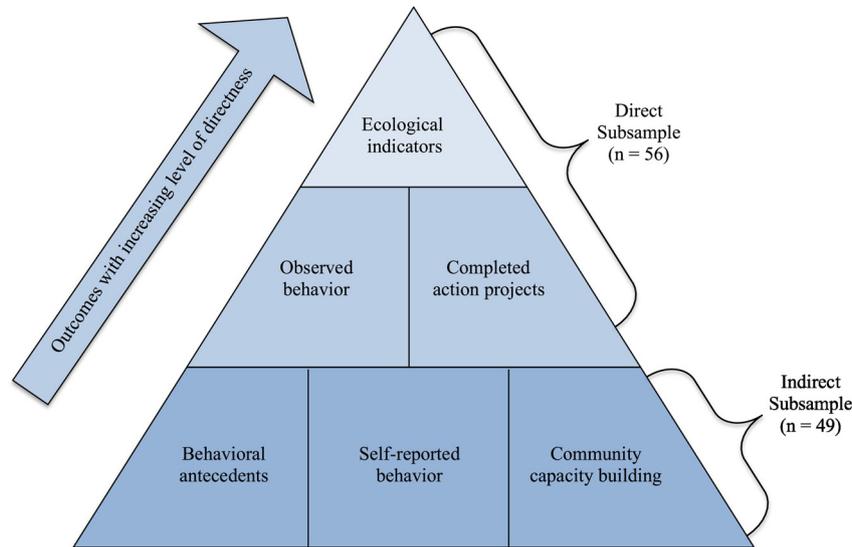


Fig. 2. Environmental quality and conservation outcomes coded in the 105 reviewed studies arranged by increasing level of proximity to direct improvement.

articles.

### 2.3. Coding and analyzing

Subsequent steps involved coding and categorizing the data in an Excel database, analyzing those data by determining frequencies, and tabulating the results. We also identified a subsample of articles for a deeper analysis. (See subsample discussion, below.)

For the coding process, we extracted the following descriptive data:

- Publication information: authors, publication date, and journal
- Intervention: description of the educational program, covering information such as program topic, length, setting, objectives, and format
- Target audience: general description of audience and participant age
- Geographic location: country and major geographic region using the [United Nations Statistics Division's \(2019\)](#) classification scheme

When we first began coding for outcomes, our focus was on identifying and coding studies that demonstrated a direct measure of environmental improvement. We sought quantifiable physical measures of environmental improvement, what we refer to as ‘ecological indicators,’ such as improved water quality, improved air quality, or increased levels of biodiversity. During coding, it became clear that few studies reported such direct measures, so we revised our outcome coding to include an expanded range of reported program outcomes. We used an inductive and deductive approach that combined emergent outcome categories along with those outcome categories that we were likely to find, such as behavioral antecedents, behavior, actions, and ecological indicators. The latter included capacity building as well as a nuanced breakdown of the behavior category.

Beyond the initial outcome category of ecological indicators, additional outcome categories included:

- Behavioral antecedents: measured changes in intermediary outcomes (e.g., awareness, knowledge, attitudes, intention, and skills) that support individual pro-environmental behavior and action
- Environmental behaviors: changes in habitual patterns of behaviors known to alleviate environmental pressures (e.g., water- or energy-saving behaviors, waste reduction behaviors, recycling, walking rather than driving). Reviewed studies indicated that behavior was measured in one of two ways:
  - Self-reported behavior: program participants reported engaging

in targeted behaviors; and

- Observed behavior: documented actual behaviors (changes) that resulted in quantifiable amounts of, for example, waste recycled, energy conserved, or reduced CO<sub>2</sub> emissions.
- Environmental actions: undertaken by program participants to improve degraded environmental conditions (e.g., planting trees for habitat restoration, cleaning up beaches, or participating in an environmental monitoring project); measured using quantitative approaches (e.g., pounds of trash collected, acreage of habitat being restored, or number of trees planted, which is assumed to correlate with improved environmental quality and conservation through provision of services such as shade, soil stabilization, nutrient cycling, and so on) and/or qualitative approaches (e.g., undertaking measures to deter runoff as a result of student efforts to identify an environmental quality issue and then take community-scale action to resolve that issue).
- Capacity-building outcomes: reported at the community level to address environmental issues through pursuing collective actions, such as improving communication within and between groups, building effective collaborative partnerships, establishing local environmental groups, and building the professional capacity of educators.

Finally, we coded for *type of overall findings* by combining all reported outcomes in each study into a single measure. We coded overall outcomes as ‘negative’ if authors only reported decreases; ‘null’ if authors reported no changes in any outcomes; and ‘mixed/positive’ if they reported only increases or a mix of increases, decreases, and no changes.

### 2.4. Selecting a subsample

After reviewing coded outcomes, we noted that the outcomes varied in their level of directness when it came to reporting and measuring environmental quality and conservation impacts. With this in mind, we viewed outcome types as existing along a continuum (see Fig. 2). We referred to the ‘most direct outcomes’ as those involving physical ecological indicators to measure direct program impacts on conservation and environmental quality. Next on the continuum were the outcomes of observed behavior and completed environmental actions, which often served as proxy indicators of environmental improvement (Johnson et al., 2012). As such, these were not specific physical ecological indicators (e.g., air or water quality data) but ‘intermediate’

indicators that may lead to improved environmental and conservation conditions (Johnson, 2013). An observed change in energy conservation behavior, for example, might result in a given number of kilowatt hours saved and, in turn, a number of pounds of carbon dioxide saved. An environmental action project, such as habitat restoration, might be measured by the number of trees planted or acres restored.

Next, we viewed the behavioral antecedents and community capacity-building outcomes as having the potential to improve environmental quality, but through less direct paths. Various environmental behavior models link behavioral antecedents, such as environmental knowledge and environmental attitudes, with environmental behavior change that may lead to reduction in environmental pressures (Heimlich and Ardoin, 2008). Community capacity building results in improved contextual factors (Stern, 2000), which may also support development of individual and collective environmental behaviors and actions, which again may lead to environmental and conservation improvements. Finally, because of methodological concerns about the strength and accuracy of behavioral self-reports (Chao and Lam, 2011; Kormos and Gifford, 2014), we viewed self-reported behavior as an indirect measure of how a program may result in behavioral change among participants and, subsequently, how changes in behaviors might contribute to improvements in conservation measures and environmental quality.

We identified a subsample of 56 studies that we coded as having one or more of the three outcomes most directly focused on environmental quality and conservation: ecological indicators, observed behavior, and environmental actions. We refer to this subsample of 56 studies as the Direct Subsample. From the original sample of 105 studies, the remaining 49 studies that only reported behavioral antecedents, self-reported behavior, and/or community capacity-building outcomes comprised the Indirect Subsample. We exported selected descriptive data from Excel into SPSS and used crosstab analyses to examine for significant differences between the Direct Subsample and the Indirect Subsample. Through a qualitative, interpretivist cross-case analysis (Creswell, 2014; Yin, 2009), we examined the Direct Subsample studies in more depth to interrogate characteristics that may have contributed to researchers and practitioners providing evidence of more direct environmental quality and conservation improvement outcomes. That analysis involved repeated readings of the subsample studies, then coding and reflecting on common characteristics across programs. In analyzing the Direct Subsample, we did not emphasize whether programs reported positive or null results (although the large majority did report positive outcomes). We focused, rather, on how the 56 articles measured and reported more direct outcomes and how those measures related to the programmatic strategies described in each study.

### 3. Results

Our final sample consisted of 105 articles distributed across 51 peer-reviewed journals from the fields of environmental education, education, conservation, and the natural sciences. (See Supplementary Appendix A for a complete bibliography of the final sample studies.) Although the 105 studies were published throughout the targeted timeframe of 1997 to 2016, the majority have been published since 2007. (See Fig. 3 for a summary of selected descriptive characteristics of the 105 studies.)

North America was the most frequent geographic location of study, with 48 (46%) of the reviewed studies occurring in that continent; within those, the majority were based in the United States ( $n = 46$ ; 44%).

The reviewed programs included approaches ranging from more passive classroom lectures to active-engagement community-based projects. Programs addressed a diversity of topics, including habitat protection and restoration, endemic wildlife, water quality, energy conservation, climate change, recycling, air quality, ecology, agriculture, and gardening. We used Rockström et al.'s planetary

boundaries approach (2009a, 2009b), which we employed in our search process, to organize what we coded as the primary topic for the programs under study in the 105 articles. Biodiversity was the most common primary topic ( $n = 36$ , 34%), followed by climate change ( $n = 18$ , 17%). Programs were designed to address a variety of audiences: 46 (44%) of the studies described programs focusing on adults, 37 (35%) on youth (ages 0 to 18), and 22 (21%) on mixed groups of adults and youth.

#### 3.1. Environmental education outcomes

Researchers reported a variety of outcomes (Table 1) with 74 (70%) studies reporting on more than a single type of outcome concurrently. In our review sample, 103 (98%) studies reported positive or mixed results. Two studies reported only null results, and no studies presented evidence of negative findings.

##### 3.1.1. Behavioral antecedents

Most of the programs ( $n = 91$ , 87%) measured changes in a behavioral antecedent such as awareness, knowledge, intentions, or skills, either as part of a suite of measured outcomes ( $n = 69$ ) or as the sole outcome of focus ( $n = 22$ ). Mukhacheva et al. (2015), for example, reported on a yearlong conservation program for students in six Russian villages; the program's intention was to improve the students' attitudes toward Amur tigers (*Panthera tigris altaica*). Educational events included seminars and courses for students, teacher trainings, and awareness-raising projects for local community members. An implementation study, which included deployment of a survey, indicated positive changes in students' knowledge of and attitudes toward tigers immediately after the program and six months later. Wyatt et al. (2015) found that, after participating in a U.S.-based program about invasive species in agricultural landscapes, farmers and agricultural professionals reported feeling more knowledgeable about invasive species and reported a higher likelihood of reducing their pesticide use.

##### 3.1.2. Completed environmental action

Forty-eight (46%) studies reported on participants undertaking some type of environmental action during the course of an environmental education program. Most actions related to improving degraded environmental conditions, such as planting trees for habitat restoration (e.g., Harder et al., 2014); cleaning up beaches, streams, or schoolyards (e.g., Unepetty et al., 1998); removing invasive plant species (e.g., Krasny and Lee, 2002); and/or monitoring environmental conditions for data-collection purposes (e.g., Lorenzini and Nali, 2004). The majority of action projects were one-off or short term (e.g., a beach cleanup or tree-planting day during Arbor Week; Guthrie and Shackleton, 2006; Unepetty et al., 1998), although some were recurring actions spanning months or years (e.g., stream monitoring or biodiversity monitoring; Kühn et al., 2008; Overholt and MacKenzie, 2005). Dolins et al. (2010), for example, reported on a reforestation program in Madagascar in which students established tree nurseries and planted > 5000 native seedlings around their schools and villages. In this way, students helped restore degraded land and create a protective buffer for a national park. In a U.S.-based program, high school students investigated land use practices in their local watershed and identified several sources of pollution. Their findings and recommendations to remedy the pollution-related issues prompted local authorities to construct a salt storage shed to reduce runoff into local waterways (Mordock and Krasny, 2001).

##### 3.1.3. Community capacity building

Forty-one studies (39%) reported that an environmental education program contributed to increasing the capacity of communities or groups to address conservation issues. Programs often accomplished these outcomes through improved relationships and communication among stakeholder groups; increased community participation in

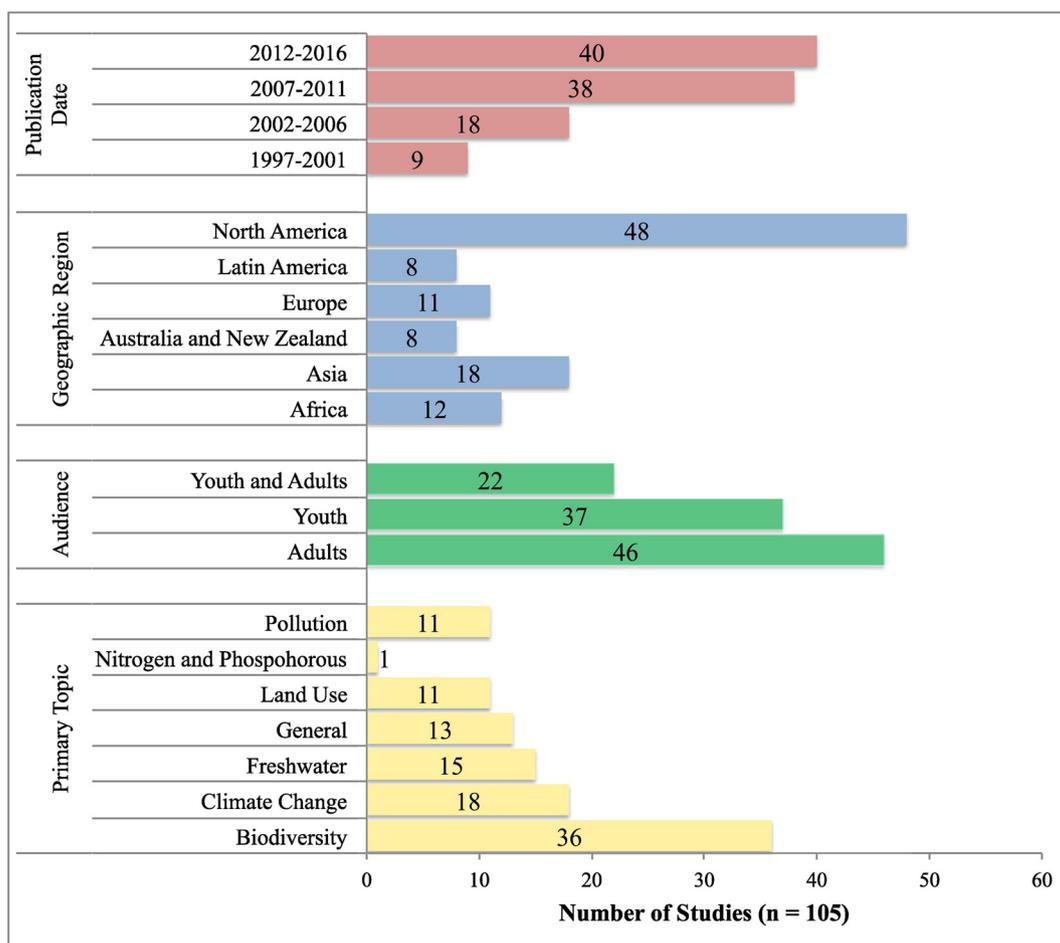


Fig. 3. Selected descriptive characteristics of the 105 reviewed studies.

**Table 1**  
Reported outcomes in sample of reviewed studies (n = 105).

Outcome	Number (and %) of articles
Behavioral antecedents	91 (87%)
Completed environmental action	48 (46%)
Capacity building	41 (39%)
Self-reported behavior	30 (29%)
Observed behavior	11 (10%)
Ecological indicators	4 (4%)

<sup>a</sup>The sum of articles is > 105 as a single article often reported more than one outcome.

conservation projects; establishing local environmental groups; and building formal or nonformal educators' professional skills and knowledge. A community-led program in New Zealand, for example, resulted in strengthening the dairy-farming community; developing understanding and trust between dairy farmers, the local shellfish industry, and local government groups; and increasing community leadership to work toward sustainable natural resource management and community ownership of the health of their waterways (Robertson et al., 2013). Gladstone et al. (2006) described how creating partnerships among a university, government agencies, and a community group allowed partners to collaboratively address an issue (in this case, the rehabilitation of a natural reserve) that would have been difficult for one group to tackle alone.

### 3.1.4. Self-reported behaviors

Thirty (29%) of the studies described self-reported changes in behavior. Stern et al. (2008), for example, used a survey to evaluate a

multiday, youth-focused residential environmental education program in a U.S. national park. They compared participants' pre- and post-experience responses to measure changes in self-reported behaviors such as turning off lights and reducing water waste. Many of the students reported increased participation in the named behaviors three months after their stay at the residential environmental education center when compared with their pre-experience responses. Middlestadt et al. (2001) found that, after being exposed to a new water conservation curriculum in Jordan, high school students reported performing recommended water conservation behaviors (such as showering instead of bathing or turning off the tap while brushing teeth) more often than students in schools that had not implemented the curriculum.

### 3.1.5. Observed behaviors

Eleven articles (10%) reported on programs that included a direct, observable measure of behavior change by program participants. Lewis et al. (2014), for example, reviewed an Australian primary school program with an explicit conservation goal: reducing 10 tons of greenhouse gas emissions in a single year. The program promoted and monitored changes in energy use and transportation behaviors of the school community. Results showed that the school achieved its goal through addressing various environmentally friendly behaviors. Two studies (Camp and Fraser, 2012; Medio et al., 1997) explored the influence on diver behavior of scuba diving briefings that included conservation or environmental education components. Both studies presented statistical data suggesting that educational briefings prior to a dive resulted in fewer diver-reef contacts and, by extension, less potential damage.

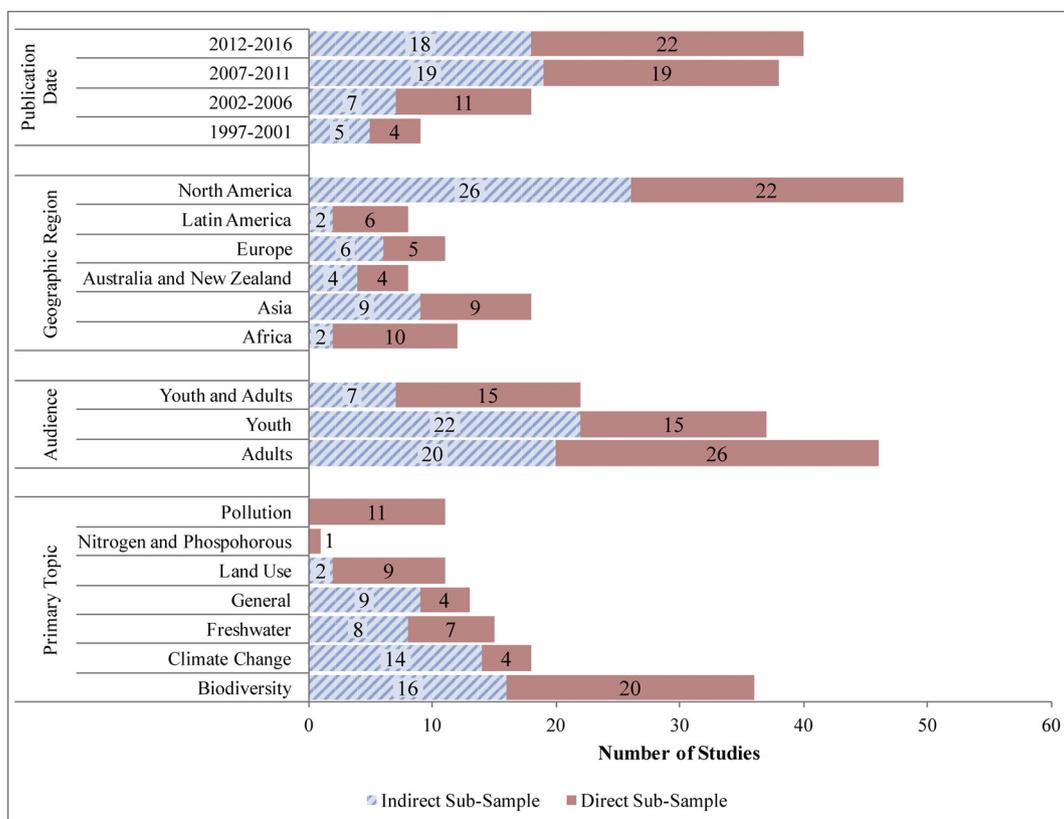


Fig. 4. Comparison of selected descriptive characteristics of the indirect subsample and direct subsample.

3.1.6. Ecological indicators

Four (4%) articles used ecological indicators, such as improved water quality or enhanced levels of biodiversity, to evaluate the ways in which environmental education programs physically impact environmental quality and/or address conservation concerns. Kobori (2009), for example, described two community education programs in Japan, one focused on restoring a natural wetland with adjacent rice paddy fields and the other on restoring dragonfly ponds to promote habitat conservation. As evidence of program success, the researcher documented biodiversity improvements, such as increases in improved habitat (e.g., more roosting sites) and indicator species, such as waterfowl and butterflies.

3.2. Comparing studies reporting direct outcomes with studies reporting indirect outcomes

To address our second research question (What trends do we see in studies that report on outcomes of directly observed behavior change, completed action projects, or ecological indicators?), we first compared characteristics of the Direct Subsample with those of the Indirect Subsample. (Fig. 4 compares data for each subsample.) Chi-square analyses suggested a significant difference for primary topic only ( $\chi^2 = 24.09, df = 6, p = .001$ ) with a moderately large effect size (Cramer's V = 0.48; Burke-Johnson and Christensen, 2014). Examination of the adjusted residuals suggested that the topic of pollution was overrepresented in the Direct Subsample and the topic of climate change was underrepresented in the Direct Subsample.

3.3. Program characteristics that facilitate measuring and reporting of direct impacts

We conducted a qualitative, interpretivist cross-case analysis (Creswell, 2014; Yin, 2009) of the Direct Subsample to suggest characteristics that may have contributed to those programs being able to

provide direct evidence of potential environmental quality and conservation improvement outcomes (i.e., outcomes beyond behavioral antecedents, self-reported behavior, and capacity-building outcomes). Our findings suggest that conservation scientists and practitioners who want or are required to demonstrate direct impacts of environmental education should prioritize measuring and reporting direct outcomes throughout program planning, development, and implementation by: (1) selecting topics with a local focus; (2) forming partnerships with scientists and natural resource managers at local agencies and nonprofit organizations; (3) incorporating action projects; and (4) being intentional, creative, and thorough in measuring and reporting program outcomes. We discuss each of these thematic implications in the subsequent section, accompanied by supporting evidence from the Direct Subsample articles.

3.3.1. Theme 1: Focus on localized environmental issues or locally relevant dimensions of broader issues

Many of the 56 articles in the Direct Subsample focused on local environmental issues and ways of addressing those issues at a commensurate scale. Programs leveraged participants' immediate home environment—occurring at a scale such as a watershed, park, nature reserve, urban green space, or schoolyard—to connect participants with broader environmental issues and engage them in environmental learning and action. Situating the issue and action locally facilitates measurement of more direct outcomes and helps mitigate issues of scale. The local environment is readily accessible: based in common sense, these programmatic foci suggest it is easier to measure water quality changes in a local creek than attempt to measure, and attribute, resulting changes in polar ice cap melt.

Local settings and context are core to many of the studies in the Direct Subsample. In a reforestation project in Mexico (Harder et al., 2014), for example, students created nurseries, improved their abilities to serve as custodians, and participated in plantings on school grounds, as well as in other deforested parts of the community, with the goal of

reconnecting with local ecosystems and enhancing student capabilities to serve as custodians. In Nigeria, [Ana et al. \(2009\)](#) studied youth-led environmental education clubs that emerged from addressing local schools' poor environmental conditions and environmental health practices.

Active engagement of communities in conservation efforts often started with involving those residents and/or their representatives in identifying problems. The programs promoted direct involvement in investigating a local issue and helping work toward solutions. [Robertson et al. \(2013\)](#) described a farmer-initiated program in New Zealand that involved farmers learning about and taking action on a pollution problem that affected the viability of the community's shellfish industry. [Trewhella et al. \(2005\)](#) reported on environmental education programs focusing on endangered fruit bats (*Pteropus livingstonii*, *P. voeltzkowi*, and *P. rodricensis*) in several Western Indian Ocean islands. Those programs illustrate how a locally relevant issue, such as the conservation of an endemic species, can address broader conservation and global biodiversity issues.

### 3.3.2. Theme 2: Collaboration with scientists and resource managers from local agencies and organizations

Environmental education programs in the Direct Subsample were often embedded in partnerships and networks developed through participatory and collaborative processes. Programs included partnerships with a variety of stakeholders including schools, universities, community groups, scientific organizations, businesses, nonprofits, and government agencies. By connecting with other organizations and experts, environmental education providers were likely to garner expertise and resources conducive to achieving a direct outcome in environmental education programs. Research studies in this vein documented that forming partnerships and networks creates an embedded context with fertile ground for action and increased results.

As an example of mutually beneficial partnerships, [Kaye et al. \(2015\)](#) reviewed five U.S.-based programs that brought together incarcerated individuals with scientists, students, and natural area managers to promote education and support ecological research and habitat restoration through plant production and captive rearing of animals in correctional facilities. Conservation practitioners provided the knowledge that resulted in over 100 incarcerated individuals raising and releasing approximately 550 frogs, 4000 butterflies, and 1 million plants. [Dunbar et al. \(2013\)](#) studied a university course that incorporated a community-based research approach in partnership with a watershed organization. Students monitored stream health, shared data with researchers, and organized outreach activities. Through this process, students increased the community's knowledge, including their own, about the watershed's health while concurrently working toward tangible watershed improvements. Staff members from the collaborating organization provided the students with expertise that guided water monitoring and supported recording and distribution of monitoring results.

### 3.3.3. Theme 3: Incorporation of action elements into programs

Direct Subsample studies often involved at least one, if not multiple, environmental action components as integral to the program. Program designs deliberately employed action-oriented learning strategies and approaches, including citizen science, service learning, project-based learning, problem-based learning, place-based learning, and issue investigation. Often the action component explicitly tackled environmental challenges through *direct physical environmental improvements* to degraded land, water, air, and species in the form of activities such as removing invasive plant species and replanting with natives; organizing and implementing litter cleanups; and performing water quality tests and, subsequently, installing complementary filtering wetland systems. A project-based university course in Australia, for example, included class lectures complemented by field work, such as monitoring and regeneration activities in partnership with a bushcare group ([Gladstone](#)

[et al., 2006](#)). The researchers reported that students increased their knowledge and skills and detailed tangible improvements at the restoration site where, working alongside bushcare-group staff, students cleared a large, ecologically important patch of habitat of litter and weeds and planted native seedlings. Another commonly reported form of action was ecological monitoring, wherein participants collected and shared data measured from specific indicators, such as water quality, air quality, or number of species present in an area. In one study, approximately 1000 students in multiple schools across Italy collected roughly 6500 measurements of air quality ([Lorenzini and Nali, 2004](#)). The data helped provide an overall picture of air quality in the region and this raised awareness and concern among students and community members.

Other projects focused on *actions with indirect physical or environmental improvements*, often with evidence of policy and community engagement outcomes and impacts. Such projects frequently ranged from motivating and supporting inquiries into local environmental issues to sharing data to assist with streamlining conservation efforts; and from guiding development of resource management plans for community education purposes to advocating for on-the-ground change. Yet still others included ecological monitoring with the intention of collecting data to share with researchers, scientists, and local, regional, or national agencies or community partners, in service of improving environmental quality and conservation conditions. [Ollervides and Farrell \(2007\)](#) described university students' sea turtle research and habitat assessment in Mexico, which resulted in submitting a proposal to the Mexican government for a marine protected area, with recommendations for fishing activity zones for resource and ecotourism uses. In Union of the Comoros, East Africa, local residents and scientists collaborated to undertake monitoring activities, resulting in pressure on the local government to initiate legislation protecting critically endangered bats and their habitats, eventually resulting in establishment of a forest reserve ([Trewhella et al., 2005](#)). Whether these program-embedded actions involved physically altering or monitoring the environment, or were indirect and focused on policy or community engagement, the results were similar: taking action as an embedded element of the program frequently surfaced and created the opportunity to measure and subsequently report a direct outcome.

### 3.3.4. Theme 4: Intentional, thorough, and innovative measurement and reporting of program outcomes

A striking feature of several studies that presented evidence of documented, direct outcomes was the thought and preparation dedicated to program reporting and evaluation. Thorough program planning involved taking painstaking care to record quantitative data, such as number of trees planted (e.g., [Bull, 2013](#)) or amount of trash removed (e.g., [Uneputy et al., 1998](#)). In describing an evaluation of a reforestation education initiative in Mexico, [Harder et al. \(2014\)](#) went beyond reporting number of trees planted and provided data on the survival rates of planted trees. In several studies, researchers described the ways in which evaluation was an intentional, critical part of program development; this prioritization of evaluation and impact likely facilitated reporting direct outcomes. For example, in their study, [Valladares-Padua et al. \(2002\)](#) named evaluation as a critical program component and, perhaps relatedly, they reported specific outcomes: the Brazilian environmental education program under study resulted in establishing 11 community agro-forestry nurseries with a yearly mean capacity of 30,000 seedlings. [Trewhella et al. \(2005\)](#) also foregrounded outcomes and impacts of environmental education programs as part of conservation initiatives to address endangered species issues in the western Indian Ocean islands. The researchers discussed program evaluation at length and reported a wealth of quantified data including number of trees planted, population estimates of endangered species based on program monitoring, and number of roosts provided for endangered species. To complement numerical data, both [Valladares-Padua et al. \(2002\)](#) and [Trewhella et al. \(2005\)](#) included qualitative

evidence when describing challenging-to-quantify outcomes, such as increased capacity and connections in the community. Additionally, by detailing program development and outcomes, it was clear that environmental educators took the time to incorporate the features mentioned in Themes 1 through 3: emphasizing local connections, forming partnerships, and pursuing an action project.

A number of the Direct Subsample studies seemed to be intentionally designed around explicit conservation goals; because of that attention to the desired outcome, those programs were able to report high-quality quantitative data related to ecological indicators. In one of the most rigorous studies in the Direct Subsample, [Betts and Alsharif \(2014\)](#) evaluated a U.S.-based adopt-a-pond program's impact on water quality. They did so not by measuring participant outcomes (e.g., changes in knowledge or attitudes), but rather by directly collecting water samples and conducting vegetation surveys. Although the analysis did not indicate changes in ecological indicators, the data collected offered program providers information about needed program improvements and showcased how to intentionally design programs to measure direct ecological indicators. In an effort to protect coral reefs, [Camp and Fraser \(2012\)](#) examined the impact of sharing educational information prior to a scuba diving experience. The researchers assessed post-programmatic changes in attitudes, knowledge, and behaviors through a survey of scuba divers in the United States. To triangulate self-reported behaviors, they observed divers' underwater interactions with and behaviors toward the coral reefs. Including the latter component connected the educational programming with direct impacts on the environment (or, conversely, environmentally protective behaviors). [Curti and Valdez \(2009\)](#) described a community-based environmental education program designed to promote the long-term survival of the Harpy Eagle (*Harpia harpyja*) living near populated areas in Panama. The researchers noted that the program's desired priority outcome was minimizing or eliminating human-caused eagle deaths. Although their evaluation lacked a formal control group, the study included data related to their desired outcome: 40 eagles had been released, 6 of them lived in forests near populated areas, and only 1 human-caused eagle death had occurred in areas that were part of the education program.

## 4. Discussion

### 4.1. Reported outcomes

Nearly all of the reviewed articles ( $n = 103$ , 98%) reported on environmental education programs that demonstrated some level of increase in a desirable, measured outcome. Only two of the studies (2%) reported solely null results ([Betts and Alsharif, 2014](#); [Wagenet et al., 2005](#)); none presented evidence of negative findings. The overwhelmingly positive results likely reflect some effect related to publication bias in which researchers fail to report on programs that did not result in the desired outcomes and editors are more likely to publish work reporting positive results ([Franco et al., 2014](#); [Polanin et al., 2015](#)). Inflated positive findings have been noted in prior environmental education reviews ([Ardoin et al., 2018](#); [Stern et al., 2014](#); [Stevenson et al., 2019](#)) and in conservation journals, more broadly ([Catalano et al., 2018](#)).

Environmental education addresses complex topics within dynamic systems and, many times, aims to shift behaviors; none of these undertakings are simple. The presence of documented successes, however, suggests that environmental education can be effective in addressing an array of conservation and environmental quality outcomes, with those outcomes occurring along a continuum from indirect to more direct. This finding lays the groundwork for a richer discussion of environmental action via behavioral antecedents; creating enabling conditions through building community capacity; supporting actual changes in behaviors; and engaging individuals and communities in direct actions that result in improvements related to conservation challenges and

environmental quality issues. In a review of 44 citizen science programs, [Ballard et al., 2017](#) similarly reported that the studied programs impacted conservation via direct outcomes (e.g., species management) and indirect outcomes (e.g., policy impacts and research).

In our full review sample, behavioral antecedents were the most frequently reported outcomes (91 studies; 87%). Researchers familiar with ubiquitous theoretical models in behavioral science, such as the Theory of Planned Behavior, the Theory of Reasoned Action, and Social Cognitive Theory ([Ajzen, 1985](#); [Ajzen and Fishbein, 1980](#); [Fishbein and Ajzen, 1975](#); [Bandura, 1999](#)), would be encouraged by this finding: Those theories recognize the critical link between antecedents—such as attitudes, knowledge, skills—and actual behavior ([Heimlich and Ardoin, 2008](#); [Stern, 2000](#)). As educators, we applaud and support efforts to focus on those antecedents, which can be powerful, nimble, and transferrable. Yet, we also recognize the value of designing programs for, and seeking evidence of, more direct outcomes. The emphasis on behavioral antecedents in the empirical literature may relate to difficulties inherent in documenting environmental improvement and conservation outcomes as well as linking that evidence through a causal chain to educational programming and interventions as well as other social strategies ([Baynham-Herd et al., 2018](#); [Johnson, 2013](#); [Thomas et al., 2018](#)). Accurately measuring and reporting on conservation and environmental quality outcomes requires intensive investment of time and resources, as those outcomes manifest over time and require creative, careful, human-resource-heavy efforts to document ([Fien et al., 2001](#); [Kuhar et al., 2010](#); [Trehwella et al., 2005](#)). Compounding this, environmental education is often deployed as part of a suite of strategies, particularly when it occurs within a conservation organization or agency setting ([Ardoin and Heimlich, 2013](#); [Fien et al., 2001](#); [Johnson, 2013](#); [Krasny et al., 2010](#)). Although this embedded structure can enhance environmental education's efficacy by leveraging complementarity among approaches, it can also complicate measurement ([Carleton-Hug and Hug, 2010](#); [Heimlich, 2010](#)).

In our overall sample, 56 articles reported *direct outcomes* of observed behavior, action projects completed during the course of a program, or changes in ecological indicators. The remaining 49 studies reported one or more of what we categorized as *indirect outcomes*, including behavioral antecedents, self-reported behavior, and community capacity building. As those direct outcomes provide clearer, more visible, and easier-to-document evidence of environmental education's direct contribution to environmental quality and conservation improvement, we focused on that Direct Subsample for further analyses. We sought implications for conservation practitioners and environmental managers who may wish to, first, achieve more direct conservation outcomes and/or improve environmental conditions, and, second, measure and report those outcomes. Such programs are designed in such a way so as to provide strong evidence (through quantitative and/or qualitative measures) that supports environmental quality and conservation outcomes.

### 4.2. Designing environmental education to more easily document and report direct outcomes

From our focus on the 56 studies in the Direct Subsample, we highlight thematic implications for conservation practitioners, resource managers, and educators interested in designing and implementing environmental education programs with direct outcomes. Through a qualitative (narrative) analytic process, the following four themes emerged: (1) focusing on topics with a local focus; (2) forming partnerships for program implementation with scientists, natural resource managers, and local organizations; (3) integrating action projects into the educational program itself; and (4) being intentional, creative, and thorough in measuring and reporting program outcomes. We anticipate that implementing such recommendations will assist in forging a path toward measurable, documentable environmental quality outcomes. The common thread across the four themes is a connection to

synergistic spaces where research findings and knowledge converge with and within local communities and ecosystems (Toomey et al., 2017). Supporting productive research-implementation spaces by emphasizing a local focus, encouraging partnerships, taking local-scale action, and incorporating consideration of measurement and documentation from the outset, as well as co-developing those measures with stakeholders helps ensure more positive and productive research-implementation spaces. Concurrently, such considerations also help create conditions for documenting the ways in which environmental education might address on-the-ground environmental and conservation issues.

Citizen science is one environmental education approach that is receiving particular attention in the conservation biology field (Ellwood et al., 2017). When thoughtfully implemented following certain principles, citizen science reflects the four themes highlighted in our qualitative review. At its best, citizen science involves members of the general public participating in aspects of science initiatives, from design to implementation, that yield reliable, usable data (McKinley et al., 2017). Although citizen science can address issues at local, regional, and global scales, at its core it relies on collecting local-scale data, in some way, shape, or form (Theme 1: *local focus*). Many citizen science projects involve the public working directly alongside scientists (Theme 2: *forming partnerships*) on some type of research project (Theme 3: *action project*). As the production of useful data is a desired and clearly articulated goal, citizen science results, in a natural way, in data related to documented outcomes; moreover, citizen science's research focus facilitates collecting and measuring related data (Theme 4: *reporting program outcomes*).

Like environmental education more generally, citizen science creates a synergistic environment where scientists, local community members, and other stakeholders can productively navigate research-implementation spaces (Toomey et al., 2017). Although the 56 Direct Subsample studies rarely used the term "citizen science," several described programs that could be classified as such. Kühn et al. (2008), for example, reported on a program in Germany where members of the public volunteered in a butterfly monitoring program. Volunteers collected data over two years; upon review, researchers deemed the data of high enough quality for use in scientific analysis and research. Similarly, Lovell et al. (2009) described a terrestrial invertebrate monitoring program in South Africa. Scientists assessed data collected by Earth-Watch Institute volunteers to be comparable in quality to data collected by expert researchers. Other studies provided examples of environmental action that fits within the citizen science frame, yet termed the programs 'community-based research' (Dunbar et al., 2013) or 'participatory-action research' (Ballard and Belsky, 2010; Bywater, 2014; Mordock and Krasny, 2001). In sum, citizen science's participatory, research-oriented structure facilitates its alignment for conservation scientists and practitioners wishing to report direct outcomes, and several studies in our review (as described above) provide examples of implementation.

We compared certain characteristics of the Direct Subsample to those of the Indirect Subsample, finding that program topics impacted the type of outcome reported (direct or indirect). Specifically, climate change-focused programs were more likely to report indirect outcomes, while programs focused on more tangible issues, such as pollution, were more likely to report direct outcomes. This finding is perhaps not surprising: Given climate change's amorphous nature as well as broad temporal and spatial scale, environmental education programs that seek and document measurable climate change outcomes may struggle to produce locally visible, documentable outcomes in the short term. Our results do not imply that climate change programs cannot and should not be measured directly and, relatedly, that they cannot make a direct impact on environmental quality; in fact four of the Direct Subsample studies (Hollweg, 2009; Kinsey and Haberland, 2012; Lewis et al., 2014; Marcell et al., 2004) reported climate change outcomes by documenting changes in observed behavior and reporting completed actions. Lewis

et al. (2014), for example, demonstrated and documented participants' greenhouse gas reductions for actions such as waste disposal through composting and transformed transportation mode (walking to school, rather than driving). The participating school documented reaching its goal of saving 10 tons of greenhouse gas emissions. In a separate review of climate change education, Monroe et al. (2017) identified strategies for effective climate change education, which included emphasizing a personal, local connection and undertaking action projects. Overall, such findings suggest that, although some topics may lend themselves more readily to producing visible, direct environmental quality or conservation outcomes, at least in the short term, with careful planning and implementation, other programs concerned with topics broader in temporal and spatial scale, can also achieve success.

By contrast, programs focused on issues with tangible, local dimensions, such as pollution remediation, watershed improvement, or even biodiversity conservation, more readily scale, with the opportunity for action nested levels, from individual to group engagement. Such programs have the potential for satisfying, visible, tangible outputs, outcomes, and impacts. The results of such actions can be measured and documented, either with quantitative or qualitative data, or a combination of both. Programs in this category, which can result in direct physical environmental quality improvement, at least in the short term, include: removing invasive species from a natural area (Krasny and Lee, 2002), planting native species at a local nature preserve (Gladstone et al., 2006), and removing litter from sensitive habitat (Ollervides and Farrell, 2007; Unepetty et al., 1998).

Researchers, conservation organization professionals, and agency staff alike have viewed achieving and measuring direct environmental quality and conservation impacts through environmental education strategies as resource intensive and complex. With forethought and collaborative planning, however, such documentation may be less onerous and, in the end, more effective from a program as well as resource perspective.

#### 4.3. Study limitations and future research

A limitation of this systematic review, and one common to reviews more generally, involves selection of the final sample of studies. Our search terms focused on topics identified as important planetary boundaries but, as those topics can be challenging to address on a smaller scale, we unwittingly excluded studies focusing on more general, broader issues. Our English language criterion certainly resulted in excluding relevant work published in other languages. Moreover, to constrain the review and enhance the feasibility of our undertaking, we focused on peer-reviewed literature. High-quality research and evaluation absolutely exist outside of this dimension of the literature, yet the gray literature is more difficult to access systematically (Godin et al., 2015; Mahood et al., 2014). Future work would benefit from an in-depth search for relevant work in that aspect of the literature. Relatedly, readers must interpret our findings in light of possible publication bias (see discussion of publication bias in section 4.1). We echo prior calls for researchers and journal editors to publish more studies with null results (cf., Stern et al., 2014; Stevenson et al., 2019) and encourage conservation and environmental education professionals to embrace notions of learning from failure (Catalano et al., 2018).

Numerous studies exist documenting positive outcomes—from knowledge, to attitudes, to skills—that accrue to environmental education participants. Yet a persistent question for conservation and environmental stakeholders is: What good is environmental education for the environment? Our findings indicate, overall, positive trends related to participants' pro-environmental behaviors as well as, when documented, to direct actions that support conservation and environmental quality outcomes. Across the literature, however, we find a substantial opportunity for environmental education programs that are intentionally designed to pursue environmental quality and conservation outcomes. Relatedly, to date, the environmental education and

conservation fields have been challenged in developing and implementing measures that facilitate documenting conservation outcomes in ways that are specific, compelling, and visible.

Our findings suggest a need for future focus on several key areas of programmatic and research-and-evaluation emphasis. First, we find a need to develop and implement robust evaluation systems that more effectively track conservation and environmental quality outcomes. Within this context, a need exists to delve into the harder-to-measure ecological outcomes, such as short-, medium-, and long-term direct environmental impacts, as well as socioecological outcomes (Jacobson et al., 2015; Krasny and Roth, 2010; Mellish et al., 2019; Shirk et al., 2012; Thomas et al., 2018). Second, with regard to individual actions with direct impact, we find a need for more innovative ways to measure observable individual behaviors, as prior research suggests caution when relying on self-reported behavioral measures (Chao and Lam, 2011; Kormos and Gifford, 2014). Additionally, when environmental education programs are part of larger conservation efforts, or are one in a suite of interventions, few measures exist that effectively and specifically characterize environmental education efforts within the broader system (cf., Trewbella et al., 2005). Finally, as conservation and the behavioral sciences increasingly emphasize scaling up, recognizing and accounting for the importance of collective action, in addition to and/or in support of individual efforts, becomes increasingly important (Ardoin et al., 2013).

#### 4.4. Conclusion

When we initially started this review, we intended to include only articles that reported measured changes in an ecological indicator or a composite suite of indicators. We envisioned surfacing studies of environmental education programs that provided quantified data describing a change in, for example, air quality, water quantity or quality, acres of land with tree cover, or population numbers of a threatened species. We quickly realized, however, that few studies included all of the components originally sought. This gap in the literature spotlighted not as much a shortcoming in environmental education itself as a failure in our thinking: We failed to account for the nuance of operating within a complex coupled social-ecological system (Catalano et al., 2018). By redesigning the review to allow for more diverse pathways to, and robust understandings of, our outcomes of interest, we discovered the many varied ways in which environmental education can and does address environmental and conservation issues. In the articles surfaced in this review, conservation and environmental education researchers shared an increasing knowledge about the development and implementation of educational programming that has a range of outcomes across temporal and spatial scales. We found little support for a simple, linear model suggesting that, once an environmental education program is implemented, knowledge is shared, skills are developed, proenvironmental actions are undertaken (and documented) in clear, straightforward, and measurable ways—and, as a result, ecosystems are changed. Relatedly, we did not find support for a straightforward model suggesting that, when researchers share findings from research-and-evaluation reports and articles, the outcome is a commensurate shift in ecosystem quality. Instead, our findings suggest a collaborative path that creates an implementation space open to various stakeholders. In such a space, partners can negotiate meanings, co-design initiatives, innovate measures, and in this way enhance the likelihood that their shared undertakings will achieve concrete, measurable conservation and environmental quality outcomes.

Overall, the data and themes that arise from this review encourage intentionality, creativity, and inclusivity when developing and implementing programs that impact environmental quality and conservation outcomes and, relatedly, that glean data demonstrating this impact. The diversity of outcome data—knowledge, attitudes, capacity, opportunities for action, behavior, and ecological—suggests abundant options for researchers wishing to measure and report impacts. As

evidenced in the discussed themes, our recommendations emphasize practical, straightforward strategies, such as incorporating an action-project component into a discussion-based program; connecting with researchers to set parameters for ecological monitoring and ensure the data collected are useful in ongoing conservation research; basing programs in local natural areas; and designing conservation initiatives based on community needs. Reviewed studies highlight hands-on approaches, such as citizen science, and collaborative processes, such as participatory action research, which demonstrate ways in which the thematic findings apply to achieve educational and conservation outcomes.

Although publication bias may inflate reporting of overwhelmingly positive outcomes, overall literature-review findings remain unequivocal: environmental education can create synergistic research-implementation spaces that invite participation, collaboration, and co-production among diverse stakeholders (Lemos et al., 2018; Toomey et al., 2017). Through engagement in those generative spaces, environmental education research and practice contribute to transformative activity that can impact environmental quality through a variety of avenues—and, indeed, we can all benefit from those impacts, in the short and long term.

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#### Appendix A. Bibliography for the 105 final sample studies

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.biocon.2019.108224>.

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<sup>1</sup> Note: A complete bibliography of the 105 studies included in the final sample is available in an online supplement.

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