Course-based undergraduate research to advance environmental education, science, and resource management

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Main text

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Abstract

Course-based Undergraduate Research Experiences (CUREs) are widely regarded as a powerful way to engage students in experiential learning that results in well-documented pedagogical benefits. Much less appreciated, however, is the potential for CUREs to contribute long-term data that advance scientific knowledge and management. By providing the first global synthesis of CUREs in ecology, we map the geography and temporal extent of CUREs, review the data collected, highlight the benefits of these experiences to both students and instructors, explore the challenges that instructors face to maintain these research opportunities, and offer perspectives on how CUREs can more broadly contribute to science, management, and policy. To address missed opportunities associated with CUREs, we highlight how existing networks and resources, enhanced institutional support, and synergies with the broader science community can help them achieve their full potential for contributing to both education and ecological science for society.

In a nutshell

- CUREs collect diverse environmental data over time scales comparable to long-term ecological monitoring efforts.
- Instructors reported significant personal benefits to teaching CUREs, but modest academic gains and insufficient financial and institutional support.
- Students were perceived to gain a suite of academic skills through CUREs, a heightened understanding of the scientific process, and improved ability for collaboration.
- Most data collected by CUREs are inaccessible to the scientific community.
- For CUREs to realize their potential, we recommend full democratization of CURE data with online repositories, leveraging synergies with long-term ecological research and citizen science initiatives, and higher levels of institutional support.

Inquiry-based instruction is a fundamental science teaching strategy in higher education with wide-ranging and well-recognized benefits (Schwab 1958; National Research Council 2012; Eagan *et al.* 2013). This form of research-driven learning is viewed as a welcome departure from education focused solely on content. It promotes engagement in the scientific process by encouraging students to pose research questions, generate and analyze data, draw conclusions, and communicate findings to diverse audiences. Teaching through inquiry is thought to foster scientific literacy and has the potential to improve both student understanding of science and engagement in science (Minner *et al.* 2010).

Inquiry-based instruction typically occurs in one of two types: project-based Undergraduate Research Experiences (UREs) occurring outside of curriculum requirements, or Course-based Undergraduate Research Experiences (CUREs) (Linn *et al.* 2015). UREs are considered apprenticeships where individual students spend multiple semesters in a research laboratory receiving one-on-one mentoring. However, most institutions of higher education lack the resources to involve all or even most undergraduates in UREs, and the structure of how students are selected for these positions can also be exclusive and perpetuate inequities in the research community (Auchincloss *et al.* 2014; Bangera and Brownell 2014). CUREs, by contrast, provide research opportunities and educational benefits to a broader number and diversity of students (Auchincloss *et al.* 2014; Corwin *et al.* 2015). CUREs offer students opportunities to develop their conceptual understanding by integrating lectures and readings with hands-on research experiences (Shaffer *et al.* 2014) and can significantly influence their academic and career paths (Eagan *et al.* 2013; Auchincloss *et al.* 2014).

Ongoing research focuses on the educational and psychosocial outcomes associated with CUREs (e.g., Linn *et al.* 2015; Anderson *et al.* 2020). Much less appreciated, however, is the potential for these efforts to contribute to greater and more widespread understanding of ecological systems. Long-term environmental research is considered fundamental for testing and developing theory, for understanding complex ecological and evolutionary patterns, and for capturing non-stationary processes and ecological surprises, all of which are critical to inform natural resource management and policy (Callahan 1984; Lindenmayer *et al.* 2010; Kuebbing *et al.* 2018). In fact, the last decade has seen a rise in the number of synthesis centers that capitalize on large ecological datasets, ranging in subject from the gene to the biosphere, to fuel transdisciplinary collaborations (Hampton and Parker 2011; Baron *et al.* 2017). Many scientists

and funding agencies approach long-term projects with trepidation because of perceived financial and logistical obstacles. However, recent attention has focused on leveraging the enthusiasm of students, and more broadly citizen scientists, to generate valuable long-term environmental datasets (Dickinson *et al.* 2010; Hoopes *et al.* 2013; Quinn 2015; Ryan *et al.* 2017).

Given the seemingly widespread occurrence of CUREs across institutions of higher education, we ask whether ecological and environmental data collected by undergraduate students as part of course curricula represent a valuable, albeit underappreciated, contribution to the natural sciences. By providing the first global synthesis of CUREs in ecology, we map the geography and temporal extent of CUREs, review the data collected, highlight the benefits of these experiences to both students and instructors, and explore the challenges that instructors face to maintain these research opportunities. We then explore opportunities for the better assimilation and dissemination of the vast data generated from CUREs, as well as call attention to existing resources and networks for supporting CURE instructors. Finally, we share our perspectives on how CUREs can more broadly contribute to science and management, including through enhanced collaborations with existing Long-Term Ecological Research (LTER) and citizen science initiatives.

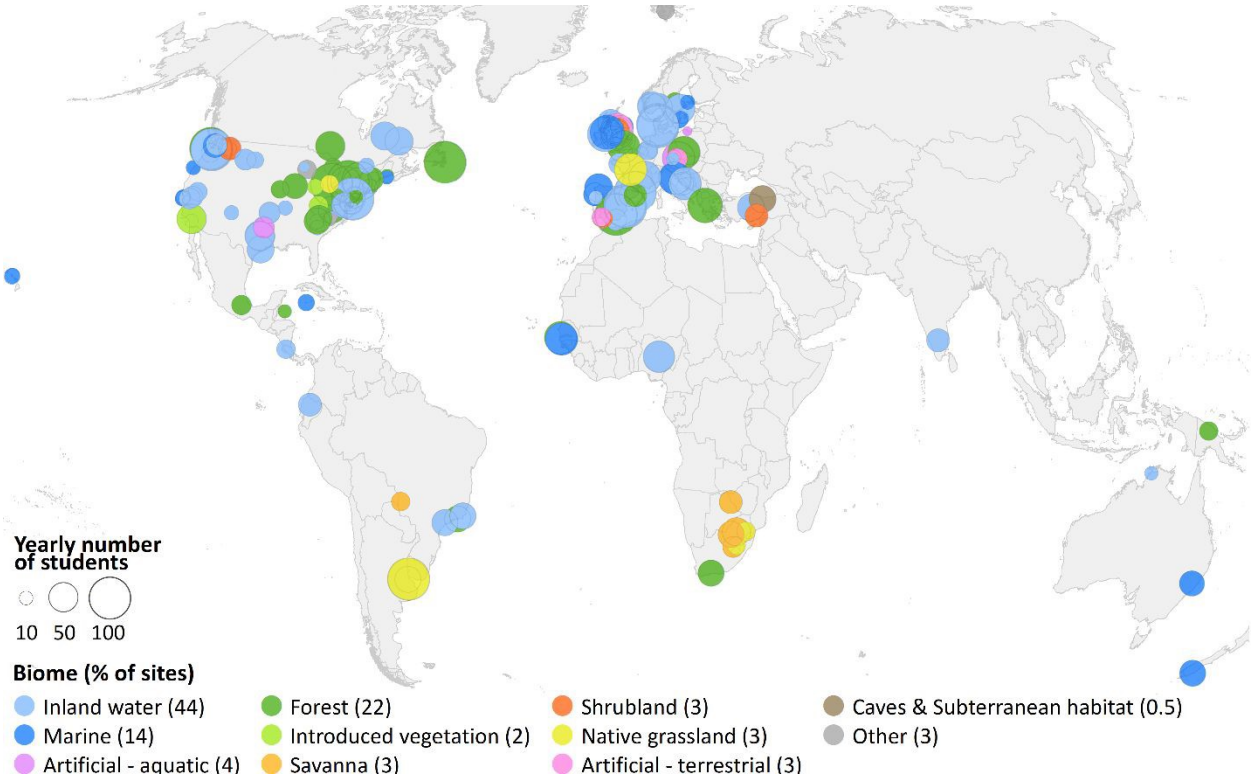
A global survey of CURE instructors

We conducted a standardized online survey of CUREs involving the collection of ecological and environmental data with the aim to gather information about their distribution and characteristics, challenges in implementation, and the scientific opportunities and outcomes associated with data collection for both students and instructors. The survey was targeted at instructors from institutions of higher-education who are currently leading, or have led, undergraduate student collection of ecological data through course-based activities. To reach survey participants, we systematically searched for and contacted ecological scientific societies (via e-mail and social media, if applicable) to request that the survey be announced to all society members (see **WebPanel 1** for details on survey deployment, and **WebPanel 2** for the survey). The invitation also included a request that society members forward the survey on to relevant contacts and colleagues within their network. The final list included 103 ecological societies located in 50 countries, and an additional 26 ecological societies with significant continental or

116 international membership (**WebTable 1**). A summary of survey responses is presented in
117 **WebPanel 3**.

118 **Widespread and diverse long-term data collection by CUREs**

119 The distribution of CUREs is widespread, both geographically and ecologically (**Fig. 1**). The 132
120 respondents surveyed here were affiliated with at least 111 institutions of higher education in 31
121 countries. Through their work, at least 60,500 students have been involved in ecological data
122 collection across 220 field locations spanning most biomes on the planet.



123

124 **Figure 1. Global distribution of ecological field data collection through course-based**
125 **undergraduate research experiences.** Point colors show the biome of the field sites (n_{sites}=220)
126 associated with CUREs (n_{CUREs}=115, some CUREs were associated with multiple field sites, and 17 out of
127 132 respondents did not provide site locations), and point sizes reflect the yearly student enrollment
128 participating in data collection. The percentages of sites per biome do not add up to 100 due to rounding.
129

130 The wealth of data collected through CUREs represents an ecological record of global
131 significance, further underlining their scientific and educational value (**Fig. 2A**). Nearly all
132 (99%) CUREs surveyed here collected biological data, including information on the occurrence,

abundance, density, or biomass of one or more plant or animal species (95%). More than half of field excursions involved the simultaneous collection of biological, physical, and chemical data, with each investigating an average of three biological, five physical, and five chemical variables. In total, the respondents reported nearly 15,500 days of data collection.

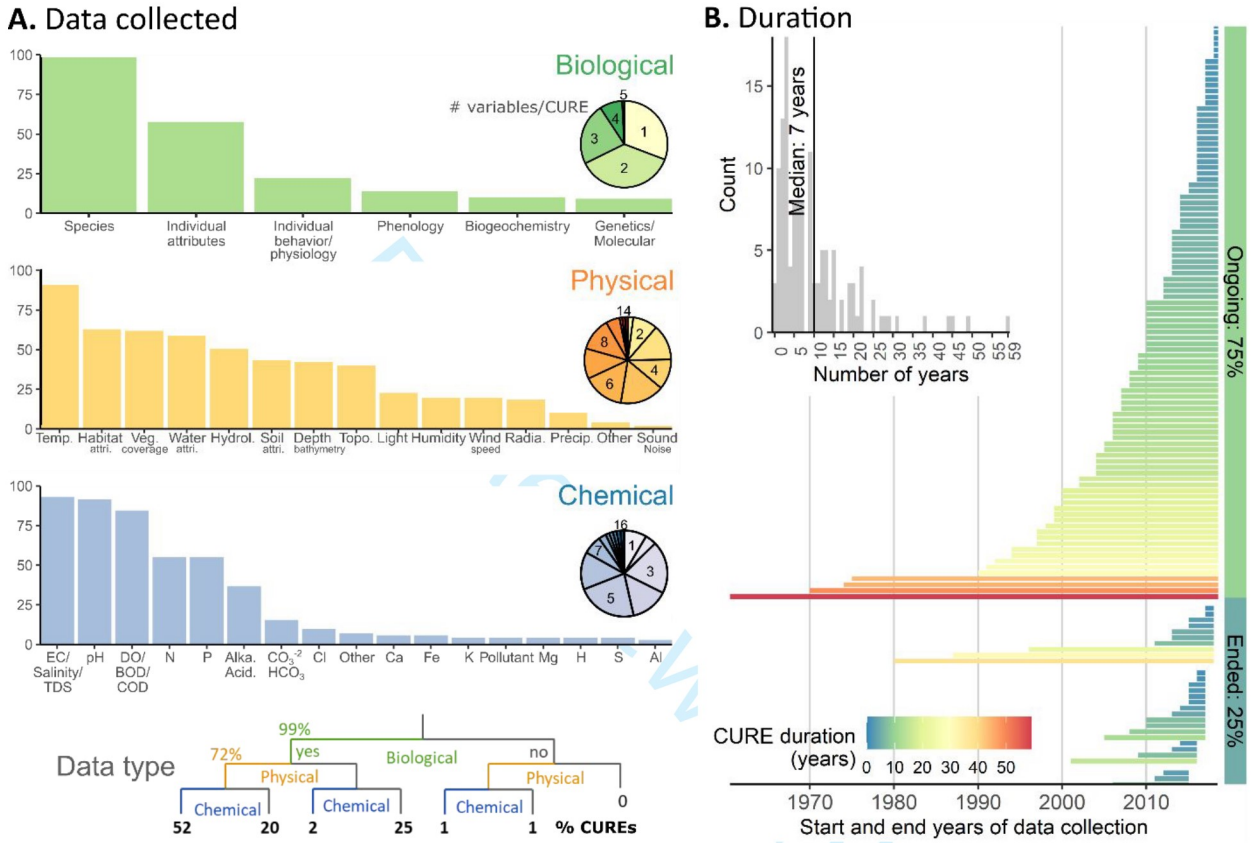


Figure 2. Types and duration of ecological field data collected by course-based undergraduate research experiences (n=132 CUREs). (A) Histograms indicate the percentage of surveyed CUREs collecting each variable by data type (biological, physical, or chemical), pie charts indicate the number of variables by data type per CURE, and the classification tree shows the % of CUREs collecting different combinations of data types. (B) The colored bar chart shows the start and end year of field data collection across all CUREs and the inset (grey) histogram shows the distribution of CURE durations.

Our study confirms that CUREs offer opportunities for longer-term data collection (Quinn 2015). Being embedded in a standard educational curriculum can afford CUREs relative stability over time (**Fig. 2B**). More than a fifth of the CUREs documented through this study have collected datasets exceeding 15 years, with a median and maximum duration of 7 and 59

149 years, respectively. By comparison, the median time since establishment of the 733 sites in the
150 International Long Term Ecological Research (ILTER, Mirtl *et al.* 2018) network is 24 years,
151 and a quarter have been established for 14 years or less (as of 2018 at the time of the survey; year
152 of establishment retrieved from the ILTER data repository API at https://deims.org/; Wohner *et*
153 *al.* 2019). The duration and scope of data collection by CUREs creates the potential to
154 meaningfully contribute to long-term ecological research.

155 **CUREs benefit students and instructors, but are associated with significant challenges**

156 *Benefits of implementing CUREs*

157 Respondents strongly agreed that both students and instructors benefit from participating in
158 CUREs in terms of personal growth (**Fig. 3)**. Over 95% of instructors moderately to strongly
159 agreed that students likely benefitted from collecting and analyzing ecological data by
160 developing a heightened awareness of the natural world, an increased interest in the topic area,
161 and deepened relationships with classmates. By contrast, few instructors found that CUREs
162 allow students to network with scientists, with over half (58%) reporting little to no networking
163 benefits. Students were also reported to gain a suite of academic skills, both hard and soft. The
164 most noticeable gains in terms of hard skills were increased fluency in field sampling (average
165 score = 2.6 out of 3.0, based on a Likert scale from 0 "no gain" to 3 "high gain") and data
166 analysis (2.3). In terms of soft skills, students were perceived by instructors to grow most in their
167 understanding of the scientific process (2.4) and ability to perform collaborative research (2.3).
168 However, instructors reported varied skill gains in laboratory methods (1.9), scientific writing
169 (1.8) and public speaking (1.5), presumably due to our focus on field-based CUREs. We
170 acknowledge that these results reflect the instructors' perceptions of benefits to students rather
171 than the perception of students themselves, which we recognize is highly valuable. However, the
172 multifaceted goal of our survey required that we target instructors. Moreover, our results are
173 consistent with student-oriented studies that found increased long-term interest and connection
174 with research associated with participation in CUREs. For instance, CUREs facilitate stronger
175 research connections as a result of greater ownership in data collection and analysis (Corwin *et*
176 *al.* 2018; Cooper *et al.* 2020), better understanding of the scientific process (Olimpo *et al.* 2016),
177 and increased opportunities to engage with an instructor and classmates (Quinn 2015). In this

way, CUREs may also play a significant role in (re-)establishing connections with nature that facilitate long-term environmental engagement and conservation advocacy (Mitchell *et al.* 2017).

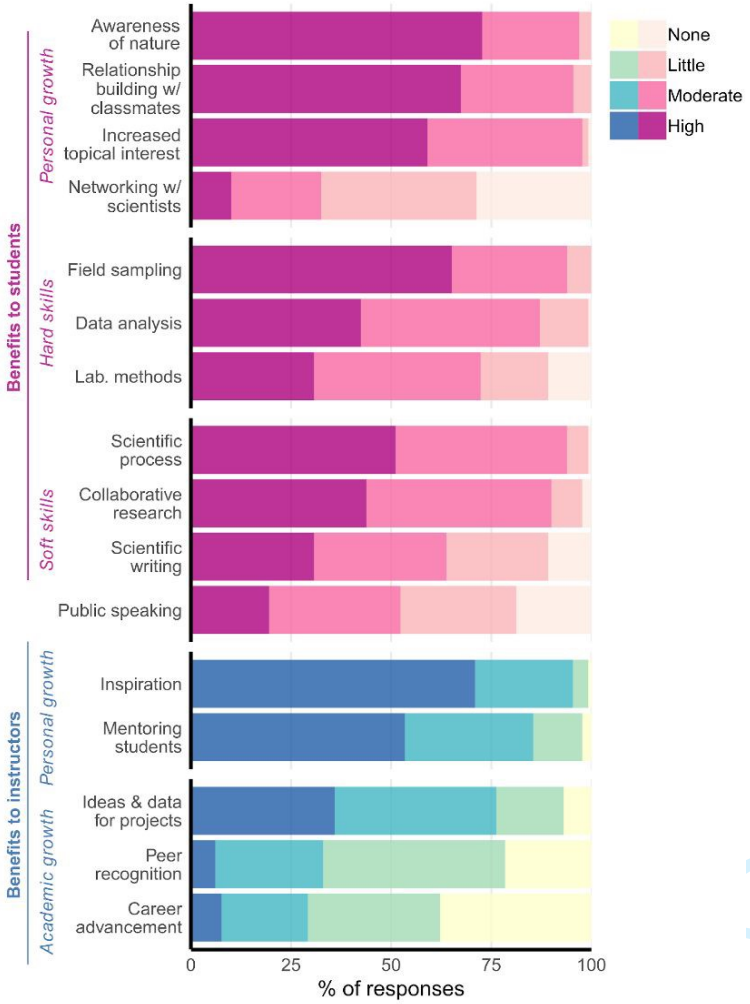
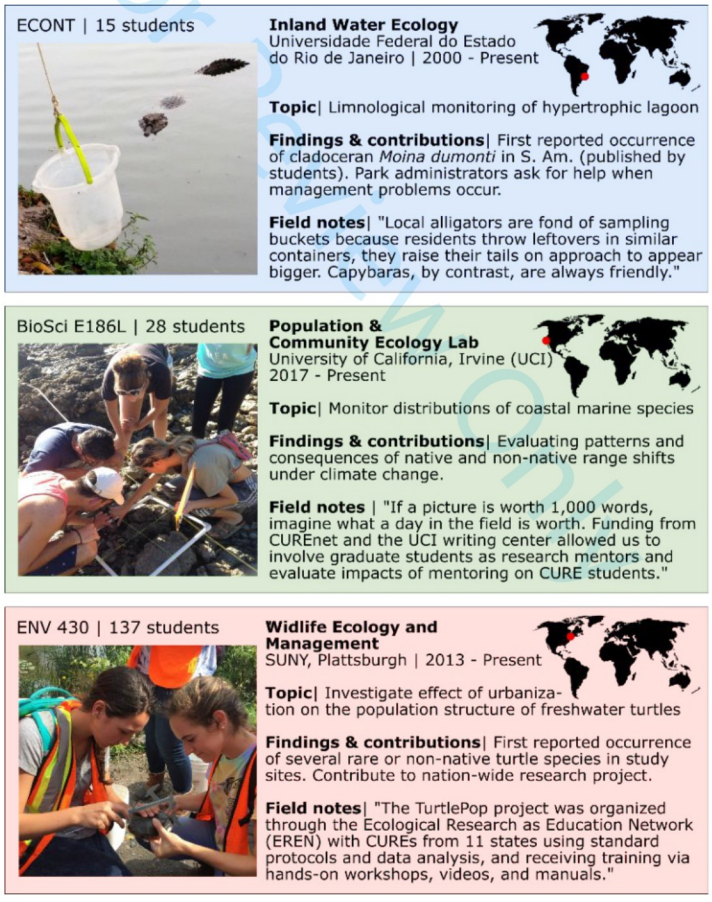


Figure 3. Benefits to students and instructors from participating in and teaching CUREs, respectively, as perceived by current and past instructors (n = 132).

Instructors were nearly unanimous in reporting high to moderate personal benefits from mentoring students (2.4), and the inspiration (2.7) that comes with teaching a class involving ecological data collection. CUREs also often sparked new ideas for future projects (2.1). Of those instructors that have organized CURE field excursions for more than five years, close to half (45%) have also used the class data for other projects. For example, more than a quarter of CUREs surveyed here have helped inform a management or conservation outcome, led to environmental outreach, or supported other long-term data collection efforts (see **Fig. 4** for examples). Further, 19% of surveyed instructors reported publishing peer-reviewed articles based

191 on CURE field data for a total of 67 publications, of which a high proportion (74%) involved
192 students. Generally speaking, these results align with a qualitative study of faculty perspectives
193 by Shortlidge *et al.* (2016), where high percentages of instructors reported personal enjoyment,
194 expanded research ideas and publications as benefits of teaching CUREs.

195 With respect to personal benefits, CURE instructors reported only modest academic
196 gains. Most respondents (56%) reported earning little to no peer recognition (1.2) or career
197 advancement (1.0) from teaching a CURE (**Fig. 3**). This result presents a troubling contrast with
198 Shortlidge *et al.* (2016), who reported that more than two-thirds of instructors agreed that
199 teaching a CURE could contribute to promotion or tenure — although this discrepancy may be
200 explained, at least in part, by the high levels of institutional or structural support reported in their
201 study (discussed more below).



202

203 ***Figure 4. CUREs contribute to education, environmental science and management.***
204 *Photographs credits and associated publication: Christina Castelo Branco, Da Silva Farias et*
205 *al. 2017 (top); Cascade Sorte (middle); and Danielle Garneau, Bowne et al. 2018 (bottom).*
206

Challenges to implementing CUREs

Several widespread challenges were reported in implementing or sustaining CUREs (**Fig. 5A**). Most instructors reported insufficient financial and institutional support (e.g., lack of technicians, teaching assistants, academic recognition) as their two top challenges, followed by a lack of time to invest in the course. These difficulties are likely what led instructors to enlist outside help: while 51% of CUREs were entirely financed by their university or academic department, the remaining relied at least partially on additional fees paid by students (34%), personal funds contributed by the instructors (13%), and funds from an outside organization that included other universities, government agencies, and citizen science groups (10%). Beyond financial support, nearly half of CUREs also depended on an outside organization for logistical assistance, including access to field locations, staff, and equipment. These findings reflect the logistical complexity, additional instructor time, and higher costs that are often cited as a hurdle to implementing CUREs as compared with standard courses in ecology (Quinn 2015; Shortlidge *et al.* 2016). Our survey therefore suggests that, despite the well-documented pedagogical benefits of CUREs, standard institutional support is a consistent challenge to implementing and sustaining them.

Beyond benefits to students and instructors, the potential for CUREs to contribute more broadly to science and management largely resides in reliable access to datasets and publication of CURE-based research. Despite this, instructors in our survey reported that their ecological data are rarely shared and are vulnerable to being lost or destroyed. Only 28% of respondents currently share data collected as part of a CURE (**Fig. 5B**). Of these, most datasets are available only upon request, with varied conditions of use including authorship (30%) or acknowledgement (19%). Encouragingly, one third of those who do not currently share data are willing to make them openly available online, the majority of which (89%) requiring at least an acknowledgement or citation, and half (49%) requiring authorship.

The lack of accessibility of CURE data partly compounds their vulnerability to being pushed to obscurity. As previously discussed, 19% of respondents had published peer-reviewed articles based on CURE collected data, indicating the potential for CURE data to routinely contribute to broader research knowledge. However, difficulties in synthesizing and analyzing CURE data were commonly reported. A main challenge identified by instructors was inputting the raw field data into a database (48%). Furthermore, more than half (54%) of instructors

reported having data archived only locally either as hard copies or on local computer storage; an additional 11% have not analyzed the samples or archived data. Temporal or spatial gaps in data collection were also frequently cited (46% of respondents) as an analytical challenge. Gaps were typically due to logistical difficulties in implementing the protocol (e.g., weather, safety concerns, 64%), staff or funding shortages (33%), or a lack of instructor time (31%). It is worth noting, however, that only a third of the surveyed CUREs reported gaps amounting to more than 10% of the study period. Finally, respondents listed low confidence in data quality (60%), class-specific design (70%), and lack of time (41%) as the primary reasons for not using the data outside of class-based projects.

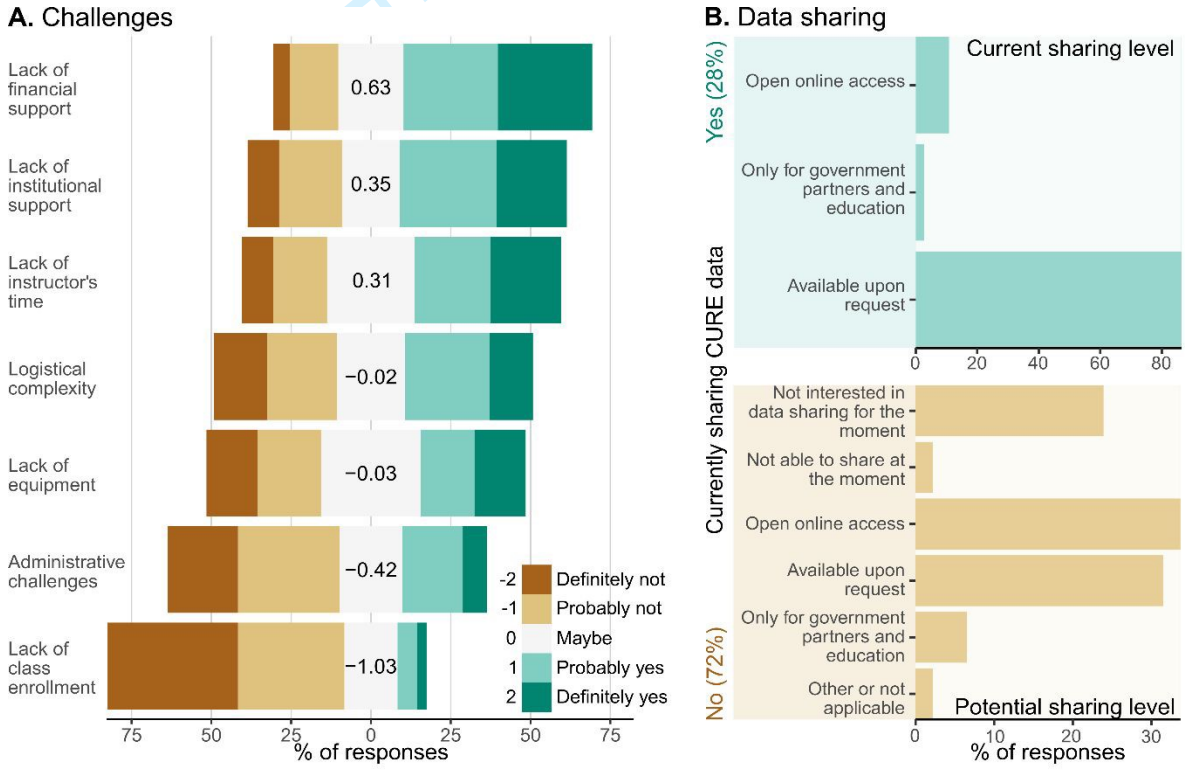


Figure 5. Challenges and data sharing practices reported by past and current CURE instructors (n = 132). (A) Main challenges in teaching a CURE reported by instructors. The numbers in black are the average scores based on a Likert scale from "definitely not" (-2) to "definitely yes" (2). (B) Levels of CURE data sharing by instructors; the top-right histogram shows the levels of sharing for instructors that currently share data; the bottom-right histogram shows the levels of sharing at which instructors who do not currently share data would be willing to share.

Perspectives on ensuring the scientific value and sustainability of CUREs

CUREs require careful implementation, robust institutional backing, and support from the broader science community to achieve both educational and scientific goals. Instructors are responsible for the educational experience of students and the maintenance of collected data, yet the burden of realizing the dual potential of CUREs to both educate students and advance ecological knowledge cannot fall on instructors alone. Networks and published guidance can assist instructors with launching and maintaining a CURE (Quinn 2015; Govindan *et al.* 2020, **Table 1**), but a suite of additional actions is necessary to ensure its value in supporting scientific research and management.

Leveraging existing frameworks and resources may help instructors design and implement CUREs more easily and efficiently, and support democratizing the collected data. Existing networks of CURE instructors such as the Ecological Research as Education Network (EREN) and CUREnet (**Table 1**) provide networking opportunities, project ideas, course material, and other practical advice to design and sustain CUREs. As open science continues to be promoted in the ecological sciences, equipping students with the skills required for data sharing as part of the course curriculum is critical (Hampton *et al.* 2013). Data repositories hosted by CURE networks provide low-barrier opportunities to archive and pool collected data among instructors while generalized data repositories (e.g., Dryad, figshare, Environmental Data Initiative) can be leveraged to connect and share data more broadly (**Table 1**). Journals specializing in the publication and description of datasets also offer a way to cite and credit dataset authors, combining open-access with peer-review and citation tracking (Walters 2020).

Along with networking opportunities and published guidance that assist instructors, we urge established networks of CURE instructors to continue advocating for increased institutional support. Increased support in the form of time, funding, and recognition can help alleviate the individual burden assumed by instructors to ensure CURE longevity and impact, including archiving data in publicly accessible data repositories with standardized metadata (Fegraus *et al.* 2005; Karasti *et al.* 2006; Jones *et al.* 2019). Individual researchers remain reluctant to develop CUREs because their professional success depends on producing publications at high frequency and on shorter-time frames (Kuebbing *et al.* 2018, see **WebPanel 4** for comments by surveyed instructors). Establishing or maintaining a CURE warrants institutional recognition as mentoring,

teaching and research, and should be valued for academic promotion and tenure (Morrison *et al.* 2019).

In evaluating the potential of CUREs to advance scientific research, we find strong convergence with two practices in ecology: long-term ecological research (LTER) and citizen science. Survey respondents emphasized similar challenges in implementing CUREs as have been identified in LTER. Common challenges include maintaining resources and research focus over time, and reconciling the value of long-term investment with institutional and professional rewards for short-term outcomes (Kuebbing *et al.* 2018). CURE instructors can leverage the structure and consistency of data collection protocols developed by LTER observatories with minimal time investment, while expanding and using datasets that promote student learning, analysis, and publication (Langen *et al.* 2014). One of at least three existing networks to promote and facilitate CUREs (**Table 1**) is already associated with two well-established LTER observatories: the U.S. National Ecological Observatory Network and the Global Lake Ecological Observatory Network. Some LTER networks even provide ready-made teaching modules (e.g., https://www.neonscience.org/resources/learning-hub/teaching-modules) that emphasize the analysis of long-term, high-frequency, and sensor-based datasets, which is especially needed to equip the next generation of ecologists with the quantitative literacy to enter the era of ecological big data (Langen *et al.* 2014; Klug *et al.* 2017). Simultaneously, LTER stands to gain through broadened exposure, new or expanded data collection, and value-added contributions to undergraduate education and training.

We also found that CUREs share many challenges and opportunities with community-based monitoring and citizen science initiatives. Citizen science is similarly tasked with the creation of meaningful research and protocols that can be implemented with consistency over time and by diverse practitioners. Surveyed CURE instructors reported challenges in consistent implementation of protocols by students, leading at times to low confidence in data quality. This is also a common problem in community-based and citizen science projects, leading to the development of mitigating processes and techniques (Dobson *et al.* 2020). Like CURE instructors, citizen science practitioners must also find ways to manage, archive, and publicize data (i.e., via analysis and publication of research or data) that may be collected over long time periods (Quinn 2015; Ryan *et al.* 2017). Citizen science platforms may offer features that can help instructors implement CUREs more efficiently and sustainably (**Table 1**). For example,

CUREs could be designed around existing citizen science projects (e.g., Rowland *et al.* 2016), or students could collect and contribute observations to global datasets (e.g., eBird or iNaturalist). The benefits of this approach for instructors include access to larger datasets and less time spent developing protocols and creating systems to archive and manage data — although additional considerations regarding the learning outcomes of the class would be required (Mitchell *et al.* 2017).

Alongside collaborating with and leveraging strategies from successful LTER and citizen science programs, instructors and students could benefit from the support of the global science community. For example, there is opportunity for those with robust open science backgrounds to strengthen networks and establish tools for integrating data across globally dispersed projects and platforms. CURE repositories from independent projects worldwide, similar to the one hosted by EREN, could also be included within a repository network like DataONE (https://www.dataone.org/) in order to bolster their visibility and prompt collaborations. Alternatively, national CURE networks could be expanded or launched to connect with international long term monitoring efforts (e.g., ILTER https://www.ilter.network/). When buttressed through networks, institutional support, and the broader science community, the many-fold benefits of CUREs such as training the next generation of scientists, making environmentalists of students, and providing data for research on crucial global processes cannot be understated.

Leveraging CUREs to advance science, management, and policy

CUREs are fostering the next generation of science professionals through their unique ability to include more students in experiential learning (NAS 2017). The technical skills and research experiences that students gain in the field, reported by our survey participants and across other studies, translate to intrinsic benefits such as increased scientific identity, perception of research ability, and emotional attachment to research (Cooper *et al.* 2020). Such intrinsic value associated with participation in CUREs promotes students' persistence in scientific fields, chance of graduating with a science degree, and intention to pursue a research-related career (NAS 2017; Hanauer *et al.* 2017; Corwin *et al.* 2018). Because CUREs reach more students than UREs while providing similar benefits, they increase the diversity and recruitment of graduates to meet the demands of the scientific workforce (Bangera and Brownell 2014; Hernandez *et al.*

2018). The role of CUREs in supporting more inclusive retention and recruitment of students to scientific careers alone should garner more institutional support and encourage broader implementation.

In addition to training students to become well-prepared scientists, CUREs are poised to contribute multiple benefits to ecological science by generating valuable long-term datasets that provide insight into ecological phenomena. A quarter of the CUREs we surveyed have already informed management or conservation actions, or contributed to ongoing long-term data collection efforts; a fifth have led to peer-reviewed articles. These results are indicative of the potential for CUREs to be more broadly integrated into the knowledge-generating process of research and subsequent management efforts in ecology. With sufficient support from their respective institutions, instructors and students can transfer the valuable research output generated by CUREs to the broader scientific community.

Finally, CUREs are comparable to other long-term ecological research practices in their potential to inform management and policy. The relative stability of CUREs afford them sufficient longevity to detect long-term trends and assess drivers of environmental change (White 2019; Cusser *et al.* 2021). Understanding such trends can disproportionately contribute to science-based management actions and shape policy discussions (Hughes *et al.* 2017). These contributions are unlikely to be reported outside survey tools or may be difficult to identify through typical keyword searches in publication databases. Additionally, data from CUREs may be subject to negative perceptions of reliability which could limit their application to decision-making (Kosmala *et al.* 2016; Lee *et al.* 2020). Continued use and development of best practices in data collection, management and archiving will only serve to facilitate greater confidence in CURE-generated data. By utilizing existing research structures, democratizing collected data and publishing research findings, CUREs can simultaneously provide robust science and train the next generation of scientists needed to tackle the grand environmental challenges faced by society.

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Table 1. Available resources to support current and prospective CURE instructors.

Type	Resource	Features to support CUREs
CURE network	CUREnet	· National network to share information, opportunities, and best practices for CUREs · Training (e.g., CURE Institutes) for instructors to implement CUREs · Curated collection of CURE projects that can be implemented locally
	Ecological Research as Education Network (EREN)	· Ecological research and education network aimed at primarily undergraduate institutions · Curated collection of CURE projects that can be implemented locally · Data repository and sharing platform · Strong links with national monitoring efforts (e.g., NEON, GLEON)
	Undergraduate Field Experiences Research Network (U-FERN)	· Collaborative network focused on fostering effective undergraduate field experiences by identifying and sharing evidence-based practices · Interdisciplinary network promoting inclusive research experiences
Citizen science project finders	Zooniverse, SciStarter	· Platform to engage a broader community in research projects · Development of protocols using citizen-science based platforms may address need to rapidly train students · Fosters a strong community of practice in support of project sustainability
Crowdsourced data	eBird, iNaturalist	· Offers existing standards (e.g., BioBlitz) for data collection and submission · Data archiving and sharing is immediate · Similar data collected from other locations can be queried for analysis
General digital repository	Dryad, figshare	· Universal digital repository for diverse data types · Meets journal standards for public access in publishing · Tags allow grouping and searching of similar data types
Environmental digital repository	Knowledge Network for Biocomplexity, Environmental Data Initiative	· Provides a platform to publish datasets that are readily cataloged with Digital Object Identifiers · Ensures detailed metadata to improve proper and increased use of data
Peer-reviewed data publication	Scientific Data, Biodiversity Data Journal, Data in Brief	· Allows for data publishing with metadata · Provides citable credit to authors for datasets · Standardized detailed descriptions and open-access make data easier to find and reuse

Course-based undergraduate research to advance environmental science and management

Web material

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WebPanel 1. Survey deployment.

We used the Google search engine to compile a list of international, continental, and national-level scientific societies focused on ecological research using the key terms: "ecology", "conservation", "limnology", "marine ecology", "restoration", "society", and "association" for the following seven global regions: "Africa", "Asia", "Central America", "Caribbean", "Europe", "Oceania", "North America", "South America". After the compilation of this list (**WebTable 1**), we contacted societies individually and requested that they circulate our survey within their members and collaborator network through email lists and social media platforms (i.e., Twitter and Facebook). The survey invitation also included a request that society members pass forward the survey on to relevant contacts and colleagues within their professional and social media network (the full invitation letter template is provided below). A summary of survey responses is provided in **WebPanel 3**.

Invitation letter template:

Dear <<society name >> Members,

We are seeking information from instructors at institutions of higher-education who are currently leading, or are interested in leading, efforts to collect ecological data through class-based activities. This survey takes approximately 15 - 20 minutes to complete, and will contribute to a global review on the extent and types of ecological data collected by students, and provide insight into the opportunities and challenges associated with these class-based efforts to support desired educational and scientific outcomes. We ask that you complete this survey and/or forward this survey to colleagues or your association list-serve (if applicable). The survey can be found here: https://tinyurl.com/EcolDataSurvey. We ask that you complete the survey by **May 17, 2018**. All responses are anonymous.

Background

Many classes (courses, units, modules) in institutions of higher-education (universities, colleges) have field excursions where instructors guide students in the collection of ecological and environmental data. Although data collection during class field excursions are undoubtedly occurring, there is little understanding of the geographic extent and characteristics of these

efforts, and the institutional and logistic challenges and opportunities that instructors have when maintaining, or considering new, class field excursions.

In order to address this issue, we are seeking the opinion of instructors from institutions of higher-education. Please click here for the survey link and complete the survey. Also, we ask that you forward this e-mail to any colleagues or organizations to reach other instructors who are currently, or might be interested in, leading class-based efforts to collect ecological data. If you have any questions or concerns, please feel free to contact the Olden Research Lab (oldenlab@uw.edu). Thank you very much for your time!

Sincerely,
Higher Education Ecological Data Survey (HEED) Team
School of Aquatic and Fishery Sciences, University of Washington

WebPanel 2. Survey instrument.

See PDF attached.

Higher Education Ecological Data (HEED)

Start of Block: 1. Introduction/Survey invite

Q1.1 **Welcome to the Higher Education Ecological Data (HEED) survey!**
We are seeking information from instructors from institutions of higher education* who are currently, or are interested in, leading class-based activities to collect ecological data. This survey takes approximately 15-20 minutes to complete. Your participation will contribute to a global review on the extent and types of student ecological data collection, and provide insight into the opportunities and challenges associated with these class-based efforts to support desired educational outcomes. We ask that you complete this survey and/or forward this survey to colleagues or your association listserv (if applicable). All responses are anonymous.
We welcome any questions or comments and thank you for your help. Sincerely, The Freshwater Ecology and Conservation Lab
School of Aquatic and Fishery Sciences, University of Washington
website: https://depts.washington.edu/oldenlab/ | email: oldenlab@uw.edu *teachers, professors, lecturers in universities or colleges

Q1.2 Do you consent to taking this survey? All respondents that complete this survey by May 17th can be entered into a drawing for one of two $50 gift cards by entering their email address at the end.

- ○ Yes
- ○ No

End of Block: 1. Introduction/Survey invite

Start of Block: 2. Have Data

WebPanel 3. Summary of survey responses (n = 132). Numbering (e.g., Q2.2) corresponds to survey instrument (WebPanel 2). Only questions for which the results were not plotted in the main text are included.

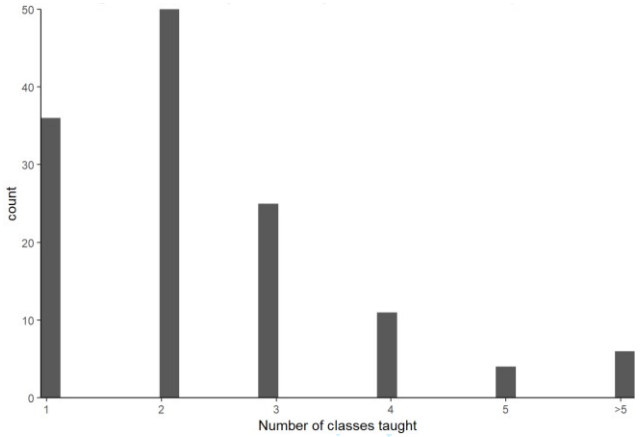


Figure S3.1. Survey responses to Q2.2 "How many classes have you or do you currently teach that involve at least one field excursion to collect ecological data?"

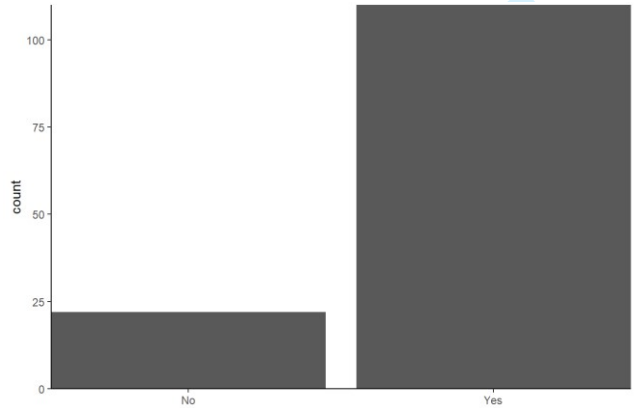


Figure S3.2. Survey responses to Q2.4 "Are/were the ecological data collected during the field excursion(s) retained after the class' end date?"

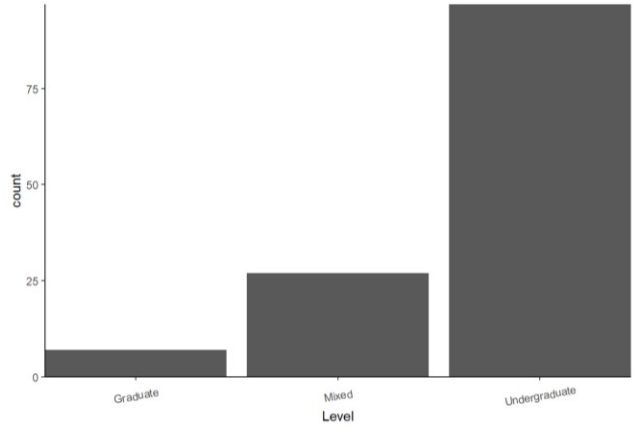


Figure S3.3. Survey response to Q8.2 "For what level of higher education is/was the class offered?"

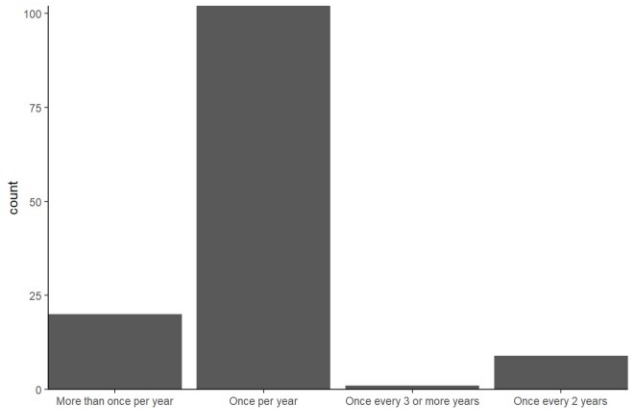


Figure S3.4. Survey responses to Q8.3 "How often is/was the class offered?"

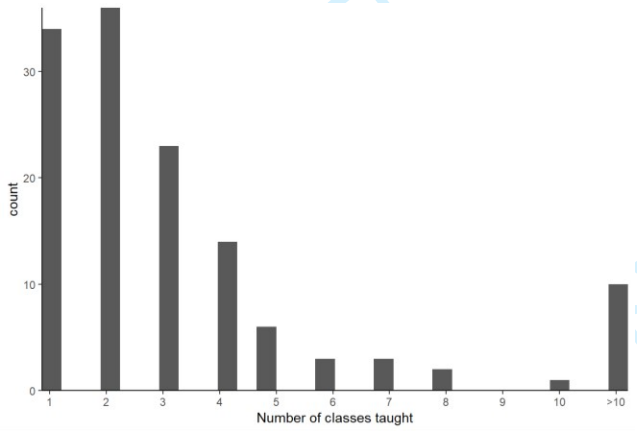


Figure S3.5. Survey responses to Q8.4 "Including yourself, how many instructors (and teaching assistants) are/were involved in implementing the field excursion(s) in a typical year?"

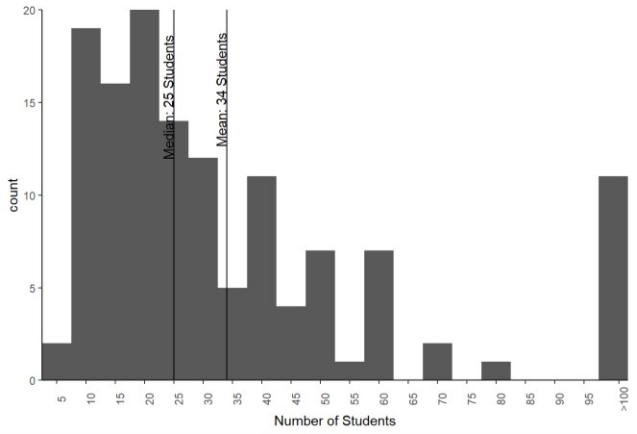


Figure S3.6. Survey responses to Q9.2 "What is/was the total number of students participating in the field excursions in a typical year?

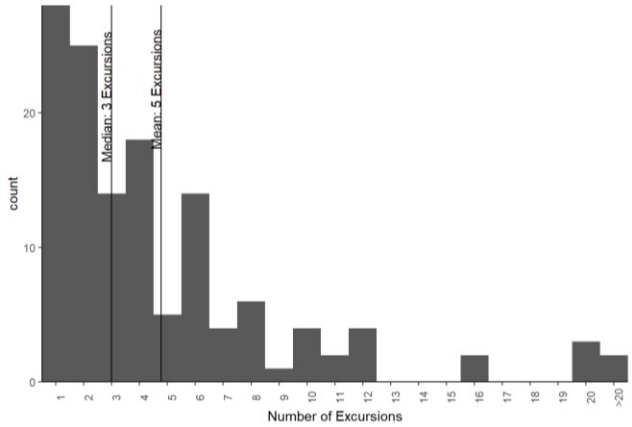


Figure S3.7. Survey responses to Q9.3 "In how many field excursions are/were ecological data collected during the class?"

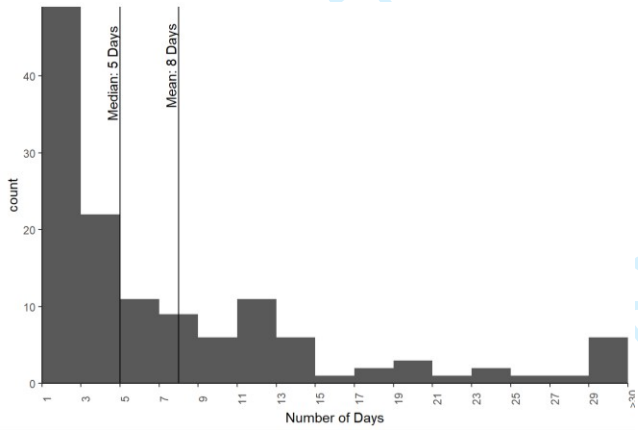


Figure S3.8. Survey responses to Q9.4 "How many total days of ecological data collection are/were involved across all field excursions in a typical year?"

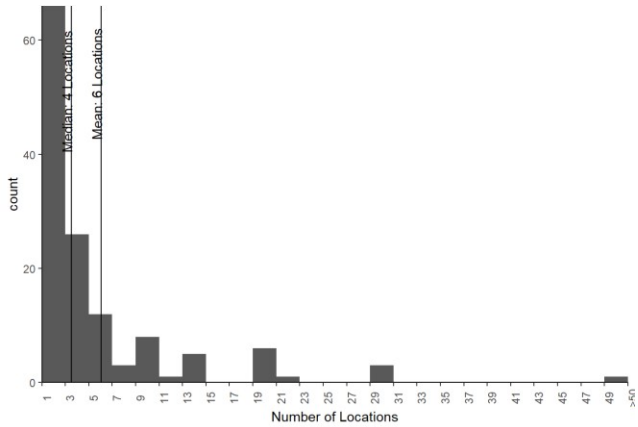


Figure S3.9. Survey responses to Q9.5 "Across all field excursions, in how many locations does/did the class collect ecological data?"

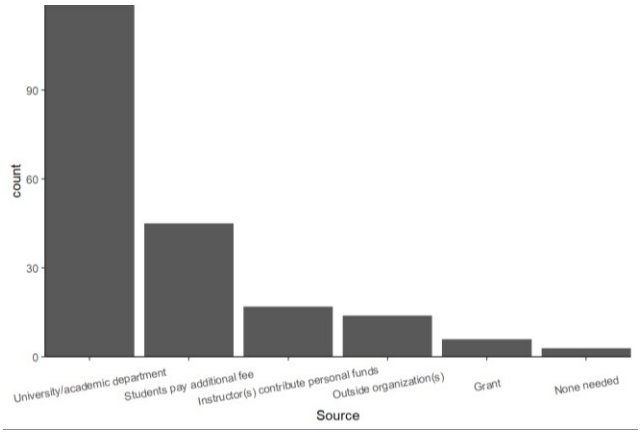


Figure S3.10. Survey responses to Q10.3 "What are/were the typical funding sources to support the field excursion(s) costs?"

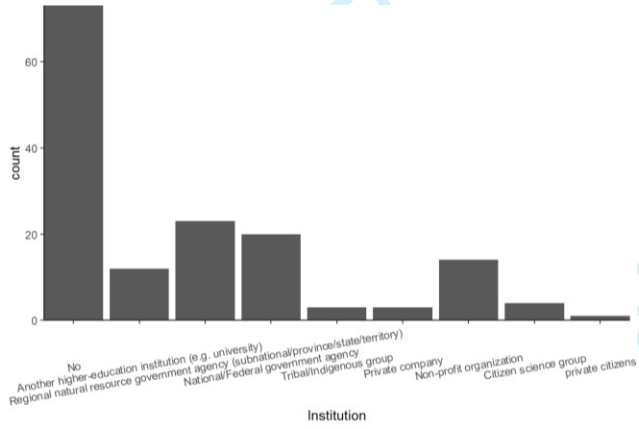


Figure S3.11. Survey responses to Q10.4 "Does/did an organization outside of your higher-education institution provide some level of support to the field excursion(s), including financial, staff, equipment, and other logistical support like site access?"

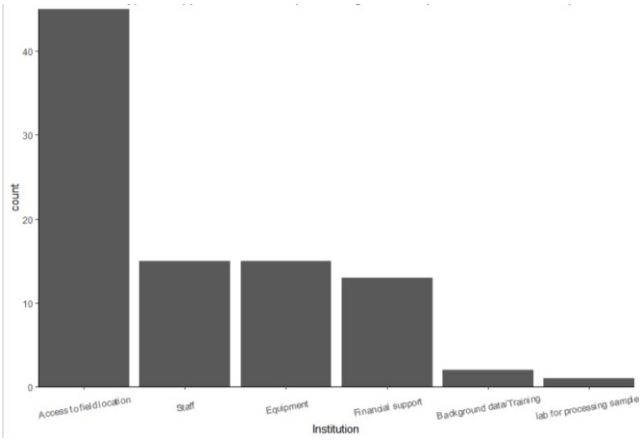


Figure S3.12. Survey responses to Q10.5 "What type of support do/did these partner organizations provide?"

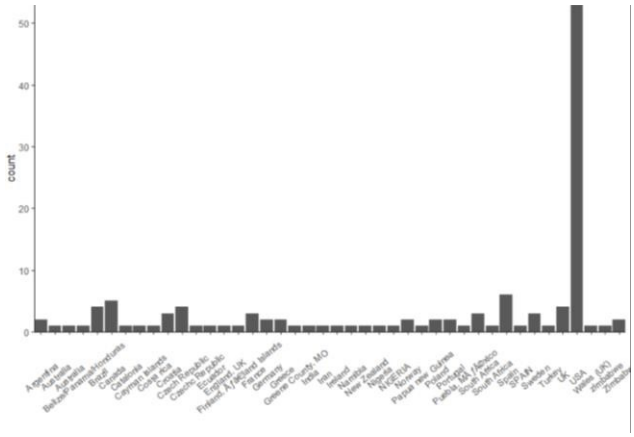


Figure S3.13. Survey responses to Q11.2 "Please enter the country where the ecological data are/were collected in the text box below."

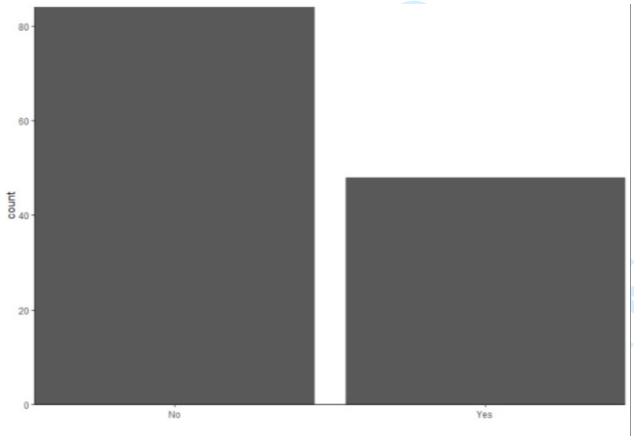


Figure S3.14. Survey responses to Q13.2 "Did you collect the data with the intention to study a specific threat to the factors of interest/environment?"

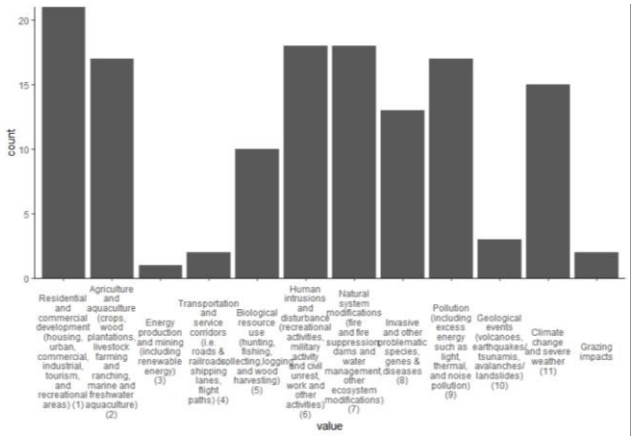


Figure S3.15. Survey responses to Q13.3 "What threat(s) is/was the data collection intended to study? *Please check all the threats that apply (for more details on the Threats Classification Scheme, Version 3.2, see IUCN documentation).*"

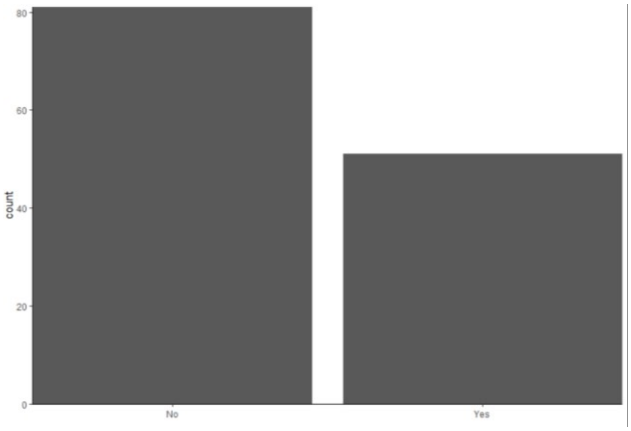


Figure S3.16. Survey responses to Q15.3 "Have you ever used the data collected in this class outside of class-based projects (e.g. publications, blog posts, grant proposals)?"

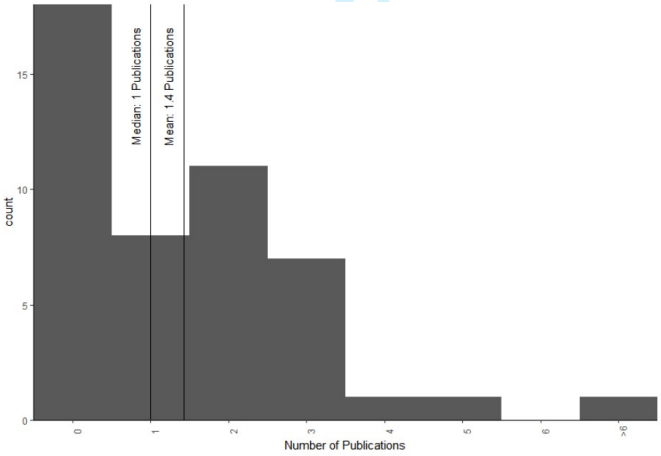


Figure S3.17. Survey responses to Q15.4 "How many peer-reviewed publications have resulted from the data collected in this class?" (n=47, answered yes to Q15.3).

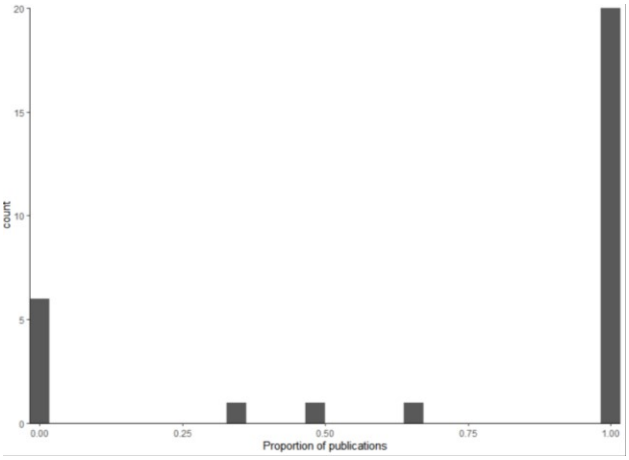


Figure S3.18. Survey responses to Q15.5 "How many peer-reviewed publications were the students involved in?" (n=29, answered > 0 to Q15.4).

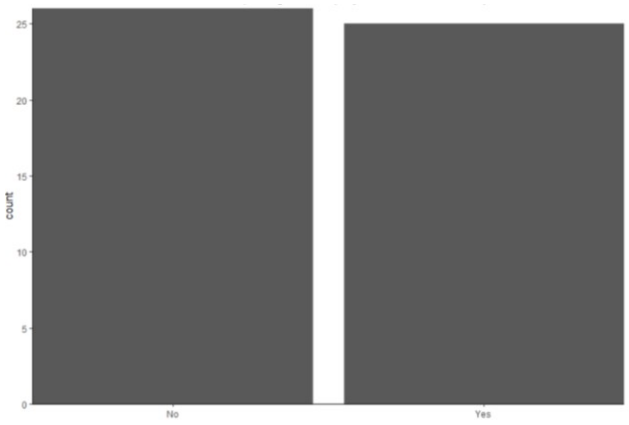


Figure S3.19. Survey responses to Q15.6 "Have these data resulted in subsequent grants or projects?" (n=51, answered yes to Q15.3).

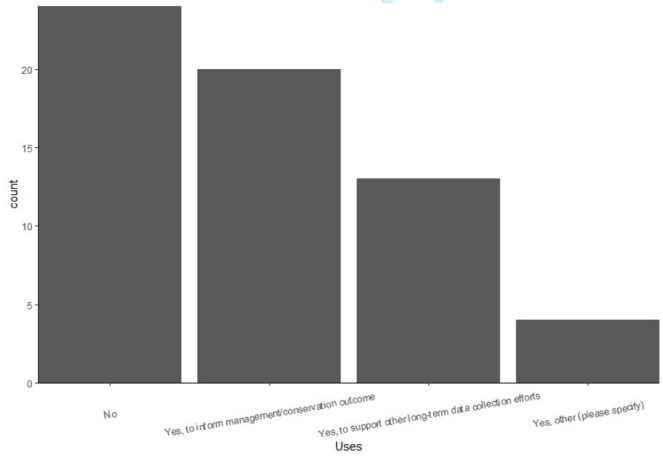


Figure S3.20. Survey responses to Q15.7 "Have these data been used by local or national government agencies?" (n=51, answered yes to Q15.3).

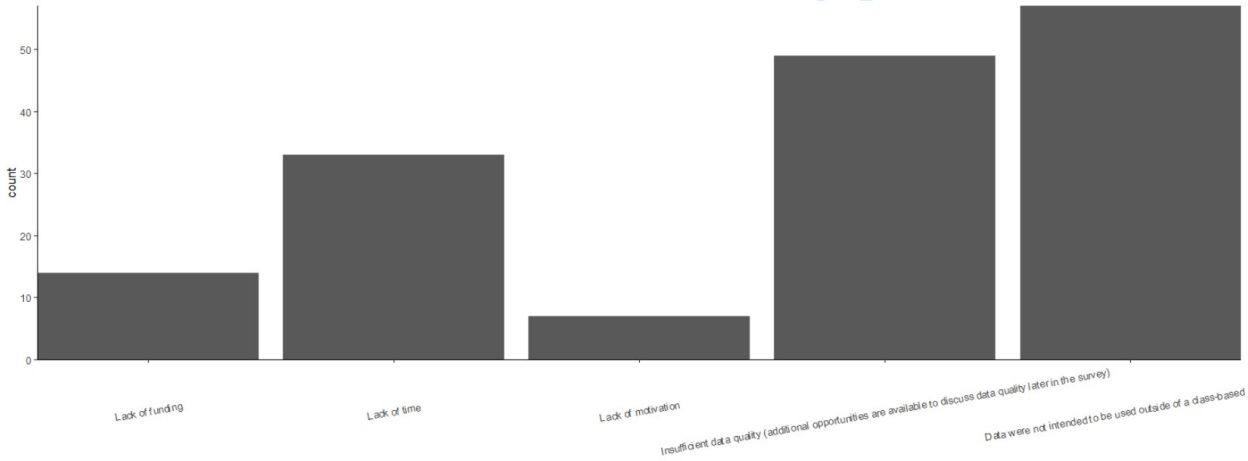


Figure S3.21. Survey responses to Q15.10 "For what main reasons have the data not been used outside of class-based projects?" (n=81, answered no to Q15.3).

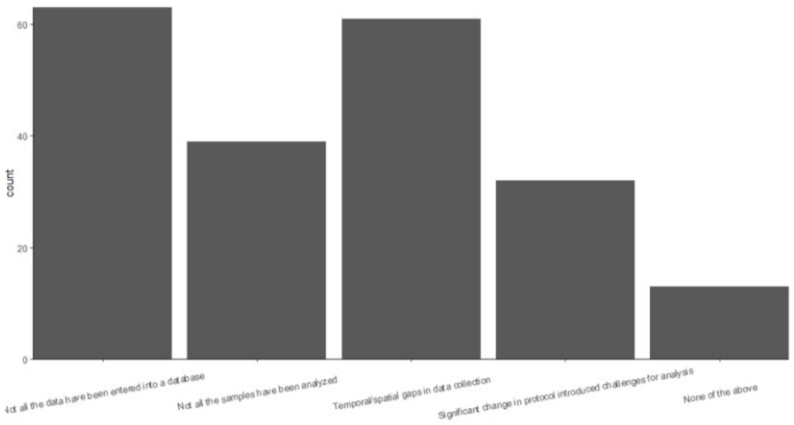


Figure S3.22. Survey responses to Q16.4 "In your experience, what are the main challenges to analyzing data collected as part of field excursions?"

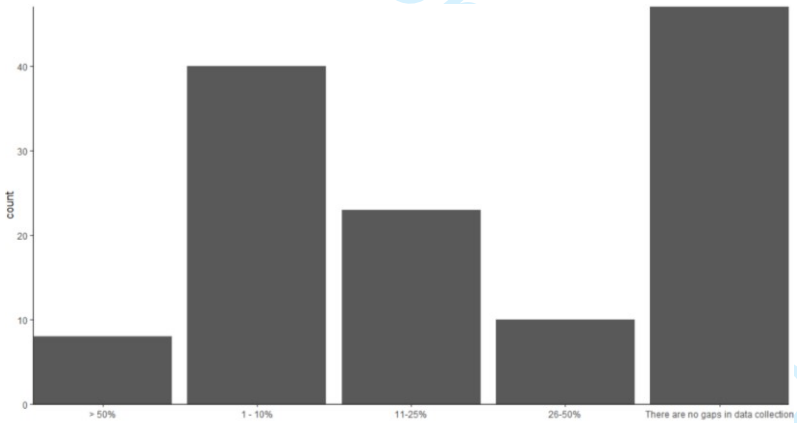


Figure S3.23. Survey responses to Q16.5 "For what percentage of the study period do gaps in data collection exist?"

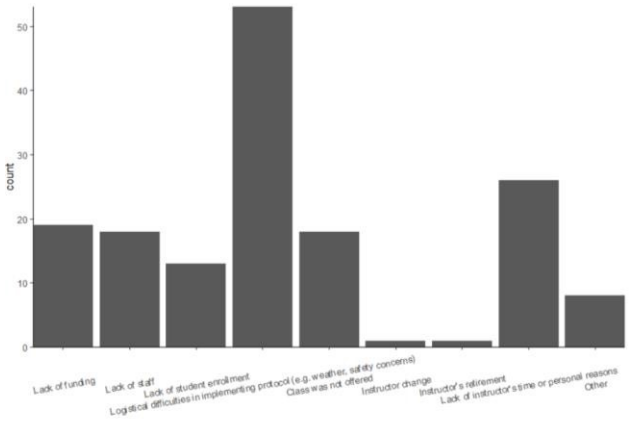


Figure S3.24. Survey responses to Q16.6 "What are the main reasons for these gaps in data collection?" (n=83, answered > 0 to Q16.5)

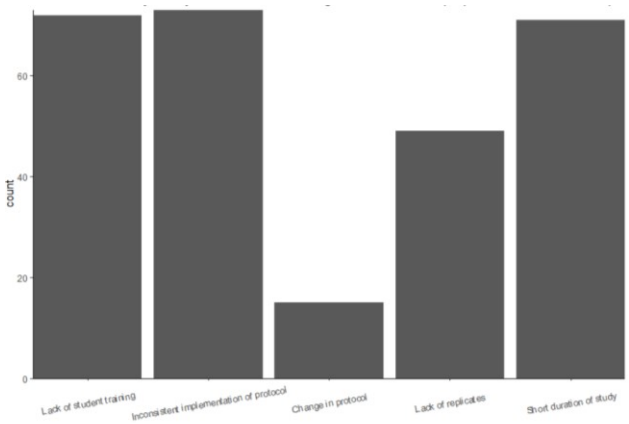


Figure S3.25. Survey responses to Q16.8 "What factors, if any, limit your confidence in using the data for other purposes than the class requirements?"

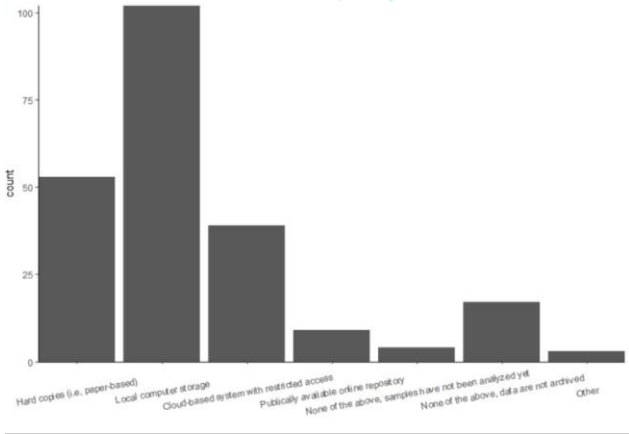


Figure S3.26. Survey responses to Q18.2 "How are/were data stored for purposes other than the class (e.g. subsequent analysis for peer-reviewed publication)?"

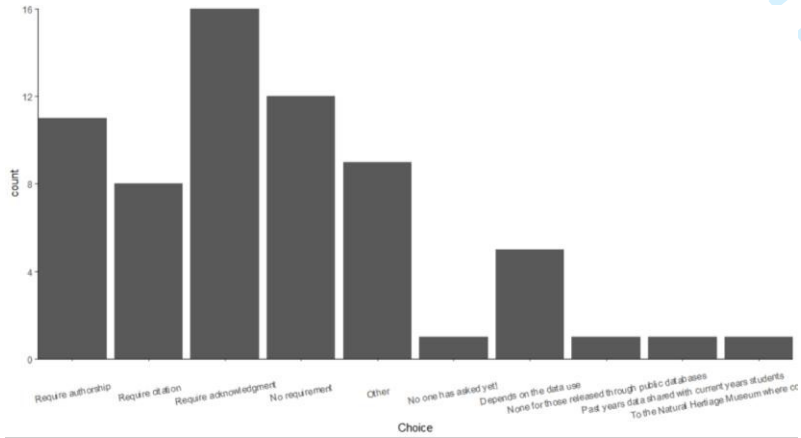


Figure S3.27. Survey responses to Q18.6 "Under what condition(s) do you share your data?" (n=32, currently share their data)

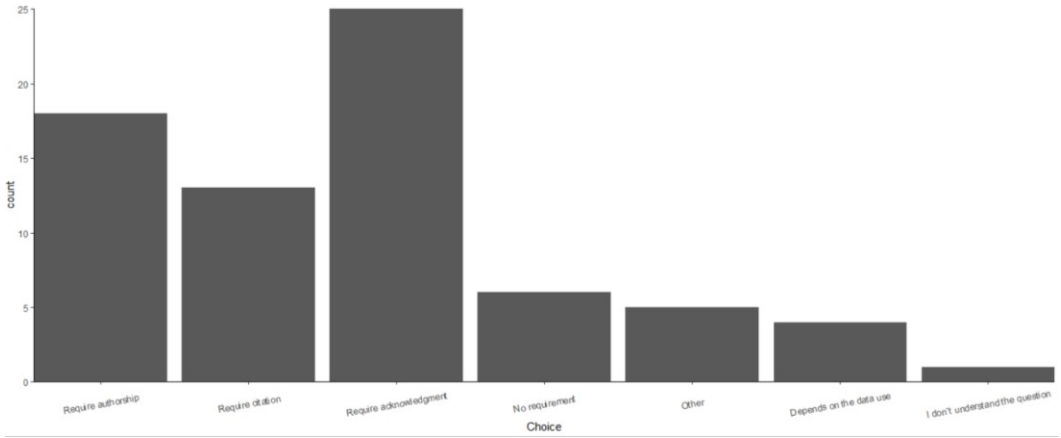


Figure S3.28. Survey responses to Q18.7 "Under what condition(s) would you be interested in sharing your data, if any?" (n=37, do not currently share their data)

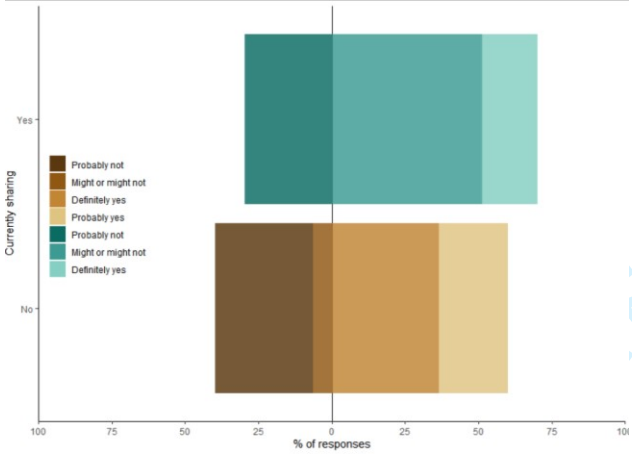


Figure S3.29. Survey responses to Q18.8 "Would you be interested in sharing your class-collected data with your peers in an online community repository specifically designed to host class-based ecological datasets?"

WebPanel 4. Highlighted comments from surveyed instructors. Square brackets show sections that have been edited for clarity and for the maintenance of respondents' anonymity.

1) **Tips and advice for instructors:**
   a) "Get something simple started ASAP that you can build on. Realize that any data will be useful as populations are always changing and climate change makes this imperative".

   b) "To ensure data quality, organize students into groups as analytical replicates! This is key to maintaining the overall data for the project because if one group fails, it only decreases your sample size slightly [but does not] compromise the entire endeavor!"

   c) "For better accuracy in data collection it is best to have different groups of students collect the same data, and then delete flagrant outliers/take the mean of the student measurements".

   d) "All our pubs have come from adding data to the NUTNET project [https://nutnet.org/]. All other data is being used in house to measure CO_2 uptake or use by the local land manager to manage their non-profit site. NutNet works because they have clear data sheets upfront".

   e) "It takes tenacity and a "can-do" approach to maintain a program that continues to collect consistent class-based data. At our institution there is usually a way to overcome obstacles that repeatedly get in the way (liability issues, availability of transportation, changes in administrative support), but one needs to be persistent and make a strong case for the importance of collection class-based data. We have been able to do this for this course and another that we have taught every fall since [the 1970s]".

   f) "Programs like I-Naturalist might make this super easy in the future".

   g) "As a professor at a PUI [Primarily Undergraduate Institution] it has helped me continue my field data collection into the fall while carrying a full teaching load".

2) Challenges for CURE persistence and maintenance:

a) "Most grant funding agencies and reviewers do not think undergraduates are capable of high enough data quality for publication. This biased perspective needs to change. With enough guidance, undergraduates can collect high quality data and massive experiments can be conducted within organized classes to the benefit of both students and faculty — especially at small teaching colleges with few resources for faculty research".

b) “It is important to stay consistent with the protocols and the training of students. This may mean deciding to collect data with lower taxonomic resolution, or that are less dependent on expertise. This can limit the kinds of questions to be addressed, but hopefully eventually provide valuable long-term information”.

c) “We are planning to apply for funding [for long-term data collection by students]. I think that if we can get the project going the challenge will be to [keep it running over the long term]. There is a need for continuity, and since teachers come and go that is a challenge”.

d) “I have been advocating for a “research as curriculum” modality since I started my tenure track job here [20 years ago]. I gained tenure and am now a full professor only because a small number of powerful advocates agreed with me. Every time I mentioned “citizen science” or “policy application”, or any synonym of either, it has cost me dearly – I have had to combat blatant myopic resistance to these dimensions of ecological research scholarship in my courses [since the 90s]. So, I learned early to keep that quiet”.

e) “Much personal effort required, next year when I retire probably the data will not be maintained”.

WebTable 1. Scientific ecological societies contacted in order to distribute the survey to members via email, Twitter and/or Facebook.

Society Name	Email	Twitter	Facebook
National			
Association for the Sciences of Limnology & Oceanography	•	•	•
Australian Centre for Ecological Analysis & Synthesis	•	•	•
Austrian Limnological Association	•		
BIOTICA Ecological Society	•		
Brazilian Association of Ecological Science & Conservation	•		•
Brazilian Association of Limnology	•		•
Brazilian Ecological Society	•		
British Ecological Society	•	•	•
Canadian Institute for Ecology & Evolution	•	•	•
Canadian Society for Ecology & Evolution	•	•	•
Chilean Society of Limnology	•		•
Croatian Association of Freshwater Ecologists	•		
Czech Limnological Society	•		•
Czech Society for Ecology	•		•
Eastern Asian Federation of Ecological Societies	•		
Ecological Association of Argentina	•		•
Ecological Movement of Uzbekistan	•		
Ecological Protection Society Malaysia	•		•
Ecological Society of America	•	•	•
Ecological Society of Australia	•	•	•
Ecological Society of Bangladesh	•		•
Ecological Society of Chile	•	•	•
Ecological Society of Iceland	•		•
Ecological Society of Iran	•		
Ecological Society of Japan	•		
Ecological Society of Korea	•		
Ecological Society of New Zealand	•	•	•
Ecological Society of the Philippines	•		•
Ecology & Evolutionary Biology Society of Turkey	•	•	•
Estonian Naturalists' Society	•		•
French Ecological Society	•	•	•
French Limnological Society	•	•	•
Freshwater Biological Association	•	•	•
German Limnological Society	•		
Green Salvation Ecological Society	•		
Hellenic Ecological Society	•		
Hungarian Ecological Society	•		
Hungarian Hydrological Society	•		•
Indian Ecological Society	•		•
Indonesian Journal of Marine Sciences	•	•	
Institute of Landscape Ecology (Slovakia)	•		
Italian Association for Oceanography & Limnology	•		•
Italian Ecological Society	•		•
Japan Association for Landscape Ecology	•		•
Japanese Society of Limnology	•		
Landscape Ecology & Environment in Vietnam	•		
Limnological Association of Argentina	•		
Limnological Society of India	•		
Macedonian Ecological Society	•	•	•
Malaysian Nature Society	•	•	•

Mexican Scientific Ecological Society	•	•	
Murmansk Marine Biological Institute	•		
National Center for Ecological Analysis & Synthesis	•		•
National Institute of Ecology	•		
Nature Society Singapore	•		•
Papua New Guinea Institute of Biological Research	•		
Polish Ecological Society	•		
Polish Hydrobiological Society	•		
Polish Limnological Society	•		•
Portuguese Ecological Society	•	•	•
Romanian Ecological Society	•		
Russian Society for Ecological Economics	•		•
Sálim Ali Centre for Ornithology & Natural History	•		•
Slovak Ecological Society	•		
Slovakian Limnological Society	•		
Soil & Water Conservation Society	•		•
Spanish Association of Terrestrial Ecology	•	•	•
Student Conservation Association	•	•	•
Swedish Society Oikos	•		
Swiss Society for Hydrology & Limnology	•		
The Finnish Limnological Society	•		•
The Israel Society of Ecology & Environmental Science	•		
The Limnological Society of Turkey	•		
Toucan Ridge Ecological & Educational Society	•	•	•
Turkish Ecological Society	•		
Continental			
East African Wildlife Society	•	•	•
Ecological Society for Eastern Africa	•	•	•
Ecological Society of Germany, Switzerland & Austria	•	•	•
EFYR Representatives	•	•	
European Ecological Federation	•	•	
European Federation for Freshwater Science	•	•	
Federation of European Societies of Plant Biology	•		•
Iberian Limnological Association	•	•	
Netherlands-Flemish Ecological Society	•		
Nordic Society Oikos	•	•	•
Society for the Advancement of Science in Africa	•		
South African Department of Agriculture, Forestry & Fisheries	•	•	•
Southern African Society of Aquatic Scientists	•		
Southern African Wildlife Management Association	•		•
International			
Aquatic Ecosystem Health & Management Society	•	•	•
Association for the Sciences of Limnology & Oceanography	•	•	•
Association for Tropical Biology & Conservation	•	•	•
International Association for Ecology	•		
International Association of Landscape Ecology	•		•
International Society of Limnology	•	•	•
Society for Conservation Biology	•		
Society for Conservation Biology	•		•
Society for Ecological Restoration	•	•	•
Society for Freshwater Science	•	•	•
Society for Human Ecology	•	•	•
Society for Urban Ecology	•		
Society of Environmental Toxicology & Chemistry	•	•	•
The International Society for Ecological Modelling	•		

Higher Education Ecological Data (HEED)

Start of Block: 1. Introduction/Survey invite

Q1.1 **Welcome to the Higher Education Ecological Data (HEED) survey!**
We are seeking information from instructors from institutions of higher education* who are currently, or are interested in, leading class-based activities to collect ecological data. This survey takes approximately 15-20 minutes to complete. Your participation will contribute to a global review on the extent and types of student ecological data collection, and provide insight into the opportunities and challenges associated with these class-based efforts to support desired educational outcomes. We ask that you complete this survey and/or forward this survey to colleagues or your association listserv (if applicable). All responses are anonymous.
We welcome any questions or comments and thank you for your help. Sincerely, The Freshwater Ecology and Conservation Lab
School of Aquatic and Fishery Sciences, University of Washington
website: https://depts.washington.edu/oldenlab/ | email: oldenlab@uw.edu *teachers, professors, lecturers in universities or colleges

Q1.2 Do you consent to taking this survey? All respondents that complete this survey by May 17th can be entered into a drawing for one of two $50 gift cards by entering their email address at the end.

- ○ Yes
- ○ No

End of Block: 1. Introduction/Survey invite

Start of Block: 2. Have Data

Q2.1 Have you or do you currently teach one or more classes that involve at least one field excursion to collect ecological data?

- ○ Yes
- ○ No

Q2.2 We are interested in hearing about your perspective.
To begin, how many classes have you or do you currently teach that involve at least one field excursion to collect ecological data? *Please click and drag slider to choose a number of classes.*

More than 5 classes

1 2 3 4 5

Number of classes	

Q2.3 If you have taught multiple classes or plan on teaching multiple classes, please focus for the remainder of this survey on the most recent class that you have taught. If you currently teach more than one class, please focus on the one that has been collecting data for the longest time.

Q2.4
Are/were the ecological data collected during the field excursion(s) retained after the class' end date?

- ○ Yes
- ○ No

Q2.5 In what year did data collection start in the context of this class? Include years when the class was taught by previous instructors if relevant. *Please click and drag slider to choose a start year.*

1900 2018

Start year

Q2.6 When was the last year of data collection, if applicable? *Please click and drag slider to choose an end year, or check 'Data collection has not stopped'.*

Data collection has not stopped.

1900 2018

End year

End of Block: 2. Have Data

Start of Block: 3. Considering

Q3.1 Are you interested or planning on teaching a class that would include ecological data collection through field excursions?

- Yes
- No

Q3.2 Do you have an expected start date for teaching a class that would include ecological data collection through field excursions? *If so, please click and drag slider to choose a date. If not, please check 'I do not have an expected start date'*

I do not have an expected start date.

2018 2019 2020 2021 2022 2022 2023 2024 2025

Start date

End of Block: 3. Considering

Start of Block: 4. Not considering

Q4.1 Thank you for your willingness to participate in this survey, but we are looking for instructors at higher-education institutions who have taught, are currently teaching, or are interested in teaching a class involving field collection of ecological data.
If you would like to recommend peer instructors for us to contact with this survey, please provide us with their email address. If you would like to directly provide them with a link to this survey, please send them the following link: https://tinyurl.com/EcolDataSurvey

End of Block: 4. Not considering

Start of Block: 5. Considering - outcomes and challenges

Q5.1 What benefits would you intend your students to gain from collecting and working with ecological data as part of your class?

	None	Little	Moderate	High
Field sampling techniques	○	○	○	○
Laboratory/sample processing techniques	○	○	○	○
Data analysis and interpretation	○	○	○	○
Collaborative research	○	○	○	○
Scientific writing	○	○	○	○
Public speaking	○	○	○	○
Understanding of the scientific process	○	○	○	○
Networking with scientists	○	○	○	○
Relationship building with classmates	○	○	○	○
Increased interest in topic area	○	○	○	○
Awareness of the natural world	○	○	○	○
Other (please specify)	○	○	○	○

Q5.2 What scientific outcomes and personal benefits would you aim for by teaching a class involving ecological data collection?

	None	Little	Moderate	High
Peer-reviewed publication	○	○	○	○
Blog/social media post	○	○	○	○
Inform natural resource management/conservation outcome	○	○	○	○
Presentation at a conference	○	○	○	○
Guide the design of future research projects	○	○	○	○
Facilitate the funding of future research projects	○	○	○	○
Peer recognition and awards (including institutional recognition)	○	○	○	○
Career advancement	○	○	○	○
Bonding time with students	○	○	○	○
Enjoyable time in the field	○	○	○	○
Other (please specify)	○	○	○	○

Page Break

Q5.3 What would you anticipate to be the main challenges to implementing and continuing class-based data collection?

	Definitely not	Probably not	Maybe	Probably yes	Definitely yes
Lack of financial support	○	○	○	○	○
Lack of institutional support (lack of staff/technicians or teaching assistants, lack of academic recognition)	○	○	○	○	○
Lack of class enrollment	○	○	○	○	○
Lack of equipment	○	○	○	○	○
Lack of instructor's time	○	○	○	○	○
Logistical complexity (e.g. access, permits, landowner permission)	○	○	○	○	○
Administrative changes (e.g. change in class requirements)	○	○	○	○	○
Other (please specify)	○	○	○	○	○

Q5.4 Do you have additional comments about potential challenges and benefits to implementing and maintaining a class-based data collection?

_____

_____

_____

_____

_____

Q5.5 What do you think would be the main challenges to analyzing **data** collected as part of class-based field excursions? *Please select all that apply or 'None of the above'*

- ☐ Entering data/converting data to digital form
- ☐ Analyzing samples
- ☐ Potential temporal/spatial gaps in data collection
- ☐ Significant change in protocol introducing challenges for analysis
- ☐ Limited data quality
- ☐ Other _____
- ☐ None of the above

Q5.6 What factors do you think would most limit your confidence in ecological data collected as part of field excursions? *Please select all that apply or 'None of the above'*

- ☐ Lack of student training
- ☐ Inconsistent implementation of protocol
- ☐ Change in protocol
- ☐ Inappropriate sampling design
- ☐ Lack of replicates
- ☐ Short duration of study
- ☐ Other (please specify) _____
- ☐ None of the above

Q5.7 Do you have additional comments about analyzing and disseminating data collected as part of field excursions?

_____

_____

_____

_____

_____

Page Break

End of Block: 5. Considering - outcomes and challenges

Start of Block: 6. Considering - Open ended

Q6.1 Do you have additional comments on classes involving ecological data collection you would like to share?

_____

_____

_____

_____

_____

End of Block: 6. Considering - Open ended

Start of Block: 7. Considering - Closing questions

Q7.1 Please enter the name of your institution of higher education below.

○ Name of institution _____

Q7.2 What country is your institution of higher education in?
Country of institution

▼ AD - Andorra ... ZW - Zimbabwe

Q7.3 How did you hear about this survey?

- ○ Scientific society (please specify) _____
- ○ University email list
- ○ Colleague/Friend
- ○ Social media
- ○ Other (please specify) _____

Q7.4 To receive updates about this study, please provide us with your email address so that we may reach you (email addresses will be kept confidential and will not be used for any other purpose).

_____

Q7.5 If you would like to recommend peer instructors for us to contact with this survey, please provide us with their email address. If you would like to directly provide them with a link to this survey, please send them the following link: https://tinyurl.com/EcolDataSurvey

_____

End of Block: 7. Considering - Closing questions

Start of Block: 8. Have data - Class

Q8.1 Please provide a general description of the class by answering the following questions:

Q8.2 For what level of higher education is/was the class offered? *Please select all that apply.*

- ☐ First year - undergraduate
- ☐ Second year - undergraduate
- ☐ Third year - undergraduate
- ☐ Fourth Year - undergraduate
- ☐ Graduate
- ☐ Other (please specify) _____

Q8.3 How often is/was the class offered?

- ○ More than once per year
- ○ Once per year
- ○ Once every 2 years
- ○ Once every 3 or more years

Q8.4 Including yourself, how many instructors (and teaching assistants) are/were involved in implementing the field excursion(s) in a typical year? *Please click and drag slider to choose a number or check 'More than 10'.*

More than 10

0 1 2 3 4 5 6 7 8 9 10

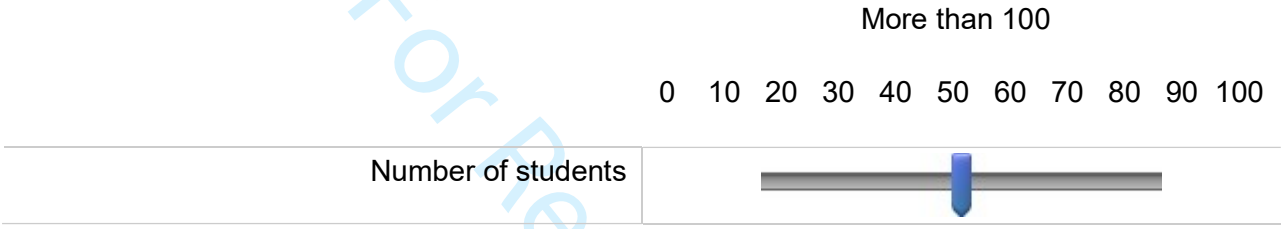
Number of instructors

End of Block: 8. Have data - Class

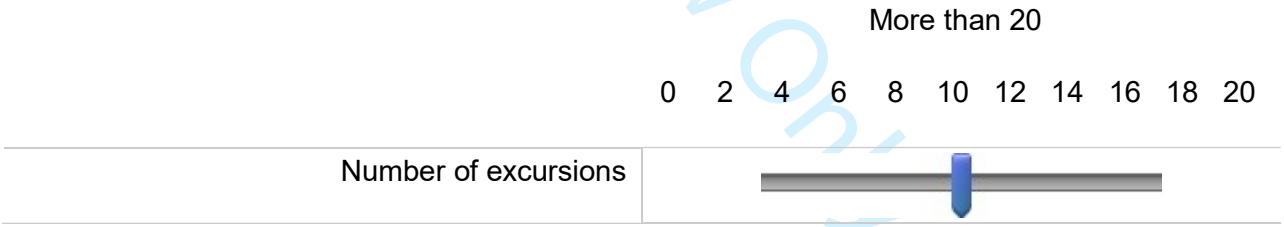
Start of Block: 9. Have data - Excursion

Q9.1 Please provide a general description of the field excursion(s) by answering the following questions. *Click and drag sliders to choose a number or check the box to the right of the slider if it applies (e.g. 'More than 20' field excursions).*

Q9.2 What is/was the total number of students participating in the field excursions in a typical year?



Q9.3 In how many field excursions are/were ecological data collected during the class?



Q9.4 How many total days of ecological data collection are/were involved across all field excursions in a typical year?

Q9.5 Across all field excursions, in how many locations does/did the class collect ecological data?

	0 5 10 15 20 25 30 35 40 45 More than 50
Number of sites	

End of Block: 9. Have data - Excursion

Start of Block: 10. Have data - Instructor/institution/partners

Q10.1 Please provide information regarding financial and institutional support for the field excursion(s) by answering the following questions:

Q10.2 What is/was the total cost of running the field excursion(s) for the class ($US) in a typical year?

- < $1000
- $1000-$2499
- $2500-$4999
- $5000-$9999
- > $10000

Q10.3 What are/were the typical funding sources to support the field excursion(s) costs?
Please select all that apply.

- ☐ University/academic department
- ☐ Students pay additional fee
- ☐ Instructor(s) contribute personal funds
- ☐ Outside organization(s)
- ☐ Other #1 (please specify) _____
- ☐ Other #2 (please specify) _____

Page Break

Q10.4 Does/did an organization outside of your higher-education institution provide some level of support to the field excursion(s), including financial, staff, equipment, and other logistical support like site access. ? *Please select all that apply or check 'No'.*

- [ ] No
- [ ] Another higher-education institution (e.g. university)
- [ ] Regional natural resource government agency (subnational/province/state/territory)
- [ ] National/Federal government agency
- [ ] Tribal/Indigenous group
- [ ] Private company
- [ ] Non-profit organization
- [ ] Citizen science group
- [ ] Other (please specify)

_____

Q10.5 What type of support do/did these partner organizations provide? *Please select all that apply.*

- ☐ Access to field location
- ☐ Staff
- ☐ Equipment
- ☐ Financial support
- ☐ Other (please specify) _____

End of Block: 10. Have data - Instructor/institution/partners

Start of Block: 11. Have data - Data attributes

Q11.1 Please provide information regarding the ecological data collected during the field excursion(s):

Q11.2 Please enter the country where the ecological data are/were collected in the text box below.

_____

JS

Q11.3 Please drag the pin to the field location as precisely as possible in the map below. *If data are/were collected in more than one region, you will be able to add additional locations below.*

_____

Q11.4 In what type of ecosystem do/did you collect ecological data as part of the class? *Please choose the ecosystem/habitat that best applies (for more details on the Habitats Classification Scheme , Version 3.1, see IUCN documentation).*
Habitat class - level 1
Habitat class - level 2
Habitat class - level 3

▼ 1. Forest ... 18. Unknown ~ Not applicable ~ Not applicable

Q11.5 Does/did your field data collection also take place in another location or ecosystem type?

- ○ No, I have entered all the locations and ecosystem types where the class collects ecological data.
- ○ Yes, I would like to enter information on an additional location or ecosystem type.

End of Block: 11. Have data - Data attributes

Start of Block: 12. Have data - Data attributes II

Q12.1 Please provide information regarding the ecological data collected during the field excursion(s), including variables collected across all field locations:

Q12.2 What type(s) of variables are/were collected during the field excursion(s)? Please check all that apply.

- ☐ Biological
- ☐ Physical
- ☐ Chemical

Q12.3 What biological variables are/were collected during the field excursion(s)? *Please check all that apply.*

- ☐ Occurrence/abundance/density/biomass (single species or multiple species)
- ☐ Individual physical attributes (body length, mass, leaf area, DBH, sex, age)
- ☐ Individual behavior
- ☐ Life history (e.g. fecundity, age)
- ☐ Physiology
- ☐ Phenology (e.g. migration timing, date of flowering)
- ☐ Genetics
- ☐ Molecular/Biochemistry
- ☐ Biogeochemistry (e.g. stable isotope, nutrient cycling, metabolism)
- ☐ Other (specify) _____

Q12.4 What physical variables are/were collected during the field excursion(s)? *Please check all that apply.*

- [ ] Temperature
- [ ] Luminosity
- [ ] Albedo
- [ ] Moonlight/lunar phase
- [ ] Pluviosity/precipitation
- [ ] Altitude/elevation
- [ ] Topography/slope/aspect
- [ ] Humidity
- [ ] Radiation
- [ ] Sound/Noise
- [ ] Granulometry/soil texture
- [ ] Substrate composition
- [ ] Erosion/sedimentation
- [ ] Vegetation coverage
- [ ] Ice coverage
- [ ] Distance (e.g. from habitat patches, matrix, water,...)

- [ ] Area (e.g. patch area, lake area)
- [ ] Intermittence/hydroperiod
- [ ] Depth/bathymetry (e.g. waterbody, sea, soil, litter)
- [ ] Wind speed
- [ ] Discharge/water flow/current
- [ ] Width (e.g. hedge width, river width)
- [ ] Water hardness
- [ ] Turbidity/transparency
- [ ] Color
- [ ] Other (specify) _____

*

Q12.5 What chemical variables are/were collected during the field excursion(s)? *Please check all that apply.*

- ☐ pH
- ☐ Electric conductivity/Salinity/Total Dissolved Solids (TDS)
- ☐ Chemical pollutant (specify) _____
- ☐ Nitrogen/NH3/NH4/NO3/NO2
- ☐ Phosphorus/phosphate
- ☐ Carbonate/bicarbonates
- ☐ Calcium/Ca2+
- ☐ Iron/Fe2+/Fe3+
- ☐ Magnesium/Mg2+
- ☐ Aluminium/Al3+
- ☐ Potassium/K+
- ☐ Hydrogen/H+
- ☐ Sulfur/sulphate
- ☐ Chlorum/chloride
- ☐ Dissolved oxygen/BOD/COD
- ☐ Alkalinity/acidity
- ☐ Others (specify) _____

End of Block: 12. Have data - Data attributes II

Start of Block: 13. Have data - threats

Q13.1 Please provide information regarding the ecological data collected during the field excursion(s):

Q13.2 Did you collect the data with the intention to study a specific threat to the factors of interest/environment?

- Yes
- No

Q13.3 What threat(s) is/was the data collection intended to study? *Please check all the threats that apply (for more details on the Threats Classification Scheme , Version 3.2, see IUCN documentation).*

- ☐ Residential and commercial development (housing, urban, commercial, industrial, tourism, and recreational areas) (1)
- ☐ Agriculture and aquaculture (crops, wood plantations, livestock farming and ranching, marine and freshwater aquaculture) (2)
- ☐ Energy production and mining (including renewable energy) (3)
- ☐ Transportation and service corridors (i.e. roads & railroads, shipping lanes, flight paths) (4)
- ☐ Biological resource use (hunting, fishing, collecting,logging and wood harvesting) (5)
- ☐ Human intrusions and disturbance (recreational activities, military activity and civil unrest, work and other activities) (6)
- ☐ Natural system modifications (fire and fire suppression, dams and water management, other ecosystem modifications) (7)
- ☐ Invasive and other problematic species, genes & diseases (8)
- ☐ Pollution (including excess energy such as light, thermal, and noise pollution) (9)
- ☐ Geological events (volcanoes, earthquakes/tsunamis, avalanches/landslides) (10)
- ☐ Climate change and severe weather (11)
- ☐ Other (please specify)

_____

End of Block: 13. Have data - threats

Start of Block: 14. Have data - break/thank you

Q14.1 You are more than halfway done, thank you for your response to these questions. Now we want to ask you about the outcomes of class-based ecological data collection for you and your students.

End of Block: 14. Have data - break/thank you

Start of Block: 15. Have data - Outcomes

Q15.1 Please provide information regarding the outcomes of the field excursions:

Q15.2 What benefits do you think your students gain/gained from collecting and working with the class' ecological dataset?

	None	Little	Moderate	High
Field sampling techniques	○	○	○	○
Laboratory/sample processing techniques	○	○	○	○
Data analysis and interpretation	○	○	○	○
Collaborative research	○	○	○	○
Scientific writing	○	○	○	○
Public speaking	○	○	○	○
Understanding of scientific process	○	○	○	○
Networking with scientists	○	○	○	○
Relationship-building with classmates	○	○	○	○
Increased interest in topic area	○	○	○	○
Awareness of the natural world	○	○	○	○
Other	○	○	○	○

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Q15.3 Have you ever used the data collected in this class outside of class-based projects (e.g. publications, blog posts, grant proposals)?

- ○ Yes
- ○ No

Q15.4 How many peer-reviewed publications have resulted from the data collected in this class? *Please click and drag slider to choose a number or check 'More than 10'.*

More than 10

0 1 2 3 4 5 6 7 8 9 10

Number of publications

Q15.5 How many peer-reviewed publications were the students involved in? *Please click and drag slider to choose a number or check 'More than 10'.*

More than 10

0 1 2 3 4 5 6 7 8 9 10

Number of publications

Q15.6 Have these data resulted in subsequent grants or projects?

- ○ Yes
- ○ No

Q15.7 Have these data been used by local or national government agencies? *Please check all that apply.*

- ☐ No
- ☐ Yes, to inform management/conservation outcome
- ☐ Yes, to support other long-term data collection efforts
- ☐ Yes, other (please specify) _____

Q15.8 What other personal benefits have you gained from teaching a class involving ecological data collection?

	None	Little	Moderate	High
Ideas and data for future project(s)	○	○	○	○
Career advancement (publications, awards)	○	○	○	○
Peer recognition	○	○	○	○
Mentoring students	○	○	○	○
Inspiration (e.g. enjoyable time in the field)	○	○	○	○
Other (please specify)	○	○	○	○

Q15.9 What other significant outcomes have you seen as a result of your class-based ecological data collection?

_____

_____

_____

_____

_____

Q15.10 For what main reasons have the data not been used outside of class-based projects? *Please check all that apply.*

- ☐ Lack of funding
- ☐ Lack of time
- ☐ Lack of motivation
- ☐ Insufficient data quality (additional opportunities are available to discuss data quality later in the survey)
- ☐ Data were not intended to be used outside of a class-based project
- ☐ Other (please specify)

_____

End of Block: 15. Have data - Outcomes

Start of Block: 16. Have data - Challenges

Q16.1 Please provide information regarding the challenges you have encountered in teaching a class involving field excursions:

Q16.2 In your experience, what are the main challenges to implementing and maintaining class-based data collection?

	Definitely not	Probably not	Maybe	Probably yes	Definitely yes
Lack of financial support	○	○	○	○	○
Lack of institutional support (e.g. lack of technicians, teaching assistants, academic recognition)	○	○	○	○	○
Lack of class enrollment	○	○	○	○	○
Lack of equipment	○	○	○	○	○
Lack of instructor's time	○	○	○	○	○
Logistical complexity (e.g. access, permits, landowner permission)	○	○	○	○	○
Administrative challenges (e.g. change in class requirements)	○	○	○	○	○
Other (please specify)	○	○	○	○	○

Q16.3 Do you have additional comments or advice from your experience implementing and maintaining class-based data collection?

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Q16.4 In your experience, what are the main challenges to analyzing data collected as part of field excursions? *Please select all that apply.*

- ☐ Not all the data have been entered into a database
- ☐ Not all the samples have been analyzed
- ☐ Temporal/spatial gaps in data collection
- ☐ Significant change in protocol introduced challenges for analysis
- ☐ Other (please specify) _____
- ☐ None of the above

Q16.5 For what percentage of the study period do gaps in data collection exist?
Here a gap refers to a period for which data were supposed to be collected according to the sampling protocol but for which no data were collected (e.g. data were not collected for one out of five years: 20% gap).

- ○ 1 - 10%
- ○ 11-25%
- ○ 26-50%
- ○ > 50%
- ○ There are no gaps in data collection

Q16.6 What are the main reasons for these gaps in data collection? *Please select all that apply.*

- [ ] Lack of funding
- [ ] Lack of staff
- [ ] Lack of student enrollment
- [ ] Logistical difficulties in implementing protocol (e.g. weather, safety concerns)
- [ ] Class was not offered
- [ ] Instructor's retirement
- [ ] Lack of instructor's time or personal reasons
- [ ] Other _____

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Q16.7 For which of the following applications do you feel comfortable using your class-based dataset?

	Extremely unlikely	Somewhat unlikely	Neither likely nor unlikely	Somewhat likely	Extremely likely
Post on internet (e.g. blog, social media)	○	○	○	○	○
Presentation at a conference	○	○	○	○	○
Natural resource management	○	○	○	○	○
Peer-reviewed publication	○	○	○	○	○
Guidance for future study design	○	○	○	○	○

Q16.8 What factors, if any, limit your confidence in using the data for other purposes than the class requirements?*Please check all that apply or 'None of the above'.*

- ☐ Lack of student training
- ☐ Inconsistent implementation of protocol
- ☐ Change in protocol
- ☐ Lack of replicates
- ☐ Short duration of study
- ☐ Other (please specify) _____
- ☐ None of the above

Q16.9 Do you have additional comments or advice from your experience analyzing and disseminating data from a class-based ecological dataset?

_____

_____

_____

_____

_____

End of Block: 16. Have data - Challenges

Start of Block: 17.Have data - break/thank you

Q17.1 Almost done, **thank you**. Just a few very important questions to ask.

End of Block: 17.Have data - break/thank you

Start of Block: 18. Have data - Data management and sharing

Q18.1 We are considering to create an online data repository to promote a network of collaboration and integration of class-based research in ecology. In this section of the survey, you will be asked about your current practices in data archiving, management, and availability.

Q18.2 How are/were data stored for purposes other than the class (e.g. subsequent analysis for peer-reviewed publication)? *Please select all that apply.*

- [ ] Hard copies (i.e. paper-based)
- [ ] Local computer storage
- [ ] Cloud-based system with restricted access
- [ ] Publically available online repository
- [ ] None of the above, samples have not been analyzed yet
- [ ] None of the above, data are not archived
- [ ] Other _____

Page Break

Q18.3 Do you currently share the data collected as part of this class?

- ○ Yes
- ○ No

Q18.4 At what level(s) do you currently share your data? *Please select all that apply*.

- ☐ Available upon request
- ☐ Only for government agency partners and educational purpose
- ☐ Open online access
- ☐ Other _____

Q18.5 What level(s) of data sharing would you be interested in, if any? *Please select all that apply.*

- ☐ Available upon request
- ☐ Only for government agency partners and educational purpose
- ☐ Open online access
- ☐ Not interested in data sharing for the moment
- ☐ Other _____

Q18.6 Under what condition(s) do you share your data? *Please select all that apply, including if conditions depend on the nature of the data request.*

- ☐ Require authorship
- ☐ Require citation
- ☐ Require acknowledgment
- ☐ No requirement
- ☐ Other _____

*

Q18.7 Under what condition(s) would you be interested in sharing your data, if any? *Please select all that apply, including if conditions depend on the nature of the data request.*

- ☐ Require authorship
- ☐ Require citation
- ☐ Require acknowledgment
- ☐ No requirement
- ☐ Other _____

Q18.8 Would you be interested in sharing your class-collected data with your peers in an online community repository specifically designed to host class-based ecological datasets?

	Definitely yes	Probably yes	Might or might not	Probably not	Definitely not
Interest level	○	○	○	○	○