Maximizing the Value of Schoolship Data: Recommendations for a Long-term Citizen Science Monitoring Strategy

University of Michigan School for Environmental and Sustainability Capstone
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EXECUTIVE SUMMARY

Inland Seas Education Association (ISEA), located in Suttons Bay, Michigan, has served as a unique Great Lakes education organization since 1989. Utilizing a 77’ schooner, thousands of children and adults have sailed Suttons Bay (Lake Michigan) to learn about plankton, fish, benthic organisms, and water quality in the Great Lakes; while also learning how to be sailors and stewards. With each sail, ISEA collects scientific field data on the bay--an impressive collection which now spans over 30 years. However, to this point, data have been housed in a mix of platforms, including Microsoft Access and Excel. These data are not easily accessible to anyone outside of ISEA’s internal staff (e.g., for use in the classroom, research, or to inform policy). With different formats, these data are also difficult to analyze as one cohesive set. Additionally, data are not currently collected with a formal monitoring plan in place, making it difficult to adapt the monitoring program into the future. Finally, with ISEA’s primary goal being education, the organization is questioning the value of continuing to collect and manage all of these data for years to come.

ISEA recruited our student team to address these issues. Over the course of 16 months, we addressed ISEA’s science monitoring and data management challenges through literature comparisons, interviews, on-site observations, and discussions with potential end-users or similar organizations. In exploring solutions for ISEA, our objectives were to:

1. Explore elements of a science strategy to guide the shipboard monitoring program;
2. Consider alternatives for data storage, management, sharing, and use; and
3. Provide recommendations to ISEA for strengthening these two aspects of their program.

We concluded that ISEA’s data has tremendous value for education, both for the general public and school-age children. It also has potential value for other audiences (i.e., researchers and policymakers) if some quality assurance and quality control measures are enacted. Thus, we created a set of recommendations to help ISEA strengthen their science monitoring program and make their data accessible to these external end users.

Recommendations

Use Data for Education

- ⚓ Prioritize uses of data for educational purposes (rather than for scientific purposes) when making decisions related to data collection and recording, data management and sharing, and what QA/QC and documentation practices to adopt.
- ⚓ Make raw data and data summaries accessible to teachers and students who have attended an ISEA program; as well as to other interested community members, researchers, and organizations.

Choosing a Database Management System (DBMS)

- When deciding what DBMS to use, consider factors of accessibility, flexibility, and capabilities for data analysis and sharing.
- Create a new project in the online citizen science platform FieldScope, to serve as the primary DBMS.

Considerations for Future Science Monitoring Strategy

- When deciding which parameters to record, consider ease of recording onboard as well as end-user needs and interests. [These must be balanced because sometimes data recording may conflict with the priority education program]
- Create a formal process for cataloging newly discovered or uncommon organisms.

Quality Assurance/Quality Control (QA/QC)

- Simplify the approaches to recording on datasheets, including but not limited to reading and writing requirements.
- Standardize data recording formats to avoid inconsistencies between volunteer instructors.
- Add a data confidence checkbox to demonstrate trust in data quality, to establish the context for "data of known quality", and to provide context for Secchi depths.
- Digitize everything on the datasheets to reduce the need for the data entry inputter to make decisions out of context.
- Create an education-grade QAPP to document data quality for end users.

Parameter-Specific QA/QC Improvements

- Record Secchi depth measurements in half-meter increments to align with scientific protocols.
- Record only presence-absence data for plankton and benthos to reduce volunteer work. [Volunteer attention needs to be maximized for student learning, so recording needs to be simple enough not to interfere with education tasks]
- Record only the first values at the water quality station to optimize data quality. [Since this station uses water that has sat onboard for a while, only the first data points are an accurate reflection of the water, given the methods ISEA uses.]

- Continue current practices for recording fish and temperature data, as these are easy and accurately performed by volunteers.
- Stop recording weather observations on datasheets but incorporate them into the data confidence checkbox to provide context for quality of other data.
- Stop recording microplastics data onboard. If a research partner is interested in analyzing the samples, providing technical support, and providing the data back to ISEA, then data can be stored in ISEA's database. [Since identification onboard is challenging, ISEA should store research-grade data from the external researcher in ISEA's microplastics database instead of the onboard data. This will be more accurate and valuable to share.]

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- University of Michigan Water Center
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- The Watershed Center Grand Traverse Bay
- University of Michigan SEAS
- Healing Our Waters-Great Lakes Coalition
- Michigan Sea Grant Extension
- Northwest Michigan College (NMC)
- Michigan Department of Natural Resources (DNR)
- Huron River Watershed Council (HRWC)

Land Acknowledgement

Our project team would also like to acknowledge our impact of conducting research on the land where the University of Michigan stands with the following statement:

The School for Environment and Sustainability acknowledges the university's origins through an 1817 land transfer from the Anishinaabek, the Three Fires People: the Odawa, Ojibwe, and Bodewadami as well as Meskwahkiasahina (Fox), Peoria and Wyandot. We further acknowledge that our university stands, like almost all property in the United States, on lands obtained, generally in unconscionable ways, from indigenous peoples. In addition, our research on environmental science and sustainability has benefited and continues to benefit from access to land originally gained through the exploitation of others. Knowing where we live and work does not change the past, but understanding and acknowledging the history, culture, and impacts of colonial practices is an important step towards the creation of an equitable and sustainable future.

-University of Michigan School for Environmental and Sustainability

INTRODUCTION

Daily human activities have an effect on the Great Lakes (Cipoletti et al., 2020; Larson et al., 2013; Wiley et al., 2010), and thus a stewardship ethic for freshwater systems is important to sustain them and foster resilience in the face of changing conditions (Cooke et al., 2021; Michigan OGL, 2016). The Laurentian Great Lakes provide many ecosystem services and are an important part of the region's economy, ecology, quality of life, and source of drinking water (Steinman et al., 2017). Furthermore, all Michiganders have an impact on the Great Lakes, yet many residents lack a basic level of water literacy (Fortner & Mayer, 1983; Fortner et al., 1991). This led to the incorporation of Great Lakes Literacy Principles (Fortner & Manzo, 2011).

Great Lakes Schoolship programs increase student knowledge and attitudes about the Great Lakes through providing an authentic and place-based STEM experience (Vail & Smith, 2013; Williamson & Dann, 1999). Towards achieving stewardship and literacy goals, environmental education serves to convey information, build understanding, improve skills, and enable sustainable actions (Ardoin et al., 2020). Environmental education programs often use citizen science as a way to engage their participants and the community in environmental concepts and projects (Ganzevoort & Van Den Born, 2019; Unger et al., 2020), while also providing a complementary role to professional ecological monitoring (Burgess et al., 2017; Dickinson et al., 2012). Place-based, water-centered educational experiences allow students to directly experience and understand complex environmental issues while also increasing the likelihood of students' developing environmental stewardship characteristics (Nation et al., 2020; O'Neil et al., 2020; Silbernagel et al., 2015; Zint et al., 2014).

Inland Seas Education Association (ISEA) is an environmental education organization based in Suttons Bay, Michigan with a mission of "inspiring a lifetime of Great Lakes curiosity, stewardship, and passion in people of all ages" (ISEA, 2021). To accomplish this, ISEA consistently runs two aquatic education programs--Next Generation and Diving Deeper--onboard their Schoolships to serve school or public groups with varying learning objectives. As part of these education programs, ISEA has been collecting limnological and biological data about the Great Lakes since 1989 by having the public and students serve as citizen scientists led by trained volunteer instructors.

As the core of their education programs, ISEA regularly collects biological data including species counts of fishes, zooplankton, and benthic invertebrates; and limnological parameters including turbidity, surface and deep-water temperatures, pH, and dissolved oxygen levels. Air temperature, weather and water conditions, as well as microplastic samples are also recorded during their annual season which runs between May and October in Grand Traverse Bay on Lake Michigan. They are the only organization in the area that has a consistent dataset covering this lengthy timespan (1989-present). Giraud (2011) evaluated the quality and usability of ISEA's historical biological data and provided recommendations to improve future data collection.

Despite the potential value of these long-term, consistent surveys, ISEA's data are not currently accessible to any end users. ISEA volunteers and staff record and digitize every piece of collected data without defined management goals or end users in mind. All collected data are stored in a digital container with the expectation that they may be of interest in the future. Currently, staff design the containers and volunteers digitize data parameters that were written manually during the shipboard educational programs. As staff have changed over the years, the format in which the data are digitized has changed as well, leaving the data spread across unharmonized datasheets in different computer programs such as MS Access or Excel. Under this scheme, it is difficult to examine trends or share data broadly. The monitoring initiative also lacks a quality assurance and quality control (QA/QC) strategy, which calls the data validity into question for research purposes. Furthermore, with ISEA's primary goal of education, there is a question of whether or not there is value in continuing to store all of this data for years to come.

To strengthen and streamline the data-supported, science dimension of the ISEA program, our study objectives were to:

1. Explore elements of a science strategy to guide the shipboard monitoring program;
2. Consider alternatives for data storage, management, sharing, and use; and
3. Provide recommendations to ISEA for strengthening these two aspects of their program.

METHODS

Research Questions

We developed a list of research questions (Table 1A) for each objective to frame our project design and select appropriate research methods. The theoretical basis of our questions came from our initial understanding of ISEA's mission, educational programs, and the accompanying data they collect and store. This understanding was developed through conversations with (and materials provided by) ISEA staff, initial review of literature on citizen science data collection methods and quality, and participation in "wet runs" of the Schoolship program (wherein volunteers rehearse their instruction before the start of the sailing season).

We used the following qualitative methods to address the full breadth of our research questions: literature review, informal meetings with experts, interviews with ISEA volunteers, a digital survey of teachers who attended Schoolship with their students, and program observation (Table 1B). For each method, the specific research questions guided our design.

(A) Objective 1: Data collection for long-term monitoring

1. What is the value of collecting and recording data on the ship?
2. Are all parameters easy for instructors to measure and record?
3. What is the quality of data collected on the ship?
4. How are/should inconsistencies on datasheets (be) handled?
5. How are/should new organisms (be) handled and recorded?
6. Would recording data in a digital citizen science platform add value to ISEA's programs?
7. What QA/QC steps (if any) should be implemented on the ship?

Objective 2: Data storage, sharing, and uses

8. How do data storage and management contribute to the educational experience?
9. What does/could ISEA use the data for?
10. Who are the potential external end users of the data and what would they use it for?
11. How/when should data be delivered to external end users?
12. What DBMS characteristics are important for those inputting and using the data?
13. What is the optimal DBMS for ISEA?
14. What QA/QC steps should be implemented when digitizing the data?

(B) Methods	**Objective 1 Research Questions**							**Objective 2 Research Questions**						
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Literature Review	✓		✓			✓	✓	✓						✓
Informal Meetings		✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓
Teacher Survey						✓				✓	✓		✓	
Instructor Interviews	✓	✓	✓	✓	✓	✓		✓	✓	✓				
Science Committee Interviews	✓		✓			✓	✓	✓	✓			✓	✓	✓
Observations		✓	✓	✓	✓	✓	✓	✓		✓			✓	

Table 1. (A) Research questions developed to frame project design and inform recommendations for the project objectives. Database Management System is referred to as DBMS. (B) Summary of methods used to answer research questions indicated by the question number found in (A).

Literature Review

We conducted a literature review of background research, qualitative analysis, and limnological data collection to familiarize the team with potential research methods and the challenges facing

ISEA. We used Mendeley Reference Manager (Elsevier, 2021) and Google Drive (Google, n.d.) to store and manage the references. References were categorized into the following groups for corresponding purposes: (1) reports on similar projects - to facilitate the overall design of the research questions and methods; (2) literature on qualitative research methods - to inform our qualitative analysis including observations, interviews, informal meetings, and survey designs; and (3) literature on aquatic sample collection - to provide guidelines for research-grade data collection protocols and QA/QC standards.

Informal Meetings with Experts and Stakeholders

Throughout the project, we scheduled informal meetings with environmental educators, experts in the fields of citizen science and aquatic science, potential data users, and other stakeholders to probe their insights on ISEA's long-term monitoring and data management strategies. We took paraphrased notes of these informal meetings instead of recording them for direct quotes. We created an initial list of potential meeting candidates based on online research and recommendations from ISEA staff, and then were able to expand the list in a form of snowball sampling during the initial meetings. In total, we conducted 13 informal meetings including five meetings with potential data users, four meetings with environmental educators, two meetings with citizen science experts, one meeting with a database expert, and a series of sessions with the data entry volunteer at ISEA. Since stakeholders were from different backgrounds, we tailored a unique set of questions for each meeting depending on their field of expertise. We rotated facilitation and note-taking roles during the meetings and encouraged a casual environment for stakeholders to share their opinions. Meeting notes were then compiled into a separate summary document by extracting themes and key suggestions. These summaries were used in our qualitative analysis (see **Qualitative Analysis** section).

Teacher Survey

To identify ISEA's potential data users and their needs, we implemented an online questionnaire to investigate if schoolteachers are interested in using ISEA's data beyond the one-day shipboard experience and how they might use these datasets (questions are listed in **Appendix I**). We built the questionnaire using the online survey platform Qualtrics and ensured that all questions conveyed the correct message to minimize confusion and errors (Floyd & Fowler, 1998; Schutt, 2001). ISEA staff emailed an invitation and link to the questionnaire to all teachers who had attended Schoolship programs with their students before or during the 2021 sailing season. Of the 401 teachers who received the questionnaire, more than 200 opened it; during the five-week active period, we received a total of 43 valid responses. We extracted key themes from these responses and summarized them within a document, which was analyzed alongside other qualitative results (see **Qualitative Analysis** section). All questionnaire entries were de-identified in this report to protect respondents' privacy.

Interviews with Volunteer Instructors

We conducted formal interviews with current and former ISEA volunteer instructors in May and June of 2021. Interview questions were exempt from Institutional Review Board (IRB) oversight after submission to the University of Michigan's IRB prior to the start of the study. All interviewees gave their written consent to participate in this study and for their interview to be included in the results of this report. Any information from interviews has been de-identified. Interviews can be classified into two broad categories: (1) interviews with volunteers who collect data and instruct in ISEA's programs; and (2) interviews with volunteers who have prior experience or interest in data management from a logistics perspective. In total, we conducted 17 interviews—14 instructor interviews and three data interviews. We interviewed some individuals for both interview categories, so in total 14 interviewees made up the 17 interviews. Interviews were held either in-person or via Zoom (Zoom Video Communications Inc., 2021), depending on volunteer comfort with COVID-19 conditions and availability. We recorded all interviews, either with the internal recording software available in Zoom or using the Otter.ai transcription app (Otter.ai, 2021). After recording, a member of our research team edited the automated transcription to correct for grammatical and translational errors and uploaded a final transcript to the secure University Dropbox platform (Dropbox, 2021) to be analyzed later in NVivo® (QSR International, 2021) (see **Qualitative Analysis** section).

Instructor Interviews

We conducted interviews with responding ISEA instructors to learn about their experiences with data collection and recording, and educating onboard the schooner during Schoolship programs. We invited all instructors currently on the ISEA volunteer email list to interview with us. We also asked them for insights about data use, including how ISEA currently uses monitoring data, as well as external groups or people who might be interested in the data; this helped inform some of our informal meetings as well as our recommendations in general (questions are listed in **Appendix II**).

Science Committee Interviews

We invited volunteer instructors with a background in data management to participate in a set of data interviews. These individuals were identified from a Science Committee formed in 2020 by ISEA’s science coordinator, as all members of this committee expressed a particular interest in the collection, storage, and sharing of ISEA’s data. Many of these volunteer instructors already had thoughts on the subject, since the 2020 committee had drafted a very short “Science Master Plan" which serves as the general framework upon which this project is based. An email was sent to the members of this committee, inviting them to speak with a member of our research team specifically about their ideas on data management and storage. This would assist us in making recommendations about an appropriate database management system (DBMS) for ISEA’s mission. At the end of the data interviews, volunteers were asked if they would like to share insights about data collection and the instructional process on the ship. Those that agreed were also interviewed as part of the Instructor Interviews (questions are listed in **Appendix III**).

Observations of ISEA's Programs

To better understand ISEA's teaching process and the quality of their citizen science data, we directly observed data collection, data recording, and education activities during ISEA's Schoolship program. We observed during the months of May and June 2021, onboard cruises and during shoreside programs at ISEA headquarters in Suttons Bay, Michigan. During that time frame, our team observed 30 school programs and 12 public sails onboard the schooner *Inland Seas*. During a four-hour sail, two researchers would jointly observe the volunteers and participants collect data and use educational materials, rotating to take notes on different aspects of the educational program. The captain introduced the researchers, so participants were aware of their presence as a form of announced observation (Gray, 2014). Additionally, the team was led through demonstrations of learning stations focused on water quality (pH and dissolved oxygen) and microplastics. These were typically parts of the ISEA program but were not held during 2021 due to COVID-19 restrictions. We captured observations with detailed, jotted field notes (Gray, 2014; Bryman, 2015) on paper with descriptive headings (an example is shown in **Appendix IV**). Within a day of the observations, the two researchers would sit together to form digital analytic memos (Saldana, 2015) of important information using these field notes. Memos were summarized versions of the pertinent observations compiled into two digital documents, one for public programs and one for school programs (an example is shown in **Appendix V**).

Image 1. Researcher (right) jotting notes during observation.

Throughout the entire observation period, we piloted citizen science online apps including iNaturalist, Great Lakes Fish Finder, the NOAA Marine Debris Tracker, Midwest Invasive Species, Lake Observer, and FieldScope to determine how well their various capabilities could be incorporated into ISEA's programming. We captured ideas about their potential incorporation in observation notes for analysis.

Qualitative Analysis

Utilizing the research questions and experience observing the programs, we developed a codebook (**Appendix VI**) (which consisted of a list of themes and their descriptions) to guide analysis of written data. Most codes were formed inductively, though two came from specific literature. We analyzed the observational memos and interview transcripts using NVivo® software, grouping codes of related observations and interview quotes to address research questions in a form of qualitative comparative analysis (Leech & Onwuegbuzie, 2008). All four researchers coded four selected documents and inter-rater reliability (IRR) was calculated within NVivo (IRR was 65 percent or greater for all documents). Researchers worked together to improve agreement and recode disagreements.

Following coding, we conducted thematic analysis (Bryman, 2015) comparing compiled data to identify broader common themes across all the data sources. We discerned themes based on coded data from interviews and observations, summarized informal meetings, and survey results. We composed these broader themes into a digital format allowing us to address research questions, document and discuss patterns, and prepare to make recommendations.

RESULTS

The following findings are sourced from across all data collection methods and are organized by key themes to address our corresponding research questions.

Instructor Ease of Parameter Measurement and Recording

Volunteer instructors found the data collection and recording processes to be efficient and easy. When asked about which parameters were the most difficult to collect during an interview, a volunteer stated “actually, they're all pretty easy to collect.” Particularly, volunteers felt fish biodiversity data are the simplest to collect and record.

However, volunteer instructors and researchers observed that the processes of data collection and recording still contain challenges for several parameters, especially due to the need to balance accurate data recording with engaging students. For example, during benthic community sampling, it is difficult to analyze PONAR grab samples given the equipment and time constraints. When asked about the process of collecting benthic data, a volunteer noted that “I think the analysis side is more inconsistent, because of time pressures”. Time pressure is exacerbated in the shoreside wetland benthic station with its increase of species diversity compared to that of the lake. Volunteers noted that working with students for the allotted time often leaves unexamined samples for volunteers to sift through after students have left to finish recording on their datasheets. A similar issue occurs with microplastics collection as volunteers struggle to identify plastic particles correctly in an allocated time while also engaging students. This station is also complicated by the need to record the boat speed on a consistent schedule while teaching students. We observed that this balance of data recording and student engagement can also become an issue for the Secchi disk recording process and especially for the plankton station. As a volunteer observed “I get the importance of [recording]. I just think practically with the limited amount of time it's kind of hard to--plus then you have…to spell out all the things”. This led to a volunteer suggesting that having a second instructor present for plankton identification would help as there would be one volunteer to focus on the students and one to operate the microscope and record diversity. We found that equipment issues such as Secchi disk ropes having missing markers, Van Dorn bottles incorrectly deploying, PONAR grabs unsuccessfully capturing benthos, and the plankton net moving horizontally rather than vertically may sometimes negatively affect the ability for volunteers to easily collect and record data.

A final complication is that several data parameters collected by the lead instructor are inconsistently measured or recorded by volunteer instructors. Specifically, weather conditions such as cloud type and wind speed are inconsistently recorded, while others such as wave height are subjective in their measurement process. Other parameters such as location are recorded without a clear nomenclature. We noticed that while the ship was in the same sampling spot, the lead instructor may record the location as “SB”, “Suttons Bay”, or “near the marina”, which complicated the digitization process for the volunteer who inputs the data.

The data entry volunteer faces challenges interpreting recorded data which lack a clear procedure for recording, a purpose in the long term, and consistency of collection. We observed that the datasheet contains a place for volunteer instructors to record parameters which do not presently have a consistent procedure for digitization. For example, only some volunteers will record the number of fish with parasites, but without a committed effort to collect and digitize this information through time, the data are partial and lose value. Likewise, the benthos datasheet contains places for volunteers to record benthic substrate texture and color but uses a dry soil chart as comparison for wet samples. Volunteers also contextualize the data by recording the volumetric amount of sediment, which was analyzed, but only sporadically. In interviews, volunteers also noticed that when recording benthic organisms which were collected using the PONAR grab and the otter trawl, the lists are in different orders (one starting with mussels and the other with midge larvae). This can lead to some confusion, especially when having to multitask onboard. This is compounded by the observation that volunteers often are unsure if benthic organisms should be counted or recorded as presence-absence, which can even be recorded differently on the same datasheet. To reduce confusion, volunteers would prefer datasheets which are one-sided to avoid flipping back and forth, which have larger text, and which are waterproof. One volunteer noted “I think it would be good to have everything on one side, but I don't know as an instructor, if that feels like a barrier, to have to flip the [data]sheet over.”

The plankton datasheet presents unique challenges for the volunteers due to its formatting. In interviews, several volunteers expressed the difficulty of writing down the scientific names of plankton while also trying to operate the equipment and engage students under time pressure. Data recording often requires time to finish after the students have rotated to the next station, which is frustrating to volunteers who want to stay with students for the end-of-program briefing. This has led some volunteers to create a “cheat sheet” using the formatting of the student logbook to record plankton diversity and then fill out the official datasheet afterwards. We observed that volunteers often struggle to calculate percentages of plankton found in the water drops and that recording as fractions would be just as effective for digitization. Phytoplankton is recorded infrequently, and without proper equipment. It also does not have a clear audience for its digitization and thus lacks a purpose on the datasheet. Lastly, the datasheet contains no standard for differentiating water drops which are empty versus those which are skipped for timing, which causes confusion for the data entry volunteer.

Through discussions with other environmental education programs, we found that the use of digital tablets has the potential to streamline the process of data recording and digitization. Organizations utilize systems such as ArcGIS Collector and Survey123 during programs with students and specifically mentioned their ease of use. Volunteer instructors have suggested that the use of tablets may pose an issue with students on the water, stating that “iPads are logistically, a big issue too with--it's not a good idea in a water environment, you know, let alone the idea that they are gonna hit something, or drop”. While we observed that a lead instructor could maintain responsibility for a single water-protected tablet with less complication, there would still need to be considerations of how to connect the tablet to the chosen database.

Quality of Collected Data

While not all collected data are rigorous enough for scientific research, the collection process provides quality data for educational purposes, even at higher education and public decision levels. Interviews indicated that volunteers are confident and comfortable with the process of identification and recording. Instructors have a clear understanding that data quality is not first priority, as student experience takes precedence, but they do make an effort towards quality data collection and recording. One volunteer noted that “data collection, I mean it's a high priority. And it is a consistently high priority”. A meeting with a water quality expert provided the insight that retaining volunteers over years increases the quality of the data as well. An aspect that reduces the data quality generally is that the data units should be recorded consistently (i.e., metric vs. customary). We also observed periodic confusion over measuring or recording sampling depth. This was sometimes due to the lead instructor not announcing the depth. Other instances were due to misreading the depth meter or not including the additional four feet of water between the surface and the meter, both of which can impact the use of other sampling equipment.

Measurement of turbidity using Secchi disks follows standard research procedure (NALMS, 2021), however several acts reduce its quality in practice. We observed that many instructors were inconsistent with their understanding of what depth is the correct measurement to record. Volunteer methods differ between recording the last depth at which the disk can be seen versus the first depth at which the disk cannot be seen. Documented procedures state that it should be the average of these two depths or the point where the disk vanishes and reappears (Simpson, 2015). Additionally, Secchi depth is recorded in whole meters, with half meters being rounded up, instead of the suggested subdivision to tenth-of-meter (Simpson, 2015). Measurements were also recorded even when the Secchi disk drifted under the ship from currents. These actions can produce observed outliers, all of which are averaged into Secchi depth measurements digitally. Volunteers also noticed that measurements will differ between the sunny and shady sides of the vessel, and that their eyesight differs from the students'. A final data quality issue arises when volunteers are unable to closely supervise Secchi depth measurement and rely on students to collect the measurement without checking their technique.

Collection of fish diversity data is of higher quality than for other parameters. Quality is due to practices such as volunteers recording fish from minnow traps before students arrive, and recording fish from the otter trawl as a tally when fish are released at the end of the program to reduce accidentally counting the same individual twice. Also, the captain is responsible for the tracking of time for the trawling and aims for a consistent speed.

The collection of microplastics and water quality data have their own data quality considerations. While microplastics are collected and analyzed according to protocol (Eriksen et al., 2013; Mason et al., 2016; Helm, 2020), the use of a manta trawl requires a specific speed which is not always feasible during the sail. Volunteers also report that distinguishing the types of plastic is challenging and often subjective, especially when poor eyesight is a factor for older individuals. Dissolved oxygen, temperature, and pH are not collected under research-grade protocols, such as using a YSI probe (Burns et al., 2005), however the student experience of using titration and wet labs is a clear benefit. The level of dissolved oxygen may also change over the duration of a sail. Due to this, one volunteer noted that they record "true values" before student rotations, writing this number instead of the dissolved oxygen values derived from students.

The balance between utilizing research-grade equipment and creating an engaging student experience creates unique data quality challenges during the collection of benthos data. Research-grade benthic diversity is typically collected using a PONAR grab, filtered through a 500 μm mesh sieve and then specimens are preserved for analysis in a laboratory (Burlakova et al., 2018; Mehler et al., 2020; Scharold et al., 2009), meaning the ISEA method of field analysis produces only education-grade data. This is because volunteers cannot be sure that every organism is cataloged during the sail with their competing responsibilities and afterwards the sample is returned to the lake. To get truly research-grade data, the sample would need thorough analysis and scrutiny in a laboratory. In interviews, volunteers noted the tension of wanting students to direct attention towards touching benthic organisms and sediment rather than analyzing and identifying the sample. We noted that they often had to record the results after students had left. Timing is also an issue, as noted by volunteers, in that instructors must analyze both PONAR sediment samples and vegetation captured from the otter trawl. Many organisms which are attached to the vegetation captured from the otter trawl require time to find amongst the plant matter, and thus students and instructors spend time looking for the organisms instead of identifying them. We observed that the quality of sediment color data may be compromised as the key is designed for dry soil samples. Additionally, the volume of the benthic sample is standardized on the ship programs as the PONAR grab retrieves the same size sample each trial and volunteers record how much of the sample was analyzed. However, the wetlands benthic station contains inconsistent measurement protocols by varying the sample size and area from which they are collected in the wetland.

We observed several inconsistencies within plankton data collection and water drop creation protocols which affect the quality of the data. ISEA uses a modified version of plankton diversity analysis, as established procedures call for plankton to be preserved for laboratory analysis (Barbiero et al., 2019; EPA, 2021b). Although the ISEA procedure creates a systematic comparison of plankton samples, each volunteer differed in their technique. We observed differences in how volunteers created water drops for examination including: whether to stir the sample cup prior to drawing drops, which part of the sample cup drops were pulled from, whether the instructor or students created a drop, whether the Petri dish was wiped down in between stations, the size of the drops, whether drops were crowded together or spaced apart, whether drops were diluted with extra water, and whether a second Petri dish was used to press drops into a flatter shape. We also recognized that dead plankton were occasionally recorded. When engaging students with a time limit, volunteer instructors will sometimes focus on finding interesting organisms or creating new drops to display plankton instead of fully analyzing the existing five drops. It is important to center student education, but also reduces data quality.

Datasheet Inconsistencies

Despite volunteers' high confidence in data recording, we observed certain inconsistencies on the datasheets and learned of several others through our informal meetings with the volunteer who currently inputs ISEA's data. Many of these inconsistencies are important in the translation of the paper datasheets to the digital database.

The plankton datasheet seemed to have the most recording inconsistencies across all data parameters. Specifically, we observed that there was no definitive way to distinguish between an empty water drop in which no plankton were observed and a drop that the instructor skipped due to a lack of time or other circumstance. Some instructors recorded "none," some drew a solid horizontal line through the box for the drop, and others left the box blank. All three of these scenarios can be interpreted as either “there were no plankton observed” or “the instructor did not see plankton because they did not get to that drop.” Upon speaking with the data entry volunteer, we learned that this created challenges when translating the written sheets to the digital version. This lack of convention for missing data can be expanded beyond the plankton datasheet, as it was observed that all data parameters occasionally have instances of blank data boxes that are problematic for the data entry volunteer.

There were also inconsistencies that occurred with the level of detail recorded, resulting from a lack of clear instructions and examples on the datasheet. For example, occasionally the Secchi disk disappeared under the boat, and it was unclear if it would have been visible had it continued to go straight down. We observed that sometimes these values were discarded and other times they were recorded with a “greater than” value. For example, in one instance, the Secchi disk went under the boat when the students had counted to 10m, so the lead recorded this as >10m. Still another time, the disk disappeared under the boat at 13m, and it was recorded plainly as 13m. The method of recording for this situation is not clear, and the datasheet does not specify what should be done in this instance. Similar problems also occurred with other parameters. On the fish datasheets, we observed that the number of gobies with spots (indicating the presence of an ectoparasite) were sometimes recorded. This information was recorded in earlier years but is no longer of interest to ISEA; however, the datasheet still has a box to record it. The actual recording of these Round Goby spots, however, was inconsistent and was mostly performed by a few long-term volunteers.

We also found some more general issues that need to be addressed to improve the process of turning handwritten data into digital data. First, the way that inconsistencies between paper and digital datasheets are currently handled consists of the volunteer data entry volunteer “flagging” inconsistencies with sticky notes on the paper datasheet for an ISEA staff member to address. Sometimes these inconsistencies are not addressed until the end of the Schoolship season, which can create challenges for remedying the problem due to human memory. Second, the lead volunteers on the ship often make ambiguous notes and avoid making decisions about data entry while on the boat. These notes often take the form of qualitative observations such as “there was a lot of poop in the PONAR today” or “Secchi disk went under the boat” with a number accompanying it. This leaves decisions up to the person entering the data, who is not actually observing things as they happen and is not the best person to decide how to enter something questionable. Furthermore, there is no clear space for notes like this or to know if they’re truly useful, which can complicate data entry. Upon consulting other environmental education programs and asking about their experiences with data recording, we found that many other programs avoid inconsistency issues altogether by refraining from digitizing questionable data points.

New Organism Protocols

There presently is no standard protocol for what a volunteer instructor should do if they find an organism that may be new or uncommon, although this scenario was observed several times during our observation season. Here, we discuss "new" species as those that ISEA volunteers and staff have never seen before, and "uncommon" species as those that are not typical or easy to identify with the standard instructional dichotomous keys. Uncommon species may also include "releaser" fish that are too large to keep in the tank for student observation, even if they are common in Suttons Bay, as these fish are not commonly caught in the otter trawl.

Although there is no standard protocol to record these new organisms, volunteers have a general idea of what to do when they encounter them. Interviews and observations both illustrated practices such as asking the lead instructor for a second opinion and using keys and field guides beyond those typically used for onboard instruction. Most instructors also take photos of unknown organisms and make a note on the datasheet about their findings. However, none of these procedures are currently required, and an instructor can choose to do some combination of the above, or nothing at all, when encountering a new organism.

Interviews suggested that ISEA should either physically preserve unidentified species or document them with photographs for further identification. At present, most volunteers photograph unknown organisms and upload the photographs to the iNaturalist citizen science app. This has been suggested by ISEA staff but is not required. Some volunteers prefer saving physical specimens because they believe it is more accurate to use local resources than a community app that is not specific to Michigan. To quote one volunteer, "I more frequently have saved the specimen and handed it to [an ISEA staff member]." One volunteer suggested having a checkbox to say that an unidentified organism was found and a follow-up box to say whether a picture was taken as a way to improve the process of tracking unidentified organisms. One challenge we observed with photographic preservation is that there is currently no way to store photographs in ISEA's digital database and not all databases have the capacity to store this type of data.

Citizen Science Platform Value

Digital citizen science platforms can benefit students and the public by providing user-friendly access to data. One environmental education group shared that they store their data in GLOBE Observer, which adds value to their program by allowing participants to access their own data and create visualizations to explore it. A nonprofit who manages and delivers Great Lakes data and information to regional users reported that storing data in a platform managed externally is "ideal" for a small organization such as ISEA.

Volunteer instructors conveyed mixed opinions about using citizen science apps while onboard with students. In interviews, some volunteers expressed that use of a citizen science platform will add value to ISEA's programs by showing kids how their data can reach the community. One instructor, however, noted that using a citizen science app with students "would be more powerful in the land-based work than the boat-based work," as glare from the sun or rain would introduce challenges while on the ship. Other volunteer instructors felt that using an app while onboard would devalue the hands-on learning experience:

> Here's a problem I see. It's increasingly the case that you no longer need to go out and put your hands on things to know them. You can look so much stuff up…So I guess I would say that Inland Seas ought to bring in citizen science applications, but in such a way that it preserves hands-on learning. I'm very much against having an iPad on the coach roof or the schooner while teaching the station. I'm very much for a citizen science application being the destination of our collected data.

In observations, we saw that the educational process already faces time constraints, thus there is little time available for students to execute an additional step of digitally recording their data.

In our online teacher questionnaire, we found that nearly half (48.84%) of responding teachers are comfortable using or learning to use a citizen science platform interface for accessing their students and ISEA's data. Citizen science platforms were the second most common selection of potential formats for receiving data, ranking after pre-made charts (90.70%), and before raw data (44.19%).

In piloting the utility of various citizen science platforms, we found that FieldScope is a potential candidate for storing ISEA's data. This platform houses the Great Lakes Watershed project, which stores over 27,000 observations by contributors across the region (FieldScope, 2022a). The data are accessible to anyone who makes a free account, and it has built-in tools for filtering data, creating maps, visualizing trends, and generating summaries. Though the Watershed project does not capture the full extent of parameters ISEA measures, it includes a variety of biotic and abiotic variables that ISEA routinely collects.

The iNaturalist app is useful in identifying and recording new organisms but is not compatible with most of ISEA's protocols. In interviews, we heard that a few volunteers use iNaturalist when they encounter an unfamiliar specimen during data collection, which allows them to both record the finding and receive a suggested identification. We attempted to use the app to record the full range of data collected during a sail and found that it is capable of recording any of the living organisms caught during sampling, but it cannot be used to record ISEA's abiotic measurements. Additionally, iNaturalist is not able to record a count when multiples of a species are captured; instead, each organism found requires a separate entry. This is problematic for the numerous fish, plankton, and benthic organisms sampled by ISEA, which will typically result in several to tens of duplicates per sail.

We piloted the use of several other citizen science platforms and found that none were suitable for ISEA's data recording needs. Though GLOBE Observer captures many of the biotic and abiotic variables ISEA measures, it requires instructors to be trained on GLOBE's protocols, many of which differ from ISEA's methods. The Great Lakes Fish Finder is a project under iNaturalist, and thus has the same limitations as the parent app. The NOAA Marine Debris Tracker could be used to record ISEA's microplastics data, but no other parameters could be stored here. Similarly, Lake Observer could house ISEA's weather, Secchi depth, and water quality data, but no living organisms. The Midwest Invasive Species app was not functional, and we were unable to upload data into it.

Possible QA/QC Steps Onboard

At present, ISEA's QA/QC procedures on the boat are primarily limited to the actions of the lead instructor who collects and signs off on datasheets before bringing them to the ISEA office for digitization. With this procedure, we observed instances of mistakes on the datasheets, including incorrectly recording the date and noting the sampling depth (e.g., the depth the plankton net was lowered to) as deeper than the station depth. Our discussions with the data entry volunteer also suggest that legibility is a common problem when trying to translate onboard datasheets to digital platforms.

Our observations suggest that several other fairly common occurrences should also be incorporated into onboard QA/QC procedures, including consideration of bad weather and equipment failures and how these affect data quality. In particular, we observed that the PONAR and Van Dorn bottle were prone to improper deployment, yet nothing was done to account for the quality of data from these instances.

To address QA/QC challenges onboard, volunteers suggested several immediate actions that could be taken. During our interviews, several volunteers suggested incorporating data confidence checkboxes to the datasheet as a quality assurance measure. They noted "I thought it would be a good idea if the datasheet had three checkboxes for: I have high confidence in this datasheet, I have moderate confidence in this datasheet, or I have low confidence in this data." Another volunteer suggested having space on the datasheet for tallying fish, since in the height of the season sometimes hundreds can be caught in one trawl, but there is not a large amount of space on the sheet for keeping track of counts. This requires instructors to use the margins to help with counting, which is messy and sometimes difficult.

Informal meetings with other science groups also gave insight into QA/QC procedures that may benefit ISEA's programming. The one common method suggested would be to refrain from keeping any data points that seem questionable. For example, a Secchi depth data point that is drastically different from the others recorded on a sail (an occurrence that we regularly observed) could be removed.

Effect of Data Storage on Educational Experience

ISEA's 30-year data storage provided the opportunity to create charts displaying trends in the data which we found to be an integral part of onboard education. Interviews with volunteer instructors suggested that charts derived from ISEA's data are useful for achieving STEM education goals including how to read and draw conclusions from different types of charts. Charts used during the fish station and during Secchi depth collection were frequently noted by volunteers and seen during observation to be especially impactful when addressing the central question *"Is the bay healthy?"*. By presenting a comparison of historical and current data, participants could clearly see trends and changes to lake conditions and biodiversity that have occurred following the introduction of invasive species. Across the learning stations, volunteers use various charts for instruction providing different perspectives of lake health, which sparked student questions and led conversations into broader topics of lake resilience and ecosystem change. Additionally, they mentioned that using visual aids like charts is beneficial to learners of all ages and with varying attention spans. Because these charts are so essential to the program, interviewed volunteers requested for fish pie charts and various charts on water temperature to be updated more frequently.

We also found that ISEA's data storage provides logistical support to its onboard educational programs. In interviews, volunteers mentioned that in instances when there are complications with sampling, such as when no fish are caught in the otter trawl, historical data and charts allow the learning rotations to proceed. Even when no fish are available for students to identify, pie charts remain an effective tool to show past and current forage fish community diversity and to address the central question of the program. Volunteers also use the historical data to compare with the day's measurements to assess the status of lake health with participants, which is also confirmed in literature that data storage can provide immediate feedback to measurements of the day (Vail & Smith, 2013).

Another function of ISEA's data storage is to support ISEA's organizational identity. We learned from volunteers that ISEA's data storage is an integral part of their public perception and holds the promise that "the kids are going to do actual research, which does contribute to the collected scientific knowledge." This sets ISEA apart from other environmental education organizations that do not collect and/or store data. They also noted that this advantage may help ISEA to secure more grants or donations from federal and individual levels which will help support and grow the organization.

Identifying Potential External End Users

Educators as End Users

Through our meetings with experts and volunteer interviews, teachers emerged as a primary potential user of ISEA's data. We frequently heard that data collected during programming are not used internally or for research but are used for educational purposes. One organization shares student-collected data with the students' teachers for use in the classroom, while another organization uses their data in curated data lessons targeted at a range of age groups. A few volunteer instructors shared similar ideas of creating data lessons on ISEA's website for students to use before a Schoolship sail to help them prepare, or after they attend to maximize their learning experience. Additionally, we met with a freshwater studies educator from a local community college who expressed interest in using ISEA's raw data in the classroom to explore key benchmarks of change (e.g., when invasive species are introduced), or for comparisons with other datasets.

When we asked teachers in the online questionnaire if they are interested in using ISEA's data in their classrooms, 97.67% responded either "yes" (62.79%) or "maybe – I need more information or access to training resources" (34.88%); only one respondent (2.33%) selected "no" (Figure 1A). We found slight differences in how teachers responded to this question depending on the age group(s) they teach (Figure 1B). Teachers who instruct students in grades K-8 (n=35) more frequently responded "maybe", while teachers who instruct high school students (n=24) more frequently selected "yes". Over half of respondents identified as science teachers (n=23), the majority of whom educate at the high school level. Only one math teacher and one social studies/history teacher responded to the survey, while five respondents identified as teaching afterschool programs, and 15 identified as "other" (many of whom specified that they teach all subjects). Across subjects, more respondents selected "yes" to having interest in using ISEA's data, with the exception of afterschool teachers, who more frequently selected "maybe". A full summary of teacher responses to selected questions is provided in **Appendix VII**.

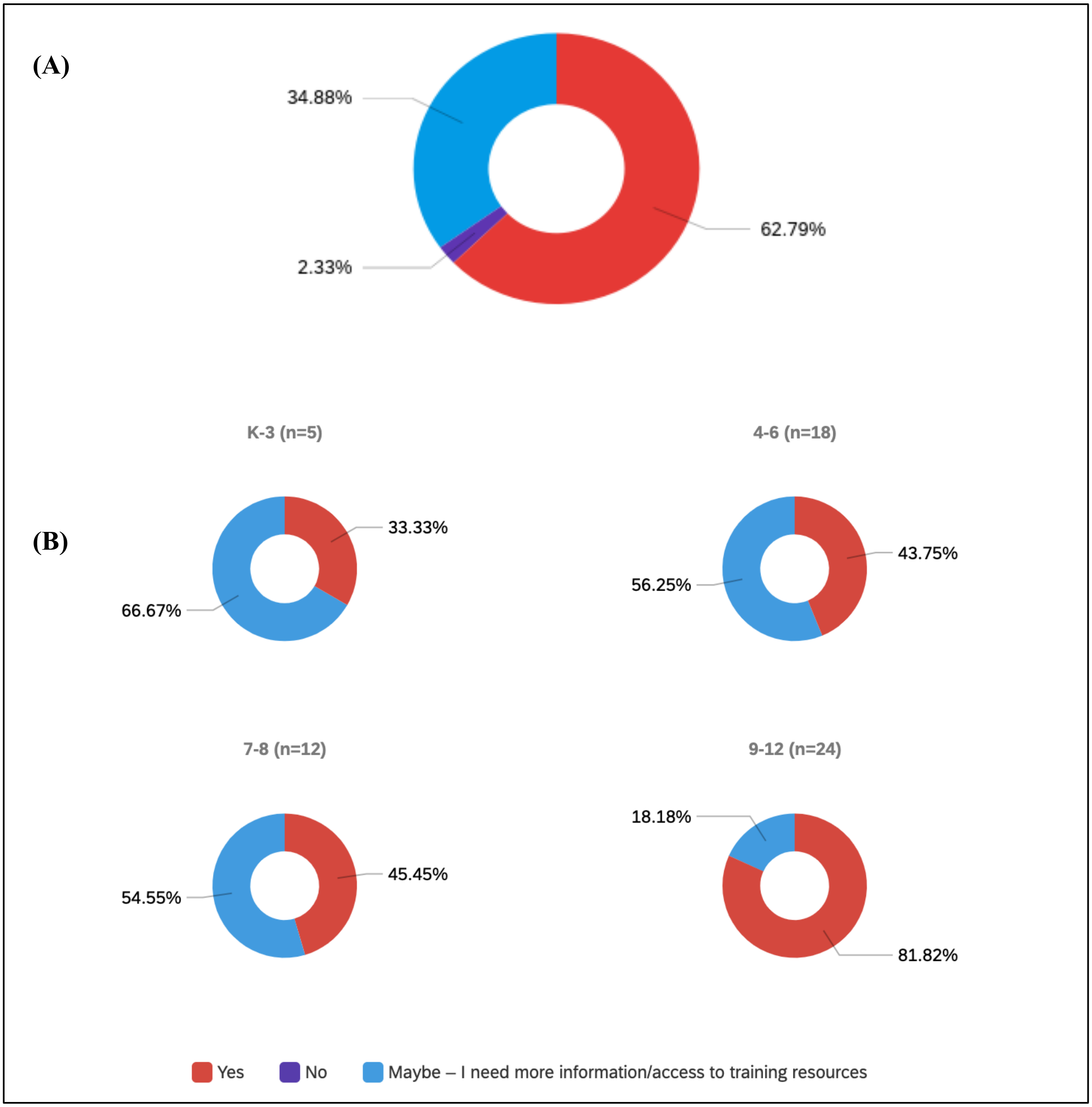
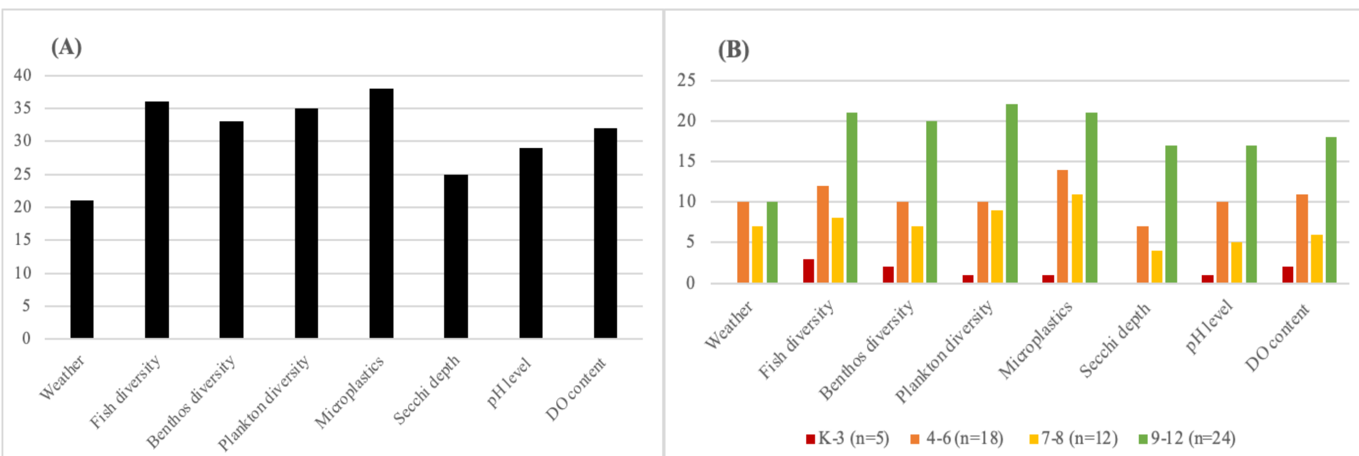


Figure 1. Pie charts summarizing teacher responses to the survey question: ISEA has recorded the data collected by students during their programming for decades. Would you be interested in using this data in your classroom? (A) Summary of all teacher responses (N=43). (B) Breakdown of teacher responses by the age group(s) they teach.

Teachers showed interest in all parameters collected during Schoolship sails. Microplastics data was the most popular parameter and was selected by 88.37% of respondents. Weather was the least popular parameter but was still selected by 48.84% of respondents (Figure 2A). We found slight differences in how teachers of different subjects and age groups responded to this question

(Figures 2B & 2C). No K-3 teachers (n=5) expressed interest in using weather or Secchi depth data with their students. Among this age group, fish biodiversity was the most popular parameter. Teachers of grades 4-6 (n=18) had greatest interest in microplastics (77.78%). Secchi depth was of least interest to this group but was still selected by 38.89%. Teachers of grades 7-8 (n=12) also had greatest interest in microplastics (91.67%), and least interest in Secchi depth (33.33%). Teachers of grades 9-12 (n=24) showed greatest interest in plankton biodiversity (91.67%), followed by fish biodiversity and microplastics (87.50% each). Teachers in this group had lower interest in weather data (41.67%). Teachers who instruct science (n=23), afterschool programs (n=5), or "other" (n=15), and the single math teacher expressed interest in all parameters. The social studies/history teacher only selected microplastics.

Teachers who completed the questionnaire envision using ISEA's data in their classrooms in a variety of ways. The most common responses to this question centered around using the data after the visit to ISEA (44.19%), but many teachers also planned to use the data before the visit, and/or as supplemental material (25.58% each). Other common responses for how the data would be used were to close gaps in knowledge after the trip, or to analyze historical and seasonal trends over time. One teacher described interest in using data lessons created by ISEA. The math teacher said they would like to use the data in lessons on modeling and statistics. The social studies/history teacher was interested in looking at historical trends.



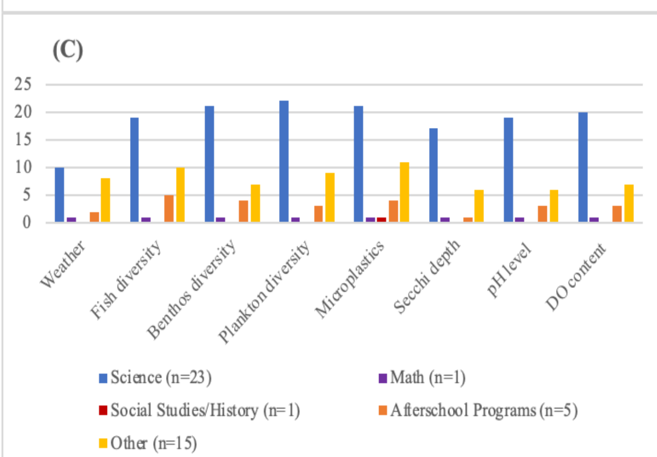


Figure 2. Bar charts summarizing teacher responses to the survey question: Which of these data topics would you potentially be interested in having access to in your classroom? (Select all that apply). Y-axes represent counts. (A) Summary of all teacher responses (N=43). (B) Breakdown of teacher responses by the age group(s) they teach. (C) Breakdown of teacher responses by the subject(s) they teach.

The Public as End Users

Volunteer interviews and informal meetings with experts revealed the public as another potential end user of ISEA's data, with an emphasis on using trends for public education and outreach. Suggestions included putting ISEA's data on their own website or on a citizen science platform so the public can access it. We frequently heard that trends, rather than raw data, would be better suited for sharing information with the public. Two environmental education organizations shared that they create reports for general audiences using trends found in their data. From ISEA's data, experts expressed that trends related to average Secchi depths, plankton communities, and forage fish communities would be useful for educating the public on how the Great Lakes are changing. We also heard that a georeferenced ArcGIS StoryMap would be a compelling way to reach the community.

Environmental Researchers as End Users

Providing researchers access to protocols will help them decide if or how they want to use the data. Volunteers had mixed opinions on whether ISEA's data are suitable for use by scientific researchers. While some interviewees expressed concerns over the rigor of the data to meet research standards, others felt they could be useful to researchers who work for groups such as the Michigan Department of Natural Resources (DNR) and the National Oceanic and Atmospheric Association (NOAA). The value arises because ISEA's dataset focuses on a spot in Grand Traverse Bay not typically sampled by researchers and has great resolution as trips are made almost daily during their sailing season. As stated previously, none of the environmental education organizations we spoke to supply their data to researchers. However, other experts expressed that the data could be useful to researchers, so long as the protocols used for data collection are supplied with the data. A nonprofit organization who manages and delivers Great Lakes data and information to regional users felt the long-term dataset would be exciting for researchers, who are savvy enough to remove anomalies from raw data when appropriate. From their perspective, data do not need to be of the highest quality, but of "known quality" for use in research. Similarly, a fisheries researcher was interested in using ISEA's forage fish data in their own research, with the request that protocols be provided, as well as notations in the long-term dataset when protocols were changed or updated.

Advocacy Groups or Policy Makers as End Users

A local watershed protection and advocacy group who authors watershed protection plans every several years (and has drawn from ISEA's data in the past) has ongoing interest in ISEA's Secchi depth, temperature, and biotic data for use in future plans. They mentioned that a Quality Assurance Project Plan (QAPP) would be beneficial to their understanding of the data quality when using it to inform watershed plans. Another organization that operates a rigorous citizen science monitoring program regularly supplies their data to the state to inform management plans. In our conversations with this organization, they repeatedly stressed the importance of using a QAPP to ensure the state's data quality standards are met.

Delivery of Data to External End Users

Delivery to Educators

Teachers are widely familiar with MS Excel, making it a good candidate for delivering data for use in classrooms. The aforementioned organization that shares student-collected data with teachers for use in the classroom delivers raw data stored in MS Excel files. The freshwater studies educator from a local community college also stated their preference would be to receive data in MS Excel.

When asked in our online questionnaire which formats of data delivery teachers would be comfortable using or learning to use, pre-made charts was the most commonly selected option (90.70%), followed by a citizen science platform (48.84%), and raw data in MS Excel or Google Sheets (44.19%) (Figure 3A). Across age groups, pre-made charts was always the most common response. No K-3 teachers selected the raw data option. Teachers of grades 9-12 were the only group to show a stronger preference for raw data (66.67%) than a citizen science platform (58.33%) (Figure 3B). Science teachers followed the same pattern as 9-12, with greatest interest in pre-made charts (91.30%), followed by raw data (60.87%), and a citizen science platform (47.83%). The math teacher selected both pre-made charts and raw data, while the social studies/history teacher selected only pre-made charts (Figure 3C).

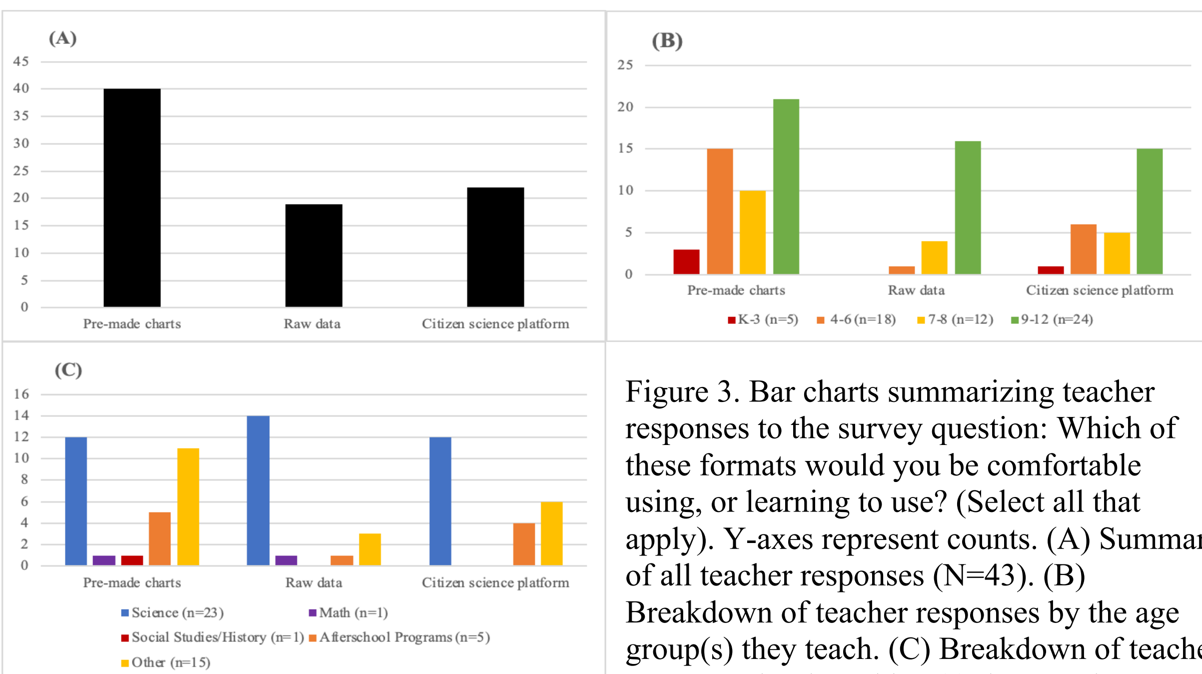


Figure 3. Bar charts summarizing teacher responses to the survey question: Which of these formats would you be comfortable using, or learning to use? (Select all that apply). Y-axes represent counts. (A) Summary of all teacher responses (N=43). (B) Breakdown of teacher responses by the age group(s) they teach. (C) Breakdown of teacher responses by the subject(s) they teach.

The majority of teachers (74.42%) were interested in receiving long-term data, rather than data collected from a single sailing season (16.28%), or the data collected only by their students (6.98%) (Figure 4). Teachers of all age groups and subjects preferred long-term data, except for K-3 teachers (n=5), and afterschool-program teachers (n=5), who more frequently selected field-season data.

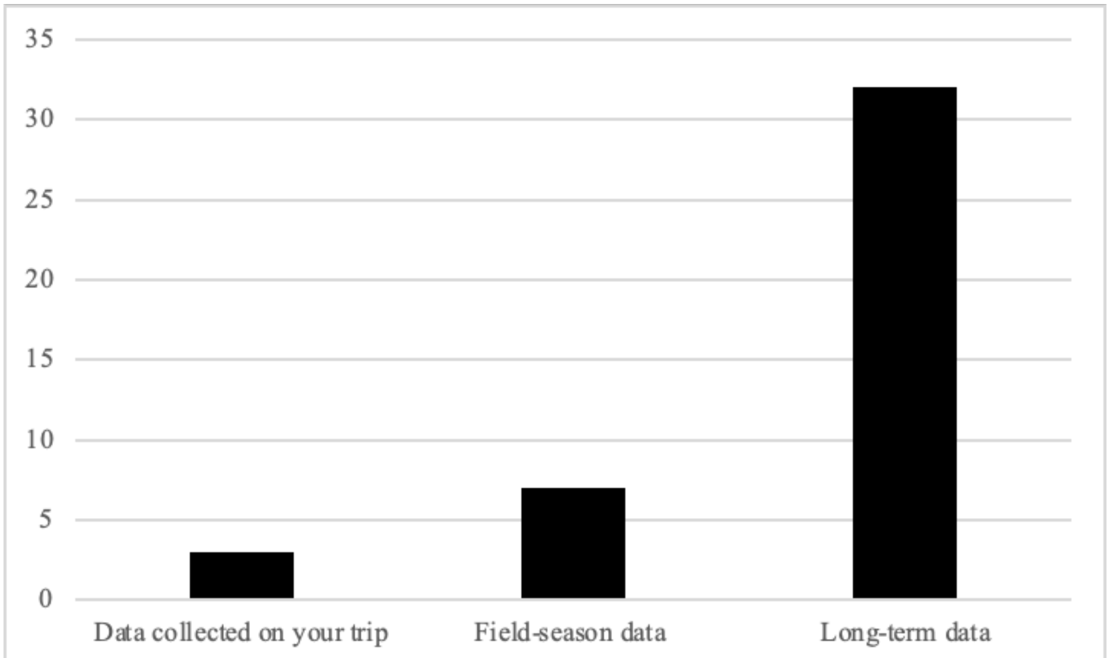


Figure 4. Bar chart summarizing all teacher responses (N=43) to the survey question: How much data would you like to receive? The Y-axis represents counts.

Delivery to Researchers and Advocacy Groups

MS Excel is also a good option when delivering raw data to researchers or advocacy groups. The fisheries expert stated that MS Excel would be most useful for their needs, as MS Excel files are easy to load into RStudio for analyses. The nonprofit organization who manages and delivers Great Lakes data and information to regional users also expressed that researchers would be interested in raw data, which would allow them to remove data points at their discretion. The watershed advocate said summarized trends or raw data would be useful when putting together watershed plans, but access to raw data in MS Excel would be best so they can sort the data in different ways.

DBMS Characteristics Important for Data Input and Use

During informal meetings with ISEA's data entry volunteer, we learned that a key factor hindering data entry efficiency and ease is that some parameters are formatted differently on the paper datasheets populated on the ship, from the digital forms stored in the database. We observed many cases where the order of variables recorded on the paper datasheets did not match the order of the same parameters in the digital entry form. This mismatch creates confusion and decreases efficiency, while also introducing potential error. In the current MS Excel database, we found that when digitizing plankton data, the data entry volunteer must often cross-check the percentages listed on the front side of the paper datasheet with the original fractions noted on the back side of the datasheet. Because the percentages calculated during instruction are frequently estimated and sometimes incorrect, the data entry volunteer prefers to use MS Excel's built-in functions for calculating percentages. The current process involves the unnecessary steps of asking the instructors to record percentages that end up being disregarded and requiring the data entry volunteer to flip the paper sheet over and search for the information that needs to be recorded.

A lack of specified standards for how a parameter should be recorded and digitized also limited data entry efficiency. For example, volunteers sometimes recorded date and location in different formats which can cause confusion during digitization. These parameters were often overlooked because they were perceived to be very easy to record, and this generated inconsistency. Another feature that limited data entry efficiency was the lack of auto-fill and drop-down list functions in the current MS Excel system, when the entry form function was used to enter data. As mentioned previously, most volunteers take a photo when they encounter an unfamiliar species during data collection, but neither the current MS Excel system nor the previous MS Access system has a designated space for digital photos to be stored (Microsoft Corporation, 2022).

Volunteer interviews and informal meetings with data experts suggested some DBMS characteristics that are important for both internal and external data use, including capabilities for data visualization, data manipulation, and cross-platform compatibility. We learned that it is crucial for the DBMS to be capable of: identifying outliers to maintain quality, generating visualizations and summaries with simple steps from different data, and performing simple calculations to maintain query efficiency. In addition, volunteers also mentioned that being compatible across multiple platforms and devices can be important especially when the database is shared to external users.

Primary Database Management System

We identified advantages and disadvantages of each database option, namely the MS Excel system, the MS Access system, and the FieldScope platform (FieldScope, 2022b; Microsoft Corporation, 2022). From the teacher survey and informal meetings, we frequently heard that potential external end users prefer to receive data in MS Excel or comma-separated values (CSV) files. Other environmental education organizations mentioned that they digitize and store their data in MS Excel based database systems. This confirmed that MS Excel is a viable database management option and is widely accepted among the public. From interviews and sessions with the ISEA data entry volunteer, we learned that people generally are more familiar with MS Excel and volunteers are satisfied with the current MS Excel database since the data entry process is smoother and more efficient than the MS Access database when entering traditional Schoolship data. This MS Access database was developed with external support and used to store all data between 2016 and 2019. However, ISEA adapted to a new programming format due to COVID restrictions in 2020 and volunteers found it difficult to store the new data into the MS Access database which was designed before pandemic. Since then, all data were stored in separate MS Excel files each year. Additionally, MS Excel is supported on all of ISEA's devices while MS Access can only be accessed on Windows operating systems. External data experts also mentioned that MS Excel allows for more flexibility in data entry and design, but this also introduces more room for error compared to the MS Access counterpart.

Informal meetings with data experts and other environmental education organizations also provided insights on the pros and cons of an MS Access based database management system for ISEA. Compared to the MS Excel database, implementing a relational database, like MS Access, allows a much more sophisticated data structure with primary keys to establish communication between data stored in disparate locations, and prevent potential duplications and mismatching. It was also suggested as "the most efficient" database system and "very well designed for data storage and analysis" during informal meetings. We observed that even though it can be difficult to build queries inside the system at the beginning, data can be queried easily with simple steps once data are set up correctly. In addition, MS Excel files can be easily formatted and imported into a MS Access database and MS Access data can also be easily exported into MS Excel files or CSV files, making it a viable option when considering the interests of external data users. We also found examples of other environmental education organizations that use MS Access for data storage and internal data analysis, while exporting MS Excel files for external use requests.

FieldScope, a digital citizen science platform, also remains as a viable option for ISEA to store their data (FieldScope, 2022b). By piloting various citizen science platforms, we found FieldScope to best fit ISEA's current data collection and storage needs. One advantage of FieldScope over the other two options is that it allows users to upload media such as photos, which could streamline the new organism protocol. Another clear advantage of using an external database like FieldScope is that it does not require ISEA staff to maintain the system after it is established and it can be accessed easily by any external user with a free account. FieldScope also provides customizable visualization tools that can be helpful in the classroom and during onboard education at ISEA. In addition to the existing Great Lakes Watershed project, there is potential for ISEA to launch their own FieldScope project that is tailored to digitize and store ISEA's data. However, establishing one will require a collaboration between ISEA staff and FieldScope developers which could be demanding. Launching a project on FieldScope requires an annual licensing fee; however, there is a waiver program that may completely or partially waive this fee (FieldScope, 2022b).

Possible QA/QC Steps for Data Digitization

Steps for digitization QA/QC involve the digital database itself; at present there are no clearly delineated QA/QC procedures in place for filling out this database and there are noticeable issues with the current system. One present issue is that there are multiple ways to denote "missing data." Similar to the issue present when denoting this concept on the paper datasheet, there needs to be a singular convention to signify that something was missing. There is also no restriction on how certain types of data are entered. For example, the date can be entered in any way that the data entry volunteer chooses (i.e., MM/DD/YYYY or MM/DD/YY), as there are no domain restrictions or examples to make it consistent. Additionally, the order of parameters as listed on the paper datasheet do not always match to the way they were listed in the current digital database. For the plankton data, it is in the same order as the datasheet; for benthos and fish, however, the species are in a different order in the computer than they are on paper. This creates difficulties for data entry and may lead to mistakes if the entry volunteer is simply writing them in as they appear rather than paying close attention to the digital labels. Finally, there is currently no place in the database for the data entry volunteer to leave notes about issues they had upon entering data, which is a lack of a quality control mechanism.

When considering the quality of data as they are entered into the database, we found that suggestions range from entering every data point to removing outliers. Several volunteers believe ISEA should digitize everything regardless of if it seems unusual or strange. This gives the user the opportunity to see the entire dataset. They noted, "rather than averaging or throwing out Secchi data, we should record all of it and let the user decide if they want averages or something else." It is important to note that citizen science QA/QC protocols often suggest filtering unusual reports, so even if they are left in the database, they need to be identified in some manner (Wiggins et al., 2011). Discussions with other organizations suggested that if the data is only being used for educational or community engagement purposes, recording all data by hand and filtering out outliers before entering it may also be an option. This would limit research use and is only a useful step if trends are the sole interest.

Value for Collecting and Recording Data on the Ship

Evidence demonstrated many student benefits from the practice of collecting and recording data onboard the ship. Evaluations of similar programs have demonstrated an increase in Great Lakes knowledge and stewardship attitudes of student participants (Williamson & Dann, 1999). We observed that students used the collected data to serve as evidence to answer the question "is the bay healthy?" while onboard. Volunteers also suggested that valuable science skills are gained through data collection including: use of dichotomous keys, using scientific equipment, and mathematics for measurement. Data collection also sparks student interest as they act as scientists and stewards in an out-of-classroom experience (Hiller & Kitsantas, 2014; Vail & Smith, 2013). Instructors noticed this as well, recalling that telling students that collected data will help to make future graphs and contribute to citizen science fosters enthusiasm and, as one interviewee said, “gets them excited about what they're doing”. Volunteers also reported that students have fun with the activities associated with data collection, e.g., using titration for water quality measures which change colors.

Recording program data also creates a dataset which has the potential to be used by various audiences to increase impact once it is in a sharable state. While other similar organizations do not digitize their student-collected data, there are benefits to its storage for both ISEA and other audiences, as it is important to note that outside interest in this information does exist in the Great Lakes region. Watershed organizations, institutions of higher education, researchers, and schoolteachers all expressed interest in accessing ISEA’s dataset. Internally, instructors noted that the long-term storage of data lends credibility to ISEA in a form of ground truthing as the organization presents ecological trends to the public. To quote a volunteer, “I think the best purpose [of the data collection] is to drive our own programs and be able to support what we're seeing. It backs up what we're saying. It really gets people thinking”. ISEA has a unique position in that other programs do not publish their student-collected data, which an instructor suggested is important marketing for the program in that it is a selling point for schools to know that their data has a use beyond student experience. The participant stated that ISEA is “able to tell schools who are considering our program versus another that we actually collect samples, identify specimens, and record. I think that's a selling point.”

Instructors noted the data collection process has an impact for themselves as volunteers too. Interviewees said that it is satisfying to create physical results from their work, and they suggested that more understanding of what the data are used for would help volunteers to pay more attention to the quality control of the data. One interviewee proposed “I think that when they're training us instructors, they could spend a little more time in helping us understand the importance of [quality control], and how to do it.”

DISCUSSION

Here we present a justified strategy for data recording and digitization, considering a variety of factors, not simply the potential utility of the data. ISEA volunteers generally supported recording and digitizing of all measured parameters, as there could be potential utility in the future. However, when creating a strategy for water quality assessment, it is important to consider: program objectives, program audience, design of monitoring including parameter selection, data quality control, data storage and treatment, and data sharing and interpretation

(Chapman et al., 1996). Throughout this section, we present our recommendations for prioritization by ISEA (signified with a ⚓), followed by our reasoning and other options that may be considered. Also included in the strategies, where appropriate, are checklists to guide future programmatic evolution.

Data Use for Education

⚓ Recommendation: Prioritize uses of data for educational purposes when making decisions related to data collection and recording, data management and sharing, and what QA/QC and documentation practices to adopt.

As an environmental education organization that also collects citizen science data, prioritizing uses of data that serve educational purposes aligns with ISEA's mission and then utilizes citizen science data in an appropriate and beneficial way (EPA, 2019). Creating informational graphics for use during education programs is the main way ISEA uses their data to contribute to their mission. We observed firsthand the impact that graphs have in demonstrating various concepts and messages to students and members of the public who attend ISEA's programs. In addition to adding value to the educational experience, using their data to create visual aids sets ISEA apart from other environmental education organizations and allows students the chance to contribute to "real science." ISEA should continue to develop new graphics as they add new programs and should consider volunteer requests to update temporal charts more frequently.

⚓ Recommendation: Make raw data and data summaries accessible to teachers and students who have attended an ISEA program; as well as to other interested community members, researchers, and organizations.

ISEA can further the educational experience of students who have attended their programs by giving teachers access to student-collected data. Teachers who responded to the teacher survey expressed strong interest in using ISEA's data in their classrooms, both through data summaries and working with raw data. Due to this broad interest, we suggest that ISEA either make raw data, data summaries, and/or data lessons available on their own website; or upload their data to a public-facing citizen science platform with tools for generating summaries and visualizations. If ISEA prefers to use their own website, there are many ways to share their data to support teachers' interests. They can make the charts used during Schoolship available for download, provide links to download raw and summarized historical or field season data, or provide access to curated data lessons. Data lessons can be developed for the range of age groups ISEA serves and can take on a variety of foci, such as demonstrating trends in long-term or seasonal data or allowing students to input their own data and create summaries in a pre-populated spreadsheet. For teachers that have an interest in specific parameters or time ranges, ISEA could provide a request form on their website where teachers can denote which pieces of information they are interested in receiving and contact information needed for delivery.

ISEA can expand the impact and benefit of their data to the Great Lakes community by making them accessible to public users, researchers, and organizations. ISEA should continue to fulfill requests from researchers or organizations who express interest in their raw data or data summaries. Additionally, external parties should be able to access ISEA's data in the same way teachers and students who have attended ISEA's programs can; either on ISEA's website directly or through a citizen science platform. The local watershed advocacy group that uses ISEA's data for regular watershed reports is an important environmental planning and protection group that oversees Grand Traverse Bay (GTB). As ISEA consistently samples in a unique location within GTB, their data are especially valuable to the organization's reporting, planning, and advocacy.

Considerations for the Database Management System

⚓ Recommendation: When deciding what DBMS to use, consider factors of accessibility, flexibility, and capabilities for data analysis and sharing.

When selecting a DBMS, ISEA needs to consider who will oversee data management, as well as the capabilities of a system to fulfill their needs for long-term data storage and sharing. All DBMS options we reviewed will require ISEA staff or volunteers to complete data entry, and thus the ease of interfacing with the system will be important regardless of who is managing the data. Additionally, a DBMS that can be accessed on different operating systems (e.g., Microsoft Windows and macOS) will be more accessible to ISEA staff and volunteers than systems restricted to a single type of device. Most options we reviewed would require ISEA to manage their data in-house, in which case ISEA should consider the level of training and documentation that would be required to manage the selected system properly for data analysis and sharing. If possible, it is ideal to select a system that is managed by an external party; this would make considerations of difficulty in using and maintaining the system for analysis and sharing irrelevant.

In terms of data storage, ISEA needs a system that is flexible enough to be adapted in the future as programs are updated, or when data collection procedures are altered. In 30 years, ISEA has altered or added to their programs several times and will continue to do this in the future. Part of the current challenge in using ISEA's data is that data are stored across multiple files and platforms, a result of ISEA changing their data recording strategies as programs have been adapted. If ISEA uses a DBMS that can be updated effectively, they can change what they are recording without losing the ability to query and summarize their data over time. The ability to batch-upload historical data is also a factor to consider, as this would allow ISEA to incorporate most of their pre-existing data with minimal effort. Additionally, we suggest ISEA select a system that can store images, as this will be useful when new organisms are found onboard and will eliminate the need to store specimens or photographs of specimens outside of the primary DBMS.

When selecting a DBMS, the capabilities for fulfilling ISEA's needs for data analysis and sharing are also important to consider. As visualizations and graphic summaries created from ISEA's data are an invaluable part of the programs they deliver, ISEA needs a system that can be used to create a variety of charts, like the pie charts of fish communities and line graphs of annual Secchi depth they currently show during Schoolship and public sail programs. All the DBMS options we reviewed have tools built in for creating statistical and graphical summaries of stored data; however, the complexity of creating these summaries depends on the construction of the DBMS. Most systems will store ISEA's data parameters in multiple tables or sheets, which can make it difficult for different pieces of data to "talk" to each other when fulfilling a data query. Capabilities for analysis are also an important consideration for external end users. Many of the potential users we spoke to and surveyed expressed interest in using summaries created by ISEA and raw data to create their own visualizations. If ISEA chooses to provide interested parties with raw data, they should select something accessible to external users, such as MS Excel which is widely known and familiar.

The affordability of a system will depend on annual licensing fees or subscriptions, as well as the cost to train staff or pay external data managers or experts. While all the systems we reviewed have some associated annual costs, only a couple would incur additional costs for intensive training or external consulting and expertise.

We suggest that ISEA use a checklist of important factors to review and compare the systems we recommend, and any other systems they wish to consider in the future. We developed and used the following checklist (Figure 5) in our ranking of DBMS options. When using this checklist, the more boxes that can be checked for a system, the better suited the system is for meeting ISEA's needs.

⚓ Recommendation: Create a new project in the online citizen science platform FieldScope to serve as the primary DBMS.

We reviewed a variety of possible DBMS options that ISEA could use to store their data based on the factors described in Figure 5. Our resultant ranking of the available options is:

1. FieldScope
2. Visual Basic for Applications (VBA) in MS Excel
3. Microsoft Access or other relational databases
4. Microsoft Excel

Checklist of Characteristics to Justify Use of a Specific DBMS
☐ (1) Is it easy for ISEA to enter new data points in this system? ☐ (2) Is this system accessible on different devices (i.e., Mac, Windows, smartphones)? ☐ (3) Will the data stored in this system be managed externally?   ☐ (3a) If managed internally, can the system be learned without intensive training? ☐ (4) Is this system flexible and adaptable to program changes and additions? ☐ (5) Can past data be batch uploaded into this system? ☐ (6) Can images be stored in this DBMS? ☐ (7) Does this system have tools for creating visualizations? ☐ (8) Can this system be used to fulfill data queries? ☐ (9) Can data easily be exported into MS Excel or CSV files from this system? ☐ (10) Is this system affordable for ISEA?

Figure 5. Recommended checklist of factors to consider when selecting a DBMS for ISEA. We used this checklist to determine our ranking of DBMS options.

FieldScope

Creating a new "ISEA Project" within the citizen science platform FieldScope will meet all of ISEA's needs for data management and use, while offering a unique opportunity to incorporate data collected by other users. FieldScope will be accessible for data entry and use on any type of device, and will be managed on the backend by BSCS Science Learning employees. With over 60 years of experience in providing science education, BSCS Science Learning has a strong likelihood of existing as a supportive platform into the future (BSCS Science Learning, n.d.). Because data are stored in a relational database, this system will be flexible enough to incorporate changes in ISEA's data collection procedures, and nimble enough to fulfill complex data queries. Additionally, FieldScope is the only system we reviewed that can store images. The ability for people outside the organization to add data points is a unique feature that FieldScope can offer over the other DBMS options we reviewed. If ISEA selects FieldScope to house their data, they should consider allowing this feature to increase both the reach of their data and the potential to incorporate spatial analyses and mapping.

ISEA and external data users will be able to use FieldScope's built-in tools to create data visualizations and summaries on filtered or unfiltered data, including creating maps if data are included from sites outside of Suttons Bay, (i.e., from ISEA's chartered sails or users outside of the organization). Any interested end user will be able to access the data with a free account, and from our own experience, the various features on FieldScope's website are easy to use. Many teachers who responded to the teacher survey showed interest in using a citizen science platform like FieldScope to interact with ISEA's data. For any external users that prefer to access the data

outside of the FieldScope platform, the data can be downloaded into MS Excel with just a few clicks.
There is an annual licensing fee associated with starting a new project in FieldScope. The annual cost is dependent on the number of data points being added each year, which allows ISEA to be strategic in what data they upload. If they forgo uploading all historical data or restrict the ability to add data to only ISEA, the annual cost can be lowered.

Visual Basic for Applications (VBA) in Microsoft Excel

Microsoft's programming language, VBA, can be used with MS Excel to develop a DBMS capable of meeting ISEA's data storage and analysis needs. As data would be housed in MS Excel, this system would be accessible on different devices. One barrier to using VBA is that a staff member or volunteer would need training to learn how to set up and adapt the system, and significant documentation would need to be created so staff members can make changes in the future. A local professor of environmental engineering has offered to develop, document, and manage a VBA program for ISEA free of cost, which would allow ISEA staff to initially pursue this option without going through the processes of training and creating the system themselves. Additionally, the professor offered to upload ISEA's historical data manually, since batch uploading would be difficult to complete with VBA. VBA in MS Excel can be designed to generate graphical and statistical summaries that are easy to populate with just a few clicks, which would be helpful when ISEA updates their charts for use onboard, for use in data lessons, and for creating summaries to share with external end users. As an MS Excel-based system, the data could easily be exported and shared with external end users who want to work with ISEA's raw data in MS Excel.

The cost to employ a VBA system will include the monthly or annual subscription costs for MS Excel; though as a nonprofit organization, ISEA would be eligible for a price reduction or waiver. If the local professor is no longer available to manage the system in the future, training a staff member or hiring an external operator or consultant to maintain or update the program would introduce additional costs.

Microsoft Access or Other Relational Database

Microsoft Access has been used by ISEA in the past and is capable of meeting many of ISEA's data storage, analysis, and sharing needs. Similar to VBA in MS Excel, a MS Access system would require significant training and documentation to be developed and used properly. Further, MS Access can only be used on PC devices, of which ISEA has a limited number. As a relational database, MS Access is powerful in terms of flexibility when programs are updated, so long as the relationships between the data are correctly defined within the system. ISEA would also be able to create complex queries for both internal data analysis and visualization and at the request of external users. While batch upload of historical data is possible in MS Access, storage of images is not. Data can easily be exported into MS Excel for delivery to external users.

Due to lack of historical documentation, ISEA would need to consider developing a new system in MS Access or spend a significant amount of time and energy re-learning and documenting the old system so it can incorporate data collected in their newer programs. Training a staff member or hiring an external consultant to update the existing program would introduce additional costs to the monthly or annual subscription fees for using MS Access.

Due to the flexibility and analysis capabilities that a relational database can offer, ISEA could consider using another relational database; there are several popular options available, such as Oracle, MySQL, and IBM DB2. If ISEA chooses to explore other relational database options, they should consider the factors in the provided checklist (Figure 5) surrounding ease of use, ability to export data to MS Excel, and affordability.

Microsoft Excel

MS Excel is capable of meeting some of ISEA's needs for data entry, analysis, and sharing, but also has significant barriers for long-term data storage. MS Excel is familiar to many individuals and relatively easy to learn. Building data entry forms and entering data in MS Excel would be simple for ISEA staff and volunteers to complete, and formulas can be used to generate statistical summaries or graphs from data in just a few keystrokes. Batch uploading of historical data and exporting data for external users are also easy to do in MS Excel. As a nonprofit, ISEA would be eligible for reduced or waived subscription costs to use MS Excel. However, MS Excel is not ideal for long-term data storage due to the lack of flexibility, and limited ability for data stored in different spreadsheets to communicate when answering complex queries. To overcome this, ISEA would likely need to store data in as few spreadsheets as possible, which can lead to redundancy and large file sizes. As ISEA updates its programs or incorporates historical data, an MS Excel-based system would become cumbersome to use in data analyses and require significant storage space. For these reasons, a relational database would be better suited to ISEA's needs.

Future Science Monitoring Strategy

Recommendation: When deciding which parameters to record, consider ease of recording onboard as well as end-user needs and interests.

Our interviews and teacher questionnaire emphasized that recording data onboard is part of what makes the ISEA experience unique and is invaluable to students feeling like real scientists. Therefore, continuing to record data is important for ISEA's educational goals. Furthermore, much of ISEA's data is of interest to teachers and researchers if it is made available outside of the organization, further adding value to recording the data. However, not all parameters currently being recorded are interesting to potential end-users, and some parameters require more effort than is realized in the payoff. For example, plankton is interesting to researchers and teachers, but the way ISEA currently records it is more complex than necessary to serve the needs of these users. This cost-benefit should be considered when deciding exactly what to record now and into the future.

To decide which aspects of each parameter should be recorded, we suggest utilizing a checklist of important characteristics against which each parameter should be evaluated (Figure 6). The first thing to consider is whether any end users are interested in the information and how they would utilize the data. If no end users are interested in the data, recording that information becomes a lower priority and may not be necessary. Similarly, if an end user is interested in the data, but they are only interested in basic information, then the level of recording should be simplified (e.g., plankton). Second, data that can be visualized in a graph or chart that demonstrates significant change should be prioritized over other types of data. We know this is what end users are most interested in, and these types of graphs are the most impactful for educational purposes. The third thing to consider is whether the parameter connects to basin-wide changes in the Great Lakes. Issues such as climate change and aquatic invasive species assign more value to certain parameters versus issues like acidification which is unlikely to impact Lake Michigan severely in the coming years. Sometimes this may contradict the second characteristic, thus our final characteristic may come into play for the final decision. The final characteristic is whether the parameter is easy to record. This is somewhat subjective, but in general, if recording simply requires reading a number from a piece of equipment or identifying an organism with a clearly defined key, it can be assumed to be fairly simple. This should be checked against volunteer comfort, particularly when introducing new parameters.

Checklist of Characteristics to Justify Parameter Recording
☐ (1) Is an end user interested in this parameter?   ☐ (1a) Is the proposed manner of recording consistent with the way end users would use the information? ☐ (2) Can this parameter be used to create a graph that shows a significant change? ☐ (3) Is this parameter relevant to Great Lakes basin-wide changes? ☐ (4) Is this parameter easy to record?

Figure 6. Checklist to examine whether to continue recording a parameter or to introduce a new parameter to ISEA's trips. We used this checklist when considering many of the recommendations in the *Datasheets* section.

As an example of running one of ISEA's current parameters through this checklist, consider water temperature. We heard from multiple end users that this data is of interest as a long-running comparison as climate changes (check the first box). End users would use the numerical temperature data to see a trend over time, which is what ISEA currently records (check box 1a). Although ISEA's current water temperature data do not show great amounts of change (no check for box 2), it is of interest basin-wide in the face of climate change and may one day show a change (EPA, 2021a), thus it may be worth continuing to record (check box 3). Furthermore, it is easy to read a number from a thermometer and record that in a box (check box 4). While this does not hit all the checkboxes, it hits most of them and is, therefore, a suggestion to record.

The checklist should be used as a guideline with context taken into consideration; not used in isolation to make a final determination. The exact combination of boxes required to record a parameter may vary. Certain situations may check the first boxes, but be incredibly difficult to record, thus outweighing the other boxes. In other cases, it may be incredibly easy to record and make a chart, but no one is interested in it, and it is not relevant to larger Great Lakes trends, so it has little value.

⚓ Recommendation: Create a formal process for cataloging newly discovered or uncommon organisms.

ISEA's routine and frequent monitoring has tremendous potential for discovering new species in Lake Michigan or Grand Traverse Bay, and has proved this value in the past. In 1999, an ISEA Schoolship group was the first to find the invasive zooplankter *Cercopagis pengoi* in Lake Michigan (Shumaker, 2014); and ISEA found the first zebra mussels in Grand Traverse Bay, two years before they were formally confirmed in Lake Michigan (Giraud, 2011). Given these examples, it is not unrealistic to assume that ISEA may play an important role in the discovery of new organisms in the future, so developing a strategy for cataloging is critical.

The role of citizen scientists in detecting or monitoring new and invasive species has been broadly recognized as citizen scientists often have more access to aquatic areas at a lower cost, and with greater spatial and temporal coverage than a traditional scientist; factors that have been shown to significantly reduce time until first detection of a new species. This can result in more effective eradication, containment, and mitigation of invasives (Encarnacao et al., 2021).

After considering the options available to ISEA through interviews and observations, we determined that their new organism protocol should be heavily reliant on photographs, as ISEA staff do not have the infrastructure needed to handle physically preserved specimens. Photographs will require labeling with date and time to associate them with a particular sail, and the datasheet will need to be modified to account for better tracking of unidentified organisms. We suggest that modification occurs on the lead datasheet for quality control reasons--namely that a "new organism" section is created to allow for clear tracking. We suggest the following procedure to help ISEA efficiently track and maintain a record of new or uncommon species:

1. Station instructor takes a photograph of the organism to upload to iNaturalist.
2. Station instructor tells the lead instructor, who marks on their (lead) datasheet that they found something new, that a photo was taken, and specifies the station.
3. Lead instructor confirms that a photograph was uploaded to iNaturalist within ISEA's project for identification from the iNaturalist community.
    a. This step is important, as iNaturalist photos include the date and time, which is essential to later track it back to ISEA's database.
4. At the end of the field season (or some other consistent predetermined time), an ISEA staff member checks the ISEA iNaturalist project to confirm any identified new organisms and updates the ISEA digital database.

While this procedure requires effort from a volunteer instructor, the station lead, and an ISEA staff member, it is worth the extra effort. The process of discovering new organisms is a valuable way for ISEA to impact the larger community by contributing to discoveries. The protocol will also show students how science does not always provide immediate answers, and instead is sometimes a long process. Utilizing iNaturalist as the primary source of identification also aligns with broader suggestions for how to maximize the effectiveness of citizen science, since it is an app that already exists and reaches a wide audience (Encarnacao et al., 2021).

Quality Assurance/Quality Control

Establishing QA/QC standards is essential for ISEA to effectively provide their data to end users and assure those end users that data quality is maintained (EPA, 2019). While ISEA will have some choices for the level of QA/QC procedures to put in place, we suggest that at a minimum, standards are created for the paper datasheets, for which data to digitize, and are supported by creation of a QAPP.

Ultimately, all of ISEA's QA/QC begins with the paper datasheet. The quality of the digitized data is dependent on the quality of the data being given to the data entry volunteer. Therefore, developing a robust QA/QC protocol for onboard data entry will help tremendously with the QA/QC for the digitization person. One of the largest challenges in digitizing the data is the legibility of what is written on the paper datasheets. Addressing this before it reaches the digitization stage is important for the efficiency and quality of the digitized data. Furthermore, at present, the paper datasheet structure does not exactly match that of the digital database. For example, the trip number is always missing from the paper datasheet, which creates challenges for sorting and entering data. Data are entered chronologically, but when there are multiple trips per day (up to four with the Ship & Shore format), the date is not enough to figure out the order of the trips. Adding space for these pieces of information on the paper datasheet will improve the quality of the digital data.

Datasheets

Paper datasheets serve an important role in maintaining a high data quality; thus, we have developed recommendations on general rules for datasheet designs and improvements on each specific datasheet. Datasheets are necessary to transport data observed onboard to the digital database. Therefore, these datasheets should be designed to reduce confusion and inconvenience in the process of transferring written to digital data.

Datasheets: General Guidelines

⚓ Recommendation: Simplify the approaches to recording on datasheets, including but not limited to those for reading and writing.

We observed that volunteers often need to invest unnecessary amounts of time and energy when filling out the datasheets, which causes unnecessary confusion; therefore, we suggest that ISEA update datasheet designs to remove extraneous information. For example, volunteers are no longer asked to check for the presence of white spots (parasites) on gobies, yet the fish datasheet still has a column for volunteers to record the number of fish with spots. Another example are the sediment data on the benthos datasheet (Figure 7B). On the current sheet, it asks for the color of the sediment (Figure 7B1). Previous sheets used to ask about the texture as well, so many experienced volunteers still write this in because it has not been made explicit that this information is extraneous. Data like these that are either very subjective or are not used for any purpose do not hold any value and should not be listed on the datasheets. We suggest that ISEA review and update datasheets regularly or when changing protocols, to make datasheets consistent with what ISEA wants to monitor; otherwise, inconsistencies may cause issues during digitization.

To streamline the data recording process, some data parameters can require a more straightforward recording approach that minimizes writing. For instance, we observed that volunteers had to write down fish species' names every time, although they had been catching very similar groups of fish repetitively. We suggest that ISEA model the fish species column after the benthic species column where commonly caught species are printed on the datasheets. This will make it easier for volunteers to record without spelling out names each time. Another example is the sampling location, which is almost always "Suttons Bay" (Figure 8B1). Sometimes, the volunteers would interpret this differently and write notes that do not make sense for the location, such as "by the marina". To improve this, we would suggest either printing a list of common sampling locations for volunteers to circle or printing Suttons Bay as the default location or volunteers can make a note if the location changes (Figure 8A1).

Some data parameters require volunteers to do calculations onboard that are unnecessary; these should be removed from the datasheets. For example, volunteers teaching at the plankton station must convert the presence-absence data into a percentage showing how common each species is. This requires meticulous calculations and a calculator onboard. Nevertheless, we still observed several errors in the results which also created problems for the digitization process. Since most databases can perform simple calculations like converting fractions to percentages, we suggest that volunteers should just record fractions, leaving the conversion to be done later within the database.

Many volunteers take unnecessary notes (with good intentions) about data quality on the datasheets, but these often led to confusion during data digitization since the data entry volunteer did not know how to interpret them. Thus, we suggest that volunteers only write notes that are necessary to understand the data for the day or when there are clear instructions on what to digitize (Figure 8A2). Finally, we observed that volunteers often struggled with flipping the plankton datasheet to produce the fractions on the back and then record them on the front. We suggest that ISEA should adapt to a single-sided full-sized plankton datasheet, instead of the current double-sided half-sized datasheet, to avoid flipping the datasheets.

Recommendation: Standardize data recording formats to avoid inconsistencies between volunteer instructors.

Inconsistencies on the datasheets or in the data recording process can have an impact on data quality and student experience. Specifically, we observed that volunteers are not using consistent markings to denote the absence of data versus a zero. Even though the plankton datasheet asks to black out boxes for unexamined drops as an effort to control this, it was rarely practiced, causing issues during digitization. We suggest that ISEA develop a consistent way to mark the difference between data not collected and data not observed. In addition, volunteers noted that organisms are not listed in a consistent order across platforms. For example, the list of benthic organisms collected from the PONAR grab and the otter trawl is in a different order and does not match the order in the database (Figure 7B2). Thus, we suggest that ISEA reorder data parameters to provide a consistent order across all collection methods (Figure 7A1). Lastly, we noticed that most data are recorded in the United States Customary System instead of the International System of Units, often known as the Metric System, which is the official unit system for science and technology. For example, we also observed that ISEA uses meters to measure Secchi depths but uses feet or miles to measure the length of other parameters like station depth and visibility. We understand that using the United States Customary System is familiar to participants, but we believe that adopting the International System of Units for both temperatures and lengths can foster a more authentic scientific experience.

(A)

BENTHOS				
Filled in by (Benthos instructor):		Data entered by:	Entry checked by:	Trip #:
Date: (MM/DD/YYYY)	AM / PM / Eve	Latitude: N	Longitude: W	
Sampling Location: Suttons Bay / WGTB / Other:	Data Confidence	High / Low	Time:	Station#:

Sample Information				
Sample depth *(m)*:	**Species –** Only mark mussels if **ALIVE**			
	PONAR / Deep Sample		Otter Trawl / Shallow Sample	
Species	Presence	Absence	Presence	Absence
1 Midge Larvae	P	A	P	A
Quagga Mussel	P	A	P	A
Midge Pupa	P	A	P	A
Isopod	P	A	P	A
Amphipod	P	A	P	A
Chara	P	A	P	A
	P	A	P	A
	P	A	P	A
	P	A	P	A

Notes: Please only note things that are useful for data entry or necessary to understand the data for the day

(B)

BENTHOS				
Benthos instructor:		Data entered by:	Entry checked by:	Trip #:
Date:	AM / PM / Eve	Latitude: N	Longitude: W	
Sampling Location:			Time:	Station#:

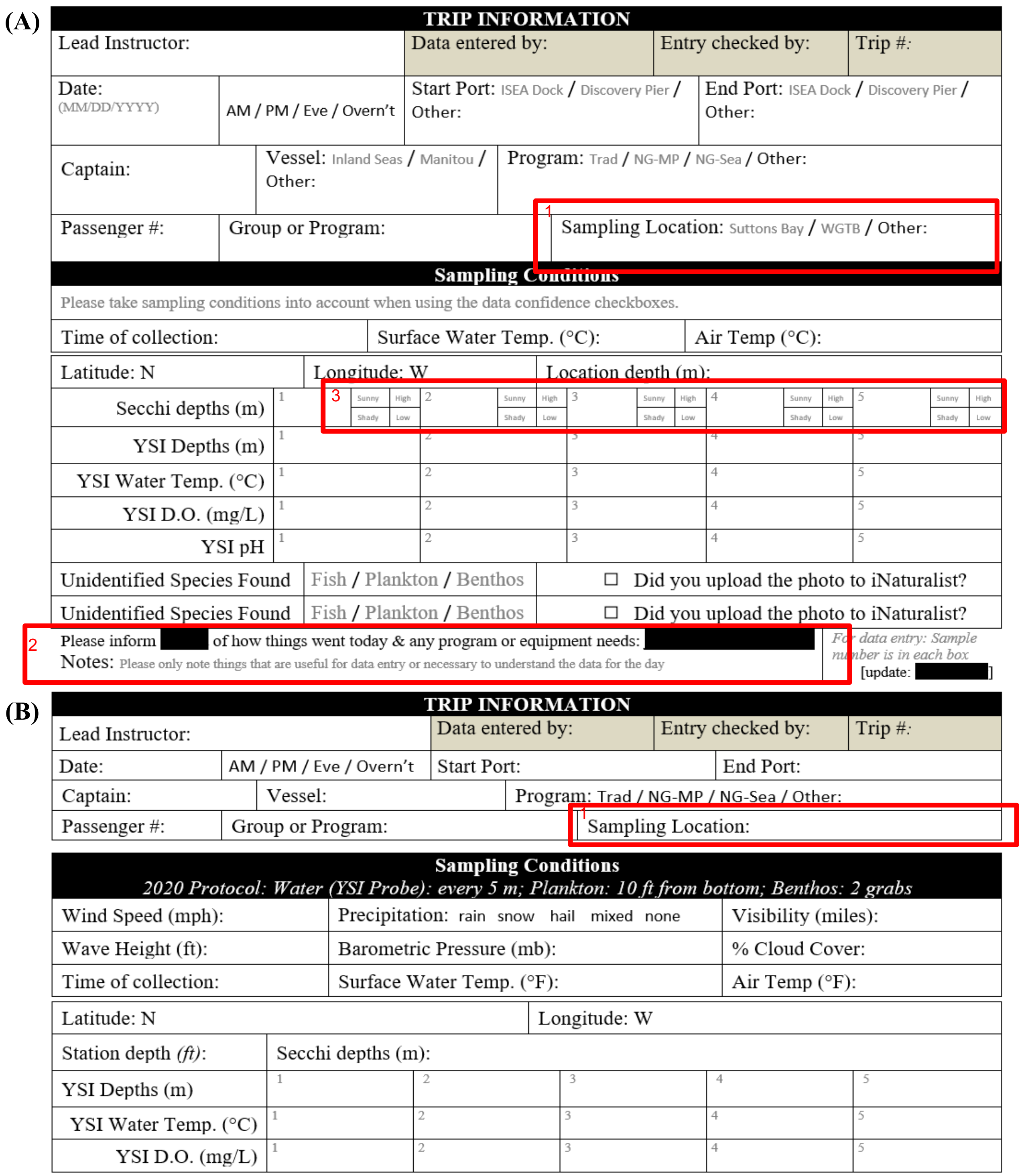
PONAR Sample Information	
Sample depth *(ft)*:	1 **Color:** Dark Gray Light Gray Olive Gray Greenish Gray Yellowish Orange Light Brown

2		Otter trawl / Shallow sample	
# of samples examined: ----------------------------------	☐ No animals found in sediment	**Presence / Absence Only**	
Species – Mark if present. Only mark mussels if **ALIVE**		☐ Midge Larvae	☐ Isopod
Species	Count	☐ Midge Pupa	☐ Chara
☐ Quagga Mussel		☐ Amphipod	☐ Eurasian Watermilfoil
☐ Midge Larvae		☐ Quagga Mussel	☐
☐		☐	☐

Figure 7. (A) The proposed new benthos datasheet that has an overall data confidence checkbox. The red box indicates the new presence-absence data format and the matching order of species list for both collection methods. (B) The original benthos datasheet in 2020 which was used to record data collected during a regular shipboard program at ISEA. The two red boxes indicate examples where (1) data are highly subjective and (2) data are recorded in different formats and orders.

⚓ Recommendation: Add a data confidence checkbox to demonstrate trust in data quality and to establish the context for “data of known quality”.

The ease of collecting data onboard can vary for many reasons including weather conditions and the age group of participants. Flagging the collections in which volunteers have difficulties maintaining data quality would be useful for external data users who require more attention to data quality. We noticed that data at some stations can be influenced by bad weather conditions. For example, it was difficult to record Secchi depth measurements during rainy or windy days, due to the ripples and currents under the boat. Similarly, when it was windy and choppy, it was difficult for volunteers at the plankton station to handle the equipment and write on the datasheets while trying to educate participants about plankton. Despite volunteers’ attempts at maintaining data quality in these extreme conditions, the quality remains questionable. Therefore, we suggest incorporating a checkbox on datasheets to denote data quality straightforwardly, so that volunteers can shift focus about the quality of data to student engagement as needed in various situations. We envision two small data confidence checkboxes, one indicating high confidence in data quality and the other indicating low data quality confidence, placed next to parameters like Secchi depths (Figure 8A3). High confidence would be the default status since volunteers are generally doing an excellent job at maintaining data quality, so volunteers would typically check off the high confidence box. In contrast, for example in rainy or windy conditions, the lead volunteer would check off the low confidence box next to all Secchi depth measurements. This will be explained in more detail below.



(A)

TRIP INFORMATION				
Lead Instructor:		Data entered by:	Entry checked by:	Trip #:
Date: (MM/DD/YYYY)	AM / PM / Eve / Overn't	Start Port: ISEA Dock / Discovery Pier / Other:	End Port: ISEA Dock / Discovery Pier / Other:	
Captain:	Vessel: Inland Seas / Manitou / Other:	Program: Trad / NG-MP / NG-Sea / Other:		
Passenger #:	Group or Program:	1 Sampling Location: Suttons Bay / WGTB / Other:		

Sampling Conditions		
Please take sampling conditions into account when using the data confidence checkboxes.		
Time of collection:	Surface Water Temp. (°C):	Air Temp (°C):
Latitude: N	Longitude: W	Location depth (m):

Secchi depths (m)	1 (3) Sunny / Shady, High / Low	2 Sunny / Shady, High / Low	3 Sunny / Shady, High / Low	4 Sunny / Shady, High / Low	5 Sunny / Shady, High / Low
YSI Depths (m)	1	2	3	4	5
YSI Water Temp. (°C)	1	2	3	4	5
YSI D.O. (mg/L)	1	2	3	4	5
YSI pH	1	2	3	4	5
Unidentified Species Found	Fish / Plankton / Benthos	☐ Did you upload the photo to iNaturalist?			
Unidentified Species Found	Fish / Plankton / Benthos	☐ Did you upload the photo to iNaturalist?			

2 Please inform [redacted] of how things went today & any program or equipment needs: [redacted]
Notes: Please only note things that are useful for data entry or necessary to understand the data for the day

For data entry: Sample number is in each box
[update: [redacted]]

(B)

TRIP INFORMATION				
Lead Instructor:		Data entered by:	Entry checked by:	Trip #:
Date:	AM / PM / Eve / Overn't	Start Port:	End Port:	
Captain:	Vessel:	Program: Trad / NG-MP / NG-Sea / Other:		
Passenger #:	Group or Program:	1 Sampling Location:		

Sampling Conditions		
2020 Protocol: Water (YSI Probe): every 5 m; Plankton: 10 ft from bottom; Benthos: 2 grabs		
Wind Speed (mph):	Precipitation: rain snow hail mixed none	Visibility (miles):
Wave Height (ft):	Barometric Pressure (mb):	% Cloud Cover:
Time of collection:	Surface Water Temp. (°F):	Air Temp (°F):

Latitude: N			Longitude: W		
Station depth *(ft)*:	Secchi depths (m):				
YSI Depths (m)	1	2	3	4	5
YSI Water Temp. (°C)	1	2	3	4	5
YSI D.O. (mg/L)	1	2	3	4	5

Figure 8. (A) The proposed new lead datasheet that incorporates the recommended changes annotated with the red boxes: (1) the addition of default choices for some parameters, (2) changes on note section to encourage volunteers to take meaningful notes, and (3) the addition of checkboxes for data confidence checkboxes and sunny-shady conditions. (B) The original lead datasheet in 2020 which the lead volunteer used to record data collected during a regular shipboard program at ISEA. The red box is to show an instance of parameters that do not give examples or default choices.

Datasheets: Secchi Depth Data (shown in **Appendix VIII**)

Secchi depth data are currently recorded on the lead datasheet with five blank spots for the lead volunteer to fill in after volunteers from each learning station announce the results to the group. The standard protocol at ISEA is to record the next meter-mark reading above the surface when the Secchi disk disappears underwater. ISEA should maintain their Secchi depths data protocol every single Secchi depth data point should be recorded and digitized into the database. This will enable data users to select and filter data to their specifications.

⚓ Recommendation: Add a data confidence checkbox to the Secchi depths data to provide context.

We found that the quality of Secchi depth data can vary significantly depending on the currents, wind, waves, sunlight, and eyesight of the participants and volunteers. Therefore, we recommend adding a data confidence checkbox to provide more context to the data users (Figure 7A3). When volunteers at each station report the Secchi depths measurements to the main group, we suggest the lead volunteer asks and records three pieces of information, (1) their Secchi depths reading, (2) if it was done on the sunny or shady side, and (3) if it went under the boat. If the Secchi disk goes under the boat for a station, we suggest the lead volunteer records it as low confidence. In addition, scientific standards often repeat or reexamine two measures that deviate more than ten percent (Smith, 2001). Although ISEA is not collecting research-grade turbidity data, we suggest the lead volunteer should use the data confidence checkbox to check outliers by marking the measure as low confidence based on their discretion. Furthermore, standard practice is to measure on the shaded side of the vessel or to contextualize the measure by noting whether the measure is from a sunny or shady side (NALMS, 2021). Thus, we think that denoting if each data point was collected on the sunny or shady side will provide significantly more context for the measurements which can be helpful for external data users (Figure 7A3).

⚓ Recommendation: Record Secchi depth measurements in half-meter increments.

We suggest that Secchi depths be measured in half-meter increments instead of whole meters as is currently done. This will increase precision of Secchi depth measurements, and it is more in line with standard practice. We do understand that this may be more difficult to institute, especially with younger students. However, during Diving Deeper programs, where more sampling time is allowed to collect more accurate data, or when ISEA has the capacity to reach research-grade data quality, half-meter measurements are preferred.

Datasheets: Plankton Data (shown in **Appendix IX**)

Plankton data are currently recorded on a double-sided half sheet. The front side records sampling information and a final percentage of how often a species appeared in the water drops.

The back side is a counting table for volunteers to record the total number of drops examined and the number of drops that contain each species of plankton.

⚓ Recommendation: Record only presence-absence data for plankton to reduce volunteer work.

ISEA's plankton collection follows research-grade protocol, but the analysis does not. Thus, we suggest changing the data analysis process to maximize its educational value. In plankton studies, researchers use sampling methods similar to ISEA's, but they thoroughly examine the entirety of a preserved subsample, counting every single collected zooplankton. This detailed level of sample analysis is unrealistic and not the primary goal of ISEA. We conclude that recording plankton biodiversity data as percentages instead of presence-absence does not provide additional value to ISEA because the current plankton biodiversity data are not made into any educational visualizations. In addition, inconsistencies in plankton collection make the quality of percentage data uncertain. We suggest that volunteers only record and digitize presence-absence data for each plankton species on their datasheet while the participants can still record plankton count per drop in their student logbook. This will remove the counting page on the back side of the datasheet and allow volunteers to focus more on the educational experience. Presence-absence data can still provide important information like emerging organisms and trends in plankton phenology. Additionally, data presented as percentages are difficult for both internal and external analysis.

An alternative option is that volunteers at the plankton station can follow current recording protocol to carefully examine a set number of drops but do so without students present. This measure would be recorded before the first rotation or after the last rotation, distinct from the drops seen with the students, to reduce balancing heavy recording and education responsibilities. We present this as a secondary option because volunteers would often prefer to stay with participants throughout programming, even after rotations.

Datasheets: Benthos Data (shown in **Appendix X**)

Benthic organisms are collected using a PONAR grab and obtained as bycatch in the fish otter trawl. The benthos datasheet asks volunteers to record the count of each species found in the PONAR grab sample and presence-absence data of each species found in the otter trawl.

⚓ Recommendation: Record only presence-absence data for benthic organisms to reduce volunteer work.

ISEA's benthos data are collected using research-grade protocols, but the program lacks the capacity to perform matching levels of analysis. Like the plankton data, ISEA does not have the capacity to closely examine the whole sample in a laboratory setting, and the current benthos count data are not providing educational value onboard. Although it could be possible for ISEA to create benthos count visuals, these would not be visually interesting for students due to the largely homogenous nature of their catches. Thus, the labor of creating such graphs does not align with ISEA's educational goals. We suggest that ISEA should convert to recording and digitizing only presence-absence data for both collection methods, the PONAR grab and the otter trawl (Figure 8A1). To conserve the educational experience, the student logbook need not be changed and participants can still record counts on their own. By doing this, ISEA can still record phenology trends and new organisms that appear without extra effort that is not feeding back into the education side of the program. In addition, the datasheet should be reformatted so that the order of organisms matches on both collection methods and in the database (Figure 8A1).

As an alternative plan, we suggest that ISEA can also keep the current procedure, but with an updated datasheet where the species order matches on all formatting. However, in this option, ISEA would still be generating data that does not feed back to the educational experience onboard.

Datasheets: Water Quality Data (shown in **Appendix XI**)

The water quality station uses the Winkler titration method to determine dissolved oxygen concentration and the Phenol red indicator to measure the pH in water samples. During each trip, about four to five DO and pH data points are recorded.

⚓ Recommendation: Record only the first values at the water quality station to optimize data quality.

We suggest only recording DO and pH values measured during the first rotation since water quality parameters change over time when exposed to air. Doing the experiment during the first rotation will allow a minimal amount of exposure. Similarly, to ensure the educational experience, volunteers should follow the current protocols so that participants would still record their own observations in their logbooks.

Alternatively, volunteers can also make these measurements before the first rotation starts and record the results as values on the datasheet. However, this requires volunteers to perform the first experiment alone, and separating volunteers from participants can potentially hinder the educational experience.

Datasheets: Weather Data (shown in **Appendix VIII**)

Weather observations are recorded on the lead datasheet before the group starts sampling and include parameters like precipitation, wave height, visibility, cloud types, cloud cover percentage, temperature, and wind speed and direction.

⚓ Recommendation: Stop recording weather observations on datasheets but incorporate them into the data confidence checkbox to provide context for quality of other data.

Weather observations have historically generated numbers through estimations of factors such as wave height and visibility. These numbers are treated as data in the database, but they function more like observations and context for other measures. Since no visualizations are made from weather data and there are no external users, we suggest ISEA stop recording weather data. Instead, ISEA can locate weather data from reputable local sources if necessary. Rather than recording weather observations, the lead volunteer should use them to determine if the weather conditions are greatly affecting the quality of other data, like how rain can impact confidence in Secchi depth measurement.

Datasheets: Microplastics (shown in **Appendix XII**)

The microplastics station at ISEA was developed through a past collaboration with an external researcher, so the collection protocols closely follow scientific standards. These involve visual examination of samples and recording descriptions of each microplastic particle including color, size, and type. The sample from each trip is preserved in jars to be sent to labs for further analysis. Creating visualizations from the microplastics data is potentially difficult and there are no current end users for the data.

⚓ Recommendation: Stop recording microplastics data onboard. If a research partner is interested in analyzing the samples, providing technical support, and providing the data back to ISEA, then data can be stored in ISEA's database.

We suggest ISEA stop recording microplastics data, until a new research partnership is formed. Participants would still record their observations in their logbooks to maintain the educational experience. If a new research partnership is established, we suggest ISEA store the research-grade data from the external researcher in ISEA's microplastics database instead of the onboard data.

An alternative would be to simply stop recording the types of microplastic particles since classifying types is extremely difficult when examining smaller pieces. This would mean that the number of microplastic pieces would be recorded and used to create graphs or trend lines for education. However, this suggestion should be weighed against whether there is potential assistance from external researchers. The checklist for recording parameters can be used in the future when deciding if ISEA should record microplastics data.

Datasheets: Others (Fish and Water Temperature; shown in **Appendices XIII** and **VIII**)

Fish data are collected using an otter trawl or a minnow trap, and the numbers of each fish species are recorded. Water temperatures are measured near the surface and at depth are recorded in degrees Fahrenheit on the lead datasheet.

Recommendation: Continue current practices for recording fish and water temperature data.

We recommend not changing the protocols for parameters like fish and water temperature as they create valuable datasets and do not exhibit specific issues for volunteers. Fish data are used by the DNR, and the public is curious about water temperature due to climate change. Fish data are noted to be of higher quality than other data, and water temperatures are collected and recorded in a very straightforward approach which is generally free of error. However, there is still room for improvement on the fish datasheet as mentioned in the general datasheet guidelines. For example, the datasheet should list species of commonly caught fish like Round Goby and Rock Bass to reduce the amount of writing for volunteers, and not include the column for parasite spots since these data are not used and are not recorded consistently.

Digitization Protocol

Recommendation: Digitize everything on the datasheets.

We suggest adding and digitizing data confidence checkboxes which can provide context regarding data quality next to the corresponding parameters. When the data are shared with external users, they can determine if they want to use all data or only data with high confidence, according to their protocols. Such flexibility is important since the purpose for using data will vary.

An alternative is to only digitize data with high confidence. This will lead to a slightly smaller database and fewer data to digitize. However, data users would then lose the flexibility to use all data if they prefer quantity over quality. In addition, we suggest adding a convention to distinguish between missing data and zero, both on the datasheets and in the database. Missing data and zero can be easily mixed up but have different meanings.

Quality Assurance Project Plan

⚓ Recommendation: Create an education-grade QAPP to document data quality for end users.

Presenting an accessible dataset is important but providing the context under which data were collected allows for more targeted use of those data (Plumb, 1997). Documentation of the programmatic goals, the data collection process, and quality controls is called a Quality Assurance Project Plan (QAPP). The level of detail documented in a QAPP can vary, but the ultimate goal is to ensure that project data are comparable to other types of data by giving them context to become "data of known quality." ISEA has established quality assurances such as: retention of trained volunteers, detailed training protocols, and review of data during digitization. Documenting these practices in a QAPP will strengthen the value of stored data. The level of rigor needed for such a plan would vary based on how ISEA hopes the data will be used. The EPA guidelines separate citizen science QAPP design into: those for education, those for research, and those for policy (EPA, 2019). We suggest ISEA design a QAPP following guidelines for educational use based on their target audiences. Local policymakers, community groups, and higher education institutions would also benefit from design of the QAPP, even at this less rigorous level. If desired, adding more information to the established QAPP could increase its value to larger policymaking entities, but we feel this is beyond ISEA's basic mission. There are several differences between the elements presented in a QAPP dependent on the level (Table 2), so we suggest that ISEA document the elements marked in the education level QAPP. These should be presented in a shareable format alongside a data portal or with shared data. The EPA Citizen Science Quality Assurance Handbook website provides a fillable QAPP template to help with formatting and decisions on element inclusion. The QAPP should be updated periodically to reflect protocol or goal shifts.

Items to Include	**Education Level QAPP**	**Research/Policy Level QAPP**	**ISEA Specific Considerations**
Project Management			
Title and Preparer Page	**X**	**X**	Context of QAPP
Problem Definition, Background, and Project Description	**X**	**X**	History of monitoring; Parameters; Background of Schoolship
Data Quality Objectives and Indicators	**X**	**X**	Educational goals; Design of quality controls on datasheets and during the process
Project Schedule		**X**	

Items to Include (Cont.)	Education Level QAPP	Research/Policy Level QAPP	ISEA Specific Considerations
Training and Specialized Experience	X	X	Volunteer training and retention; Staff qualifications
Documents and Records	X	X	DBMS, datasheets
Organization Chart		X	
Project/Task Organization		X	
Project Distribution List		X	
Data Collection			
Existing Data		X	
Sampling Design and Data Collection Methods	X	X	Protocols; Connection to education
Sample Handling and Custody		X	
Equipment/ Instrument Maintenance, Testing Inspection and Calibration		X	
Analytical Methods	X	X	Description of data compilation and review; Creation of graphs
Field and Laboratory Quality Control	X	X	Consistency of equipment; Lab protocols
Data Management		X	
Data Access			
Reporting, Oversight, and Assessments	X	X	Process of staff review of data; Finalized graphs; Checking for flagged data
Data Review			
Data Review and Usability	X	X	End users; How data is shared

Table 2. QAPP template outline with specific considerations for ISEA. The columns show different QAPP levels and rows are grouped by four major elements of a QAPP. Adapted from the EPA's Handbook for Citizen Science Quality Assurance and Documentation (2019).

Limitations and Assumptions

Our project design posed several limitations to gathering representative data. The teacher survey had a lower than optimal response rate for generalizing trends. We also sent the email containing the survey only to educators who had been on ISEA's programs before, missing out on other school teacher perspectives. Additionally, most responses were from participants in the 2021 season, meaning perspectives from earlier years and sails without COVID protocols may be underrepresented. The survey could only be completed via email and the only incentive to answer was if teachers had an interest in obtaining data. This meant we did not hear from educators who had no interest in the dataset, so their perspectives are missing. Still, we assumed that these responses are representative of teachers who attend the program. Similarly, our informal meetings only occurred with education organizations that collect data in a style similar to ISEA, so we cannot reflect on the benefits of other approaches. Given our limited time to meet with Great Lakes professionals, we utilized a snowball sampling method and spoke to individuals referred to us during previous meetings. Thus, we assume that the selected informal meetings are representative of the perspectives of experts in the region, but understand that key viewpoints are potentially lacking. Our observations occurred in the summer of 2021, so programs were adapted for COVID-19 restrictions. This meant that the typical four-hour sails were shortened to two-hour programs, splitting classes in half and supplementing the experience with activities on shore. This time restraint restricted the number of activities which could occur during a program. Students were not collecting water quality, microplastics, or fish trawl data except in rare circumstances during our observation period. Our reflections and notes reflect thoughts on programs and participants within this adapted context. Lastly, we understand that the announced observation method which we employed assumed that participants would act in the same manner as if they were unaware of our presence and research.

Positionality Statement

We recognize that our collective background informs our research scope and ultimately our project design as a whole. Our identities as graduate students, as people in our twenties, as two men and two women, and as three White American students and an international student from China affect how we interact with participants and how they interact with us. We acknowledge that our professional and academic interests in ecological science, data management, and environmental education informed the methods we used to complete this project.

Implications

Although our report has recommendations that are specific to ISEA, our findings have broader implications for the field of ecological data management and citizen science education. With global change and increasingly complex environmental issues, there is a need for better access to data from broader sources than simply credentialled researchers (Jarmin & O'Hara, 2016; Vellend et al., 2013). At the same time, there is an increase in citizen science being used for environmental education (Roche et al., 2020), which is creating or adding to existing datasets. These citizen science datasets can help fill the global need if collected data is of known quality.

Our project also highlighted the benefits of determining a streamlined science strategy for education. When instructors understand which pieces of data are important to record, more capacity is freed to teach. These goals also create a stronger feedback between the data and teaching tools, ultimately increasing Great Lakes literacy for participants and other stakeholders. Our recommendations apply to other programs utilizing citizen science to help increase the access and use of their datasets.

REFERENCES

Ardoin, N. M., Bowers, A. W., & Gaillard, E. (2020). Environmental education outcomes for conservation: A systematic review. Biological Conservation. https://doi.org/10.1016/j.biocon.2019.108224

Barbiero, R. P., Rudstam, L. G., Watkins, J. M., & Lesht, B. M. (2019). A cross-lake comparison of crustacean zooplankton communities in the Laurentian Great Lakes, 1997–2016. Journal of Great Lakes Research, 45(3), 672–690. https://doi.org/10.1016/j.jglr.2019.03.012

Biedenweg, K., Monroe, M., & Wojcik, D. (2013). Foundations of environmental education. In *Across the spectrum: Resources for environmental educators.* North American Association for Environmental Education.

Bryman, A. (2015). *Social Research Methods* (5th ed.). Oxford University Press.

Burgess, H. K., DeBey, L. B., Froehlich, H. E., Schmidt, N., Theobald, E. J., Ettinger, A. K., HilleRisLambers, J., Tewksbury, J., & Parrish, J. K. (2017). The science of citizen science: Exploring barriers to use as a primary research tool. *Biological Conservation*. https://doi.org/10.1016/j.biocon.2016.05.014

Burlakova, L. E., Barbiero, R. P., Karatayev, A. Y., Daniel, S. E., Hinchey, E. K., & Warren, G. J. (2018). The benthic community of the Laurentian Great Lakes: Analysis of spatial gradients and temporal trends from 1998 to 2014. Journal of Great Lakes Research. https://doi.org/10.1016/j.jglr.2018.04.008

Burns, N. M., Rockwell, D. C., Bertram, P. E., Dolan, D. M., & Ciborowski, J. J. H. (2005). Trends in temperature, secchi depth, and dissolved oxygen depletion rates in the central basin of Lake Erie, 1983-2002. Journal of Great Lakes Research. https://doi.org/10.1016/S0380-1330(05)70303-8

BSCS Science Learning. (n.d.). *Our story*. BSCS.org. https://bscs.org/about/our-story/

Chapman, D. V., Meybeck, M., Kimstach, V., & Helmer, R. (1996). Chapter 2 - Strategies for water quality assessment. In Water quality assessments: A guide to the use of biota, sediments, and water in environmental monitoring (2nd ed., pp. 40–79). essay, E & FN Spon.

Cipoletti, N., Jorgenson, Z. G., Banda, J. A., Kohno, S., Hummel, S. L., & Schoenfuss, H. L. (2020). Biological consequences of agricultural and urban land-use along the Maumee River, a major tributary to the Laurentian Great Lakes watershed. *Journal of Great Lakes Research*. https://doi.org/10.1016/j.jglr.2020.04.013

Cooke, S. J., Lynch, A. J., Piccolo, J. J., Olden, J. D., Reid, A. J., & Ormerod, S. J. (2021). Stewardship and management of freshwater ecosystems: From Leopold's land ethic to a freshwater ethic. *Aquatic Conservation: Marine and Freshwater Ecosystems*. https://doi.org/10.1002/aqc.3537

Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., Phillips, T., & Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. In *Frontiers in Ecology and the Environment*. https://doi.org/10.1890/110236

Dropbox. (2021). Dropbox. Dropbox.umich.edu

Elsevier. (2021). Mendeley Reference Manager. https://www.mendeley.com/reference-management/reference-manager

Encarnacao, J., Teodosio, M.A., & Morais, P. (2021). Citizen Science and Biological Invasions: A Review. *Frontiers in Environmental Science*, *8(602980)*. https://doi.org/10.3389/fenvs.2020.602980

Environmental Protection Agency (EPA). (2021a). Climate Change Indicators: Great Lakes Water Levels and Temperatures. https://www.epa.gov/climate-indicators/great-lakes

Environmental Protection Agency (EPA). (2021b). Great Lakes Zooplankton Monitoring. https://www.epa.gov/great-lakes-monitoring/great-lakes-zooplankton-monitoring#anchor3

Environmental Protection Agency (EPA). (2019). Handbook for citizen science: Quality assurance and documentation.

Eriksen, M., Mason, S., Wilson, S., Box, C., Zellers, A., Edwards, W., Farley, H., Amato, S. (2013). Microplastic pollution in the surface waters of the Laurentian Great Lakes. Marine Pollution Bulletin, 77(1–2), 177–182. https://doi.org/10.1016/j.marpolbul.2013.10.007

FieldScope. (2022a). About Great Lakes Water Quality. FieldScope. https://greatlakes.next.fieldscope.org/

FieldScope. (2022b). Platform Licensing Fees. https://fieldscope.zendesk.com/hc/en-us/articles/360053061112-Platform-Licensing-Fees

Floyd, J., & Fowler, R. (1998) *Handbook of Applied Social Research Methods*. SAGE Publications.

Fortner, R., & Mayer, V. J. (1983). Ohio Students' Knowledge and Attitudes about the Oceans and Great Lakes. *The Ohio Journal of Science*, *83*(5), 218–224.

Fortner, R. W., & Manzo, L. (2011). Great lakes literacy principles. *Eos*, *92*(13), 109–110. https://doi.org/10.1029/2011EO130002

Fortner, R. W., Mayer, V. J., Brothers, C. C., & Lichtkoppler, F. R. (1991). Knowledge about the Great Lakes Environment: A Comparison of Publics. *Journal of Great Lakes Research*, *17*(3), 394–402. https://doi.org/10.1016/S0380-1330(91)71375-0

Ganzevoort, W., & Van Den Born, R. (2019). The Thrill of Discovery: Significant Nature Experiences among Biodiversity Citizen Scientists. *Ecopsychology*. https://doi.org/10.1089/eco.2018.0062

Giraud, Samantha L.M. (2011) "Scientific Utility in Ecological Education Programs: A Case Study of the Inland Seas Education Association, Suttons Bay, MI." *University of Michigan*.

Google. (n.d.). Google Drive. https://www.google.com/drive/

Gray, David. (2014). *Doing Research in the Real World*, 3rd edition.

Inland Seas Education Association (ISEA). (2021) "About ISEA." *Inland Seas Education Association*, 4 Mar. 2021, https://schoolship.org/

Helm, P. A. (2020). Occurrence, Sources, Transport, and Fate of Microplastics in the Great Lakes–St. Lawrence River Basin. In Handbook of Environmental Chemistry (Vol. 101, pp. 15–47). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/698_2020_557

Hiller, S. E., & Kitsantas, A. (2014). The Effect of a Horseshoe Crab Citizen Science Program on Middle School Student Science Performance and STEM Career Motivation. *School Science and Mathematics*. https://doi.org/10.1111/ssm.12081

Jarmin, R. S., & O'Hara, A. B. (2016). BIG DATA AND THE TRANSFORMATION OF PUBLIC POLICY ANALYSIS. *Journal of Policy Analysis and Management*. https://doi.org/10.1002/pam.21925

Larson, J. H., Trebitz, A. S., Steinman, A. D., Wiley, M. J., Mazur, M. C., Pebbles, V., Braun, H. A., & Seelbach, P. W. (2013). Great Lakes rivermouth ecosystems: Scientific synthesis and management implications. In *Journal of Great Lakes Research*. https://doi.org/10.1016/j.jglr.2013.06.002

Leech, N. L., & Onwuegbuzie, A. J. (2008). Qualitative Data Analysis: A Compendium of Techniques and a Framework for Selection for School Psychology Research and Beyond. *School Psychology Quarterly*, *23*(4), 587–604. https://doi.org/10.1037/1045-3830.23.4.587

Mason, S. A., Kammin, L., Eriksen, M., Aleid, G., Wilson, S., Box, C., Williamson, N., Riley, A. (2016). Pelagic plastic pollution within the surface waters of Lake Michigan, USA. Journal of Great Lakes Research, 42(4), 753–759. https://doi.org/10.1016/j.jglr.2016.05.009

Mehler, K., Burlakova, L. E., Karatayev, A. Y., Elgin, A. K., Nalepa, T. F., Madenjian, C. P., & Hinchey, E. (2020). Long-term trends of Lake Michigan benthos with emphasis on the southern basin. Journal of Great Lakes Research. https://doi.org/10.1016/j.jglr.2020.03.011

Michigan Office of the Great Lakes, Department of Environmental Quality (Michigan OGL). (2016) Sustaining Michigan's Water Heritage: A Strategy for the Next Generation. https://www.michigan.gov/documents/deq/deq-ogl-waterstrategy_538161_7.pdf

Microsoft Corporation. (2022). Microsoft 365. https://www.microsoft.com/en-us/microsoft-365

Nation, M., Thomas, S., Combs, S., Daniels, E., Talamas, C., & Vignet-Williams, G. (2020). Improving Water Resilience Through Environmental Education. *Journal of Sustainability Education*.

North American Lake Management Society (NALMS). (2021). Secchi Dip-in - Secchi Disk Procedures Used in Several State Programs. https://www.nalms.org/secchidipin/monitoring-methods/the-secchi-disk/secchi-disk-procedures-used-in-several-state-programs/

O'Neil, J. M., Newton, R. J., Bone, E. K., Birney, L. B., Green, A. E., Merrick, B., Goodwin-Segal, T., Moore, G., & Fraioli, A. (2020). Using urban harbors for experiential, environmental literacy: Case studies of New York and Chesapeake Bay. In *Regional Studies in Marine Science*. https://doi.org/10.1016/j.rsma.2019.100886

Otter.ai. (2021). Otter.ai mobile version. https://otter.ai/

Plumb, Russell H. (1997). Standard guidance for the preparation of quality assurance project plans. Technical report ; D-97-1. Vicksburg, Miss.: *U.S. Army Engineer Waterways Experiment Station*.

QSR International. (2021). NVivo 2021.https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

Roche, J., Bell, L., Galvão, C., Golumbic, Y. N., Kloetzer, L., Knoben, N., Laakso, M., Lorke, J., Mannion, G., Massetti, L., Mauchline, A., Pata, K., Ruck, A., Taraba, P., & Winter, S. (2020). Citizen Science, Education, and Learning: Challenges and Opportunities. *Frontiers in Sociology*. https://doi.org/10.3389/fsoc.2020.613814

Saldana, J. M. (2015). *The coding manual for qualitative researchers* (3rd ed.). SAGE Publications.

Scharold, J., Lozano, S. J., & Corry, T. D. (2009). Status of benthic macroinvertebrates in southern nearshore lake superior, 1994-2003. In State of Lake Superior.

Schutt, R. K. (2001). *Investigating the Social World: The Process and Practice of Research* (3rd ed.). SAGE Publications.

Shumaker, Heather. (2014). *Aboard the Great Lakes Schoolship: 25 Years of Science & Stewardship with Inland Seas*. Inland Seas Education Association.

Silbernagel, J., Host, G., Hagley, C., Hart, D., Axler, R., Fortner, R., Axler, M., Smith, V., Drewes, A., Bartsch, W., Danz, N., Mathews, J., & Wagler, M. (2015). Linking place-based science to people through spatial narratives of coastal stewardship. *Journal of Coastal Conservation*. https://doi.org/10.1007/s11852-015-0380-1

Simpson, J. T. EPA. (2015). Volunteer Lake Monitoring: A Methods Manual (EPA440-4-91-002).https://www.epa.gov/sites/default/files/2015-06/documents/lakevolman.pdf

Smith, D. G. (2001). A protocol for standardizing Secchi disk measurements, including use of a viewer box. Lake and Reservoir Management. https://doi.org/10.1080/07438140109353977

Steinman, A. D., Cardinale, B. J., Munns, W. R., Ogdahl, M. E., Allan, J. D., Angadi, T., Bartlett, S., Brauman, K., Byappanahalli, M., Doss, M., Dupont, D., Johns, A., Kashian, D., Lupi, F., McIntyre, P., Miller, T., Moore, M., Muenich, R. L., Poudel, R., … Washburn, E. (2017). Ecosystem services in the Great Lakes. In *Journal of Great Lakes Research*. https://doi.org/10.1016/j.jglr.2017.02.004

Unger, S., Rollins, M., Tietz, A., & Dumais, H. (2020). iNaturalist as an engaging tool for identifying organisms in outdoor activities. *Journal of Biological Education*. https://doi.org/10.1080/00219266.2020.1739114

Vail, J. H. & Smith, M. H. (2013). An Integrative STEM Experience Onboard a Research Vessel. *2013 ASQ Advancing the STEM Agenda Conference*.

Vellend, M., Brown, C. D., Kharouba, H. M., Mccune, J. L., & Myers-Smith, I. H. (2013). Historical ecology: Using unconventional data sources to test for effects of global environmental change. In American Journal of Botany. https://doi.org/10.3732/ajb.1200503

Wiggins, A., Newman, G., Stevenson, R. D., & Crowston, K. (2011). Mechanisms for data quality and validation in citizen science. In *2011 IEEE seventh international conference on e-Science Workshops* (pp. 14-19). IEEE.

Wiley, M. J., Hyndman, D. W., Pijanowski, B. C., Kendall, A. D., Riseng, C., Rutherford, E. S., Cheng, S. T., Carlson, M. L., Tyler, J. A., Stevenson, R. J., Steen, P. J., Richards, P. L., Seelbach, P. W., Koches, J. M., & Rediske, R. R. (2010). A multi-modeling approach to evaluating climate and land use change impacts in a Great Lakes River Basin. *Hydrobiologia*. https://doi.org/10.1007/s10750-010-0239-2

Williamson, A. M., & Dann, S. L. (1999). Vessel-based education programs in the Great Lakes: An evaluation of effects on student knowledge and attitudes. *Journal of Great Lakes Research*. https://doi.org/10.1016/S0380-1330(99)70790-2

Zint, M., Kraemer, A., & Kolenic, G. (2014). Evaluating Meaningful Watershed Educational Experiences: An exploration into the effects on participating students' environmental stewardship characteristics and the relationships between these predictors of environmentally responsible behavior. *Studies in Educational Evaluation*. https://doi.org/10.1016/j.stueduc.2013.07.002

Zoom Video Communications Inc. (2021). ZOOM Cloud Meetings Version 5.9.1 https://umich.zoom.us/

APPENDICES

Appendix I: Complete list of questions in the questionnaire which was distributed to teachers who have participated in ISEA's programs. Skip logics in the survey are listed at the end of each question in italics if present.

Purpose	**Question**	**Options**
Background Information	1. Which school or organization did you come to ISEA with?	*Short Answer*
	2. Which grade level(s) do you teach? (Select all that apply)	K-3; 4-6; 7-8; 9-12
	3. What subject do you teach? *(If any of 4-6; 7-8; 9-12 are selected in Q2)*	Science; Math; Social Studies/History; Afterschool programs; Other, please specify
	4. What type of science do you teach? (*If Science is selected in Q3)*	Environmental Science; Chemistry; Biology; Physics; Other, please specify
	5. How many times have you sailed with ISEA?	1; 2-3; 4-7; 8 or more
	6. What season and year did you last sail with ISEA? (ex. Spring 2021)	*Short Answer*
	7. Which ISEA program(s) have you attended?	NextGen (including the Ship 'n' Shore option presented during COVID); Diving Deeper
Education Experience	8. ISEA aims to connect participants to the health and water quality of the Great Lakes to encourage stewardship. How do you find ISEA's guiding question "Is the bay healthy?" impacts your students' understanding of their connection to the Great Lakes?	*Short Answer*

Purpose	Question	Options
Data Use - Interest	9. ISEA has recorded the data collected by students during their programming for decades. Would you be interested in using this data in your classroom?	Yes; No; Maybe - I need more information/access to training resources
	10. Which of these data topics would you potentially be interested in having access to in your classroom? (Select all that apply)	Weather; Fish biodiversity; Benthos biodiversity; Plankton biodiversity; Microplastics; Secchi depth; pH level of the bay; Dissolved oxygen content of the bay
Data Use - How	11. How much data would you like to receive?	Data collected on your trip; Field season data (to look at seasonal trends from May-October in one year); Long-term data (to look at temporal trends over 30 years); Other, please specify
	12. Which of these formats would you be comfortable using, or learning to use? (Select all that apply)	Pre-made charts (like the ones used during Schoolship); Raw data in MS Excel or Google Sheets; Citizen science platform (ex. FieldScope, which can be used to create your own visualizations and access data collected by other users); Other, please specify

Purpose	Question	Options
Data Use-How	13. How would you like to use the data from ISEA in your classroom? (ex. before the trip to prepare, after the trip as a lesson or follow-up, supplemental in years you cannot attend, etc.)	*Short Answer*
	14. What are some reasons why you are not interested in using ISEA's data? (ex. not enough time, too much work for me, etc.) *(If No is selected in Q9)*	*Short Answer*
Closing Question	15. Do you have any other thoughts or opinions on this subject that you would like to share?	*Short Answer*

Appendix II: Complete list of interview questions asked to ISEA's volunteer instructors.

Purpose	Question
Background	Could you share your name and how long you have been volunteering with ISEA?
	What are the roles you have served with ISEA?
	From your understanding, what is the mission of ISEA?
Data Collection Process (In the context of a specific time volunteer was on a Schoolship program:)	Which station were you leading or were you the lead instructor?
	What are your thoughts about the data collection sheet?
	Which samples were difficult to collect and/or record? How so?
	Walk me through how you would handle a new specimen that you have not seen before/is not on the datasheet.
	What are some ways this sampling process could be improved?
Instructional Process	How would you describe your approach for guiding the conversation with students?
	What are the main takeaways you hope to impart on the students?
	In your perspective, what is the role of the student logbook?
	Hypothetically, if you were down to one minute, what highlights would you touch upon?
Data Use	What are some examples of the ways that you used the collected data on your last Schoolship sail?
	Which collected data are the most important for conveying the Schoolship mission?
	Which collected data do not contribute as much to that mission?
	From your perspective, how else do you envision the data from the Schoolship program could be used?
	What other tools/graphs would help you tell the story of Great Lakes health and stewardship?

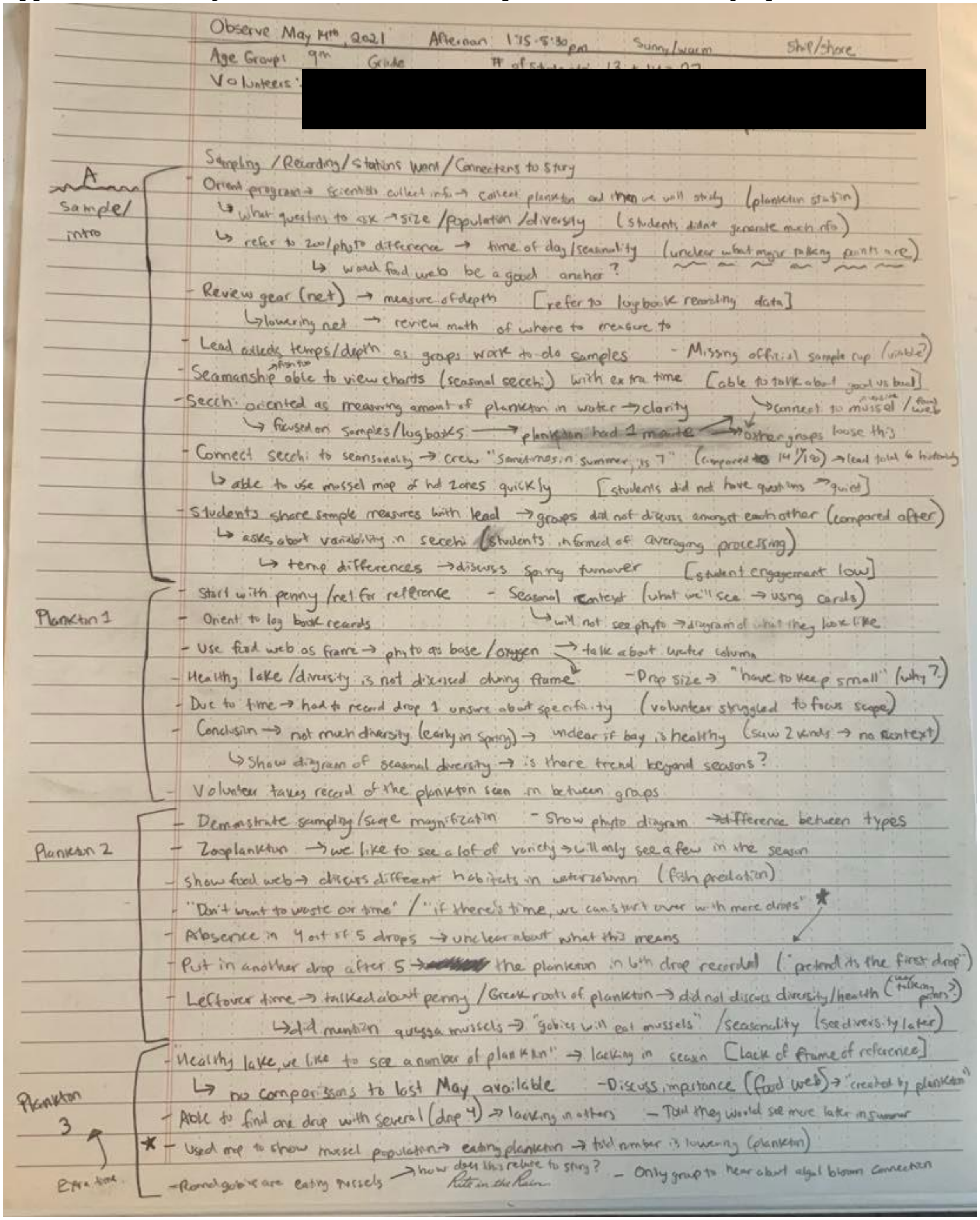
Purpose	Question
Importance of Data	What are some examples of how this dataset is important to ISEA?
	How does data collection reflect the mission of ISEA to inspire a lifetime of Great Lakes curiosity, stewardship, and passion in people of all ages?

Appendix III: Complete list of interview questions asked to select ISEA's volunteer Science Committee members.

Purpose	**Question**
Background	How long have you been volunteering with Inland Seas?
	Do you have a background in scientific data collection and/or data management?
Data Management	In what ways could long-term data storage be beneficial to the goals of Inland Seas?
	In your opinion, who do you envision using the data from Inland Seas?
	What criteria should be used to determine what data are digitized for long-term storage?
	Is there value in digitizing data parameters for which we don't have a specific end user in mind?
	What programs have you used for data storage? a. Do you have experience with Excel? b. Do you have experience with Microsoft Access? c. Have you used any other database management systems?
	In your experience, what aspects of a data system or program were most important for inputting data?
Data Quality	What QC could be implemented for [x] sampling before volunteers leave the schooner? a. What specific standards should be met for the [x] station?
	What should be done with unidentified or unfamiliar specimens?
	Would you make any changes to the [x] datasheet to simplify recording or improve data quality? What changes would you make?
	What QC should be implemented prior to digitizing the data? a. What should be done with unidentified or unfamiliar specimens?
	Who do you think should take the greatest responsibility with QC: the lead, or the station instructors?
Citizen Science Apps	Have you used any specific citizen science apps, such as iNaturalist or FieldScope? a. [If yes] In what context have you used this/these app(s)? b. Have you used any other citizen science apps?

Purpose	Question
Citizen Science Apps	What value could citizen science apps add to Inland Seas programs? a. Do you think contributing data to citizen science research fits with Inland Seas' mission?
	How and when do you envision apps would be used by ISEA?
	What criteria should we use to select apps for ISEA to use?

Appendix IV: Example of field notes taken during observation of ISEA program.



Observe May 14th, 2021 Afternoon 1:15-5:30 pm Sunny/warm Ship/shore
Age Group: 9th Grade [redacted]
Volunteers: [redacted]

Sampling / Recording / Stations Work / Connections to Story

A
Sample/intro
- Orient program → scientists collect info → collect plankton and then we will study (plankton station)
  ↳ what questions to ask → size / population / diversity (students didn't generate much info)
  ↳ refer to zoo/phyto difference → time of day / seasonality (unclear what major talking points are)
    ↳ would food web be a good anchor?
- Review gear (net) → measure of depth [refer to logbook recording data]
  ↳ lowering net → review math of where to measure to
- Lead collects temps/depth as groups work to do samples - Missing official sample cup (visible?)
- Seamanship (after the) able to view charts (seasonal secchi) with extra time [able to talk about good vs bad]
- Secchi oriented as measuring amount of plankton in water → clarity ↳ connect to mussel (invasive) / food web
  ↳ focused on samples/logbooks → ~~plankton had 1 minute~~ → other groups loose this
- Connect secchi to seasonality → crew "Sometimes in summer, is 7" (compared to 14 1/10) → lead told to history
  ↳ able to use mussel map of hot zones quickly [students did not have questions → quiet]
- Students share sample measures with lead → groups did not discuss amongst each other (compared after)
  ↳ asks about variability in secchi (students informed of averaging processing)
    ↳ temp differences → discuss spring turnover [student engagement low]

Plankton 1
- Start with penny /net for reference - Seasonal context (what we'll see → using cards)
- Orient to log book records ↳ will not see phyto → diagram of what they look like
- Use food web as frame → phyto as base / oxygen → talk about water column
- Healthy lake / diversity is not discussed during frame - Drop size → "have to keep small" (why?)
- Due to time → had to record drop 1 unsure about specificity (volunteer struggled to focus scope)
- Conclusion → not much diversity (early in spring) → unclear if bay is healthy (saw 2 kinds → no context)
  ↳ Show diagram of seasonal diversity → is there trend beyond seasons?
- Volunteer takes record of the plankton seen in between groups

Plankton 2
- Demonstrate sampling / scope magnification - Show phyto diagram → difference between types
- Zooplankton → we like to see a lot of variety → will only see a few in the season
- Show food web → discuss different habitats in water column (fish predation)
- "Don't want to waste our time" / "if there's time, we can start over with more drops" *
- Absence in 4 out of 5 drops → unclear about what this means
- Put in another drop after 5 → ~~[illegible]~~ the plankton in 6th drop recorded ("pretend its the first drop")
- Leftover time → talked about penny / Greek roots of plankton → did not discuss diversity/health (clear talking points?)
  ↳ did mention quagga mussels → "gobies will eat mussels" / seasonality (see diversity later)

Plankton 3
- "Healthy lake, we like to see a number of plankton" → lacking in season [Lack of frame of reference]
  ↳ no comparisons to last May available - Discuss importance (food web) → "created by plankton"
- Able to find one drop with several (drop 4) → lacking in others - Told they would see more later in summer
* - Used map to show mussel population → eating plankton → told number is lowering (plankton)
Extra time
- Round gobies are eating mussels → how does this relate to story? - Only group to hear about algal bloom connection

Rite in the Rain

Appendix V: Example of a digital memo formed after observation of ISEA programming.

<u>May 18, 2021 Afternoon Observations (Celia & Connor)</u>
Program Type: Ship Only
Age Group: 12th Grade
Number of Students: 5 (groups of 2-3)
Sessions: 13 minutes
Volunteers: [redacted] (Lead), [redacted] (Fish), [redacted] (Plankton), [redacted] (Seamanship)
Weather: Sunny, slight breeze, warm
Observation Strategy: Follow same group

- **Data Collection:**
  - Plankton collection occurred 50ft down even though the sampling depth was 72ft--instructors had pre decided this depth
    - Fish did something similar with 55ft being predetermined by instructor
  - Fish station recorded weather data in addition to the lead
  - Students were given the choice between Fahrenheit and Celsius
  - Debate among instructors about which number to record for secchi: last number you can see or "blackout" number (first one after you can't see anymore)
    - Confusion and a volunteer suggested the instructions be updated
  - Don't count any dead fish that are collected
- **Charts/Graphs:**
  - All groups saw secchi graphs multiple times (either as a whole group and then seamanship or with sampling group + whole group + seamanship)
    - Unclear what was actually retained or what was new with each showing because all times were fairly brief
  - At the end, fish charts brought out again for whole group→ need more data to establish the trend of diversity bouncing back
- **Process/Inconsistencies:**
  - Fish station filled downtime before sampling by discussing weather and then geographic orientation (without the use of a map)
  - Thermometer at fish broke--noted that the water was left in the VanDorn Bottle so the reading would still be accurate bc not in the sunlight
  - Before the moment of silence, there was a discussion of GL watershed connectivity, where we were in Lake MI, and which direction the boat was facing (maps used)
  - Lead brought out annual/seasonal secchi charts for the whole group after secchi numbers shared out bc one group hadn't seen it before
    - "You are contributing to real-world data"
  - Between sampling and group share-outs, plankton group was directed to connect turbidity with phytoplankton, yet we only see zooplankton below

Appendix VI: Research team codebook used in NVivo® for qualitative comparative analysis of interview and observation data. Notice sub-nodes are indented from their parent codes.

Name	Description	Source
Citizen Science Apps	Participant suggests the use or avoidance of a specific citizen science app or apps more generally.	Inductive
Data Collection	Volunteers demonstrated that the process of sampling was of varying levels of difficulty- easy or hard.	Inductive
Data Recording	Volunteers demonstrated that the process of recording was of varying levels of difficulty- easy or hard.	Inductive
DBMS	Observation of traits which would influence the choice of an ISEA DBMS.	Inductive
Guiding Question	Observation or description of a guiding question or framework during the program	(Monroe, Wojcik & Biedenweg, 2013)
Bay Health	The bay, or its habitat structure, was used a framework for student learning	
Food Web	The food web was used as a salient framework for student learning	

Name	Description	Source
Impactful Experience	Data collection onboard serves as an authentic STEM experience which increases student interest and knowledge of Great Lakes systems	(Vail & Smith, 2013; Williamson & Dann, 1999; Ardoin, Bowers & Gaillard, 2020)
New Organism Protocol	Observation or description of how new organisms are documented during or after sail	Inductive
Parameters	Sampling or recording of a specific parameter	Inductive
Abiotic	Water quality, microplastics, weather, and surface conditions	
Benthos	Sub-node of parameters relating to benthos station	
Fish	Sub-node of parameters relating to fish station	
Plankton	Sub-node of parameters relating to plankton station	
Secchi Depth	Sub-node of parameters relating to use of Secchi disk	

Name	Description	Source
Uses of Data	A potential or current use of the data was discussed or demonstrated	Inductive
Data for Community or Research	Participants suggest that the dataset has potential for public education or researcher use.	
Data for Further Education	Participant suggests the dataset has potential for further student learning if accessed by teachers	
Data for Onboard Education	Observations or descriptions of charts, graphs, information, or graphics which utilize ISEA data during their program	
Validity	Observation or description of practices which affect confidence in data validity	Inductive
Confident	Observation or description of practices which raises confidence in data validity	
Questionable	Observation or description of practices which raised concerns about confidence of data validity	
Volunteer Suggestion	Volunteer made a suggestion about process of the program or educational content	Inductive

Appendix VII: Summary of teacher responses to survey questions 9-12 (**Appendix I**). (A). Summary of all teacher responses. (B). Breakdown of teacher responses by the age group(s) they teach. (C). Breakdown of teacher responses by the subject(s) they teach.

(A) Teacher survey report: All teachers (N=43)			
Survey Question	**Field**	**Count**	**Percentage**
ISEA has recorded the data collected by students during their programming for decades. Would you be interested in using this data in your classroom?	Yes	27	62.79%
	No	1	2.33%
	Maybe – I need more information/access to training resources	15	34.88%
	Total # of responses:	**43**	
Which of these data topics would you potentially be interested in having access to in your classroom? (Select all that apply)	Weather (air & water temperature, cloud types, wind speed, etc.)	21	8.43%
	Fish biodiversity	36	14.46%
	Benthos biodiversity	33	13.25%
	Plankton biodiversity	35	14.06%
	Microplastics	38	15.26%
	Secchi depth (water clarity)	25	10.04%
	pH level of the bay	29	11.65%
	Dissolved oxygen content of the bay	32	12.85%
	Total # of responses:	**249**	
How much data would you like to receive?	Data collected on your trip	3	7.14%
	Field season data (to look at seasonal trends from May-October in one year)	7	16.67%
	Long-term data (to look at temporal trends over 30 years)	32	76.19%
	Total # of responses:	**42**	
Which of these formats would you be comfortable using, or learning to use? (Select all that apply)	Pre-made charts (like the ones used during Schoolship)	40	49.38%
	Raw data in MS Excel or Google Sheets	19	23.46%
	Citizen science platform (ex. FieldScope, which can be used to create your own visualizations and access data collected by other users)	22	27.16%
	Total # of responses:	**81**	

(B) Teacher survey report: Breakdown by age group(s)					
Survey Question	**Field**	**Count**			
		K-3 (n=5)	**4-6 (n=18)**	**7-8 (n=12)**	**9-12 (n=24)**
ISEA has recorded the data collected by students during their programming for decades. Would you be interested in using this data in your classroom?	Yes	1	7	5	18
	No	0	0	0	0
	Maybe – I need more information/access to training resources	2	9	6	4
	Total # of responses:	**3**	**16**	**11**	**22**
Which of these data topics would you potentially be interested in having access to in your classroom? (Select all that apply)	Weather (air & water temperature, cloud types, wind speed, etc.)	0	10	7	10
	Fish biodiversity	3	12	8	21
	Benthos biodiversity	2	10	7	20
	Plankton biodiversity	1	10	9	22
	Microplastics	1	14	11	21
	Secchi depth (water clarity)	0	7	4	17
	pH level of the bay	1	10	5	17
	Dissolved oxygen content of the bay	2	11	6	18
	Total # of responses:	**10**	**84**	**57**	**146**
How much data would you like to receive?	Data collected on your trip	0	1	0	2
	Field season data (to look at seasonal trends from May-October in one year)	2	4	1	2
	Long-term data (to look at temporal trends over 30 years)	1	11	10	18
	Total # of responses:	**3**	**16**	**11**	**22**
Which of these formats would you be comfortable using, or learning to use? (Select all that apply)	Pre-made charts (like the ones used during Schoolship)	3	15	10	21
	Raw data in MS Excel or Google Sheets	0	1	4	16
	Citizen science platform (ex. FieldScope, which can be used to create your own visualizations and access data collected by other users)	1	6	5	15
	Total # of responses:	**4**	**22**	**19**	**52**

(C) Teacher survey report: Breakdown by subject(s)						
Survey Question	**Field**	**Count**				
		Science	**Math**	**Social studies/History**	**Afterschool Programs**	**Other**
ISEA has recorded the data collected by students during their programming for decades. Would you be interested in using this data in your classroom?	Yes	16	1	1	1	7
	No	0	0	0	0	0
	Maybe – I need more information/access to training resources	6	0	0	4	5
Total # of responses:		**22**	**1**	**1**	**5**	**12**
Which of these data topics would you potentially be interested in having access to in your classroom? (Select all that apply)	Weather (air & water temperature, cloud types, wind speed, etc.)	10	1	0	2	8
	Fish biodiversity	19	1	0	5	10
	Benthos biodiversity	21	1	0	4	7
	Plankton biodiversity	22	1	0	3	9
	Microplastics	21	1	1	4	11
	Secchi depth (water clarity)	17	1	0	1	6
	pH level of the bay	19	1	0	3	6
	Dissolved oxygen content of the bay	20	1	0	3	7
	Total:	**149**	**8**	**1**	**25**	**64**
How much data would you like to receive?	Data collected on your trip	2	0	0	0	1
	Field season data (to look at seasonal trends from May-October in one year)	2	0	0	3	1
	Long-term data (to look at temporal trends over 30 years)	18	1	1	2	10
Total # of responses:		**22**	**1**	**1**	**5**	**12**

(C) Teacher survey report: Breakdown by subject(s)						
Survey Question	**Field**	**Count**				
		Science	**Math**	**Social Studies/History**	**Afterschool Programs**	**Other**
Which of these formats would you be comfortable using, or learning to use? (Select all that apply)	Pre-made charts (like the ones used during Schoolship)	12	1	1	5	11
	Raw data in MS Excel or Google Sheets	14	1	0	1	3
	Citizen science platform (ex. FieldScope, which can be used to create your own visualizations and access data collected by other users)	12	0	0	4	6
	Total # of responses:	**38**	**2**	**1**	**10**	**20**

Appendix VIII: (A) This is the proposed new lead datasheet with changes to optimize data quality and recording efficiency. (B) This is the original lead datasheet which the lead instructor uses to record data collected during a regular shipboard program at ISEA.

(A)

TRIP INFORMATION			
Lead Instructor:	Data entered by:	Entry checked by:	Trip #:
Date: (MM/DD/YYYY)	AM / PM / Eve / Overn't	Start Port: ISEA Dock / Discovery Pier / Other:	End Port: ISEA Dock / Discovery Pier / Other:
Captain:	Vessel: Inland Seas / Manitou / Other:	Program: Trad / NG-MP / NG-Sea / Other:	
Passenger #:	Group or Program:	Sampling Location: Suttons Bay / WGTB / Other:	

Sampling Conditions		
Please take sampling conditions into account when using the data confidence checkboxes.		
Time of collection:	Surface Water Temp. (°C):	Air Temp (°C):
Latitude: N	Longitude: W	Location depth (m):

Secchi depths (m)	1 Sunny / Shady High / Low	2 Sunny / Shady High / Low	3 Sunny / Shady High / Low	4 Sunny / Shady High / Low	5 Sunny / Shady High / Low
YSI Depths (m)	1	2	3	4	5
YSI Water Temp. (°C)	1	2	3	4	5
YSI D.O. (mg/L)	1	2	3	4	5
YSI pH	1	2	3	4	5

Unidentified Species Found	Fish / Plankton / Benthos	☐ Did you upload the photo to iNaturalist?
Unidentified Species Found	Fish / Plankton / Benthos	☐ Did you upload the photo to iNaturalist?

Please inform [redacted] of how things went today & any program or equipment needs: [redacted]
Notes: Please only note things that are useful for data entry or necessary to understand the data for the day

For data entry: Sample number is in each box
[update: [redacted]]

(B)

TRIP INFORMATION			
Lead Instructor:	Data entered by:	Entry checked by:	Trip #:
Date:	AM / PM / Eve / Overn't	Start Port:	End Port:
Captain:	Vessel:	Program: Trad / NG-MP / NG-Sea / Other:	
Passenger #:	Group or Program:	Sampling Location:	

Sampling Conditions		
2020 Protocol: Water (YSI Probe): every 5 m; Plankton: 10 ft from bottom; Benthos: 2 grabs		
Wind Speed (mph):	Precipitation: rain snow hail mixed none	Visibility (miles):
Wave Height (ft):	Barometric Pressure (mb):	% Cloud Cover:
Time of collection:	Surface Water Temp. (°F):	Air Temp (°F):

Latitude: N			Longitude: W		
Station depth *(ft)*:	Secchi depths (m):				
YSI Depths (m)	1	2	3	4	5
YSI Water Temp. (°C)	1	2	3	4	5
YSI D.O. (mg/L)	1	2	3	4	5
YSI pH	1	2	3	4	5

Please inform Juliana of how things went today & any program or equipment needs: jlisuk@schoolship.org
Notes:

For data entry: Sample number is in each box
[update: 07/2020 jev]

Appendix IX: (A) This is the proposed new plankton biodiversity single-sided datasheet with changes to optimize data quality and recording efficiency. The back counting sheet is removed. (B) (See next page) This is the original double-sided plankton biodiversity datasheet which the volunteer teaching plankton station uses to record zooplankton data collected during a regular shipboard program at ISEA. The back page is the count sheet.

(A)

PLANKTON			
Filled in by (Plankton Instructor):	Data entered by:	Entry checked by:	Trip #:

Date: (MM/DD/YYYY)	AM / PM / Eve	Latitude: N	Longitude: W

Sampling Location: Suttons Bay / WGTB / Other:	Data Confidence	High / Low	Time:	Station#:	Sample#:

Plankton Net	***Protocol: 3 m from the bottom***		
Sample depth *(m)*:	Location depth (*m)*:	☐ *Check if* ***Plankton Trap***	☐ *Check if* ***No Plankton found***

Directions: Mix sample, draw up an eyedropper of water. Place individual drops on petri dish and examine the entirety of each drop. Mark x in which each species was found.

Species	Presence	Absence	Species	Presence	Absence
Bosmina	P	A	*Asplanchna*	P	A
Calanoid Copepod	P	A	Colonial Rotifer	P	A
Cyclopoid Copepod	P	A	*Keratella*	P	A
Copepod Nauplius	P	A	*Leptodora*	P	A
Veliger	P	A	*Ostracoda*	P	A
Bythotrephes	P	A		P	A
	P	A		P	A

About how many *Bythotrephes* (spiny water fleas) are in the entire sample?

Notes: Please only note things that are useful for data entry or necessary to understand the data for the day

(B)

PLANKTON			
Filled in by (Plankton Instructor):	Data entered by:	Entry checked by:	Trip #:

Date:	AM / PM / Eve	Latitude: N	Longitude: W

Sampling Location:	Time:	Station#:	Sample#:

Plankton Net	***Protocol: 10 ft from the bottom***		
Sample depth *(ft)*:	Station depth *(ft)*:	☐ *Check if **Plankton Trap***	☐ *Check if **No Plankton found***

Directions: Mix sample, draw up an eyedropper of water. Place individual drops on petri dish and examine the entirety of each drop. Record percentage of drops in which each species was found. Add A/C/R data if desired.

Species	% of drops	Notes *Abundant/Common/Rare*	Species	% of drops	Notes *Abundant/Common/Rare*
☐ *Bosmina*			☐ *Asplanchna*		
☐ Calanoid Copepod			☐ Colonial Rotifer		
☐ Cyclopoid Copepod			☐ *Keratella*		
☐ Copepod Nauplius			☐ *Leptodora*		
☐ Veliger			☐ *Ostracoda*		
☐ *Bythotrephes*	Record count below				

About how many *Bythotrephes* (spiny water fleas) are in the entire sample?

Notes:

[update: 03/2019 jev]

PLANKTON – Counting sheet

How to use: Each small box = one drop. •Mark each box if the plankton species is present. •Black out boxes if drops were not examined. •Sum number of marks. •Divide by number of drops. •Record percent on datasheet.

Plankton Type	Group 1	Group 2	Group 3	Group 4	Group 5	Total

Notes:

Appendix X: (A) This is the proposed new benthos biodiversity datasheet with changes to optimize data quality and recording efficiency. (B) This is the original benthos biodiversity datasheet which the volunteer teaching benthos station uses to record benthic organisms biodiversity data collected during a regular shipboard program at ISEA.

(A)

BENTHOS				
Filled in by (Benthos instructor):	Data entered by:	Entry checked by:	Trip #:	
Date: (MM/DD/YYYY)	AM / PM / Eve	Latitude: N	Longitude: W	
Sampling Location: Suttons Bay / WGTB / Other:	Data Confidence (High / Low)	Time:	Station#:	
Sample Information				
Sample depth *(m)*:	**Species –** Only mark mussels if **ALIVE**			
	PONAR / Deep Sample		Otter Trawl / Shallow Sample	
Species	Presence	Absence	Presence	Absence
Midge Larvae	P	A	P	A
Quagga Mussel	P	A	P	A
Midge Pupa	P	A	P	A
Isopod	P	A	P	A
Amphipod	P	A	P	A
Chara	P	A	P	A
	P	A	P	A
	P	A	P	A
	P	A	P	A

Notes: Please only note things that are useful for data entry or necessary to understand the data for the day

(B)

BENTHOS				
Filled in by (Benthos instructor):	Data entered by:	Entry checked by:	Trip #:	
Date:	AM / PM / Eve	Latitude: N	Longitude: W	
Sampling Location:			Time:	Station#:
PONAR Sample Information				
Sample depth *(ft)*:	**Color:** Dark Gray Light Gray Olive Gray Greenish Gray Yellowish Orange Light Brown			

PONAR / Deep sample		Otter trawl / Shallow sample	
# of samples examined: ----------------------------------	☐ No animals found in sediment	**Presence / Absence Only**	
Species – Mark if present. Only mark mussels if **ALIVE**		☐ Midge Larvae	☐ Isopod
Species	Count	☐ Midge Pupa	☐ Chara
☐ Quagga Mussel		☐ Amphipod	☐ Eurasian Watermilfoil
☐ Midge Larvae		☐ Quagga Mussel	☐
☐		☐	☐
☐			
☐			

Notes:

Updated: 05/2020 rjr/jev

Appendix XI: This is the original water quality datasheet which the volunteer teaching water quality station uses to record water data collected during a regular shipboard program at ISEA.

WATER QUALITY			
Filled in by (Water Quality Instructor):	Data entered by:	Entry checked by:	Trip #:
Date: AM / PM / Eve	Latitude: N	Longitude: W	
Sampling Location:	Time:	Station#:	Sample#:

Water Sample: Van Dorn Bottle		*Protocol: 5 ft from the bottom*
Sample depth *(ft)*:	Station depth *(ft)*:	☐ *Check if surface sample only, Van Dorn not used*
Temp at depth *(°F)*:	Surface temp *(°F)*:	

Measurement					
DO (ppm)	1	2	3	4	5
pH	1	2	3	4	5

Notes: (update: 01/2020 rjr)

Appendix XII: This is the original microplastics datasheet which the volunteer teaching microplastics station uses to record microplastic particle data collected during a regular shipboard program at ISEA.

MICROPLASTICS

Filled in by (Microplastics Instructor):	Entered by:	Entry checked by:	Trip #:

Date:	AM / PM / Eve	Sampling Location:
Vessel:		

Manta Trawl (Surface Trawl)	***Protocol: Trawl for 30 min***	
Record: Latitude & Longitude @ Starting location	**Directions: Record speed about every 10 minutes** Start when trawl hits the water. End when trawl comes off the surface	
	Time [hh:mm]	**Boat Speed *(knots or mph)***
	START	
Notes:		
	END	

Visual Examination of Sample (Next Gen – Whole Sample NOT SAVED)

Directions: Use the codes below for size and type to categorize plastics to the best of your ability. All counts will be verified by the office. Please make notes!

☐ Check box if **sample not inspected**

☐ Check box if **no plastic found**

One millimeter = Ultra Fine Sharpie point

Size Code	*Description*
Small	0.333mm - <1mm
Medium	1mm - < 4.75mm
Large	>4.75mm

Type Code	*Description*
Fragment	hard jagged plastic pieces
Pellet	hard rounded plastics pieces
Line/fiber	fibrous or thin, linear plastic
Film	flimsy planes, such as from a plastic bag
Foam	lightweight, sponge-like plastic

Record each particle individually

#	Color	Size Code	Type Code	#	Color	Size Code	Type Code
1				6			
2				7			
3				8			
4				9			
5				10			

NEXT GEN SAILS: Keep any recovered plastic particles in petri dish. Label DATE, AM or PM, & VESSEL on petri dish. Return remaining (non-plastic) parts of the sample (seeds, pollen, insects…) to the lake.

Appendix XIII: (A) This is the proposed new fish biodiversity datasheet with changes to optimize data quality and recording efficiency. (B) This is the original fish biodiversity datasheet which the volunteer teaching fish station uses to record fish biodiversity data collected during a regular shipboard program at ISEA.

(A)

FISH				
Filled in by (Fish Instructor):		Data entered by:	Entry checked by:	Trip #:
Date: (MM/DD/YYYY)	AM / PM / Eve	Sample Location: Suttons Bay / WGTB / Other:	Data Confidence High / Low	Net #:

Otter Trawl		*Protocol: Trawl moving on the bottom for 10 min*	
Latitude: N		Longitude: W	
Start time:	End time:	Start depth *(m)*:	End depth *(m)*:

SPECIES INFORMATION			
☐ No fish caught ☐ Trawl not successful			**NOTES:** Please only note things that are useful for data entry or necessary to understand the data for the day
Species	**Otter Trawl**	**Traps**	
Round goby			
Rock Bass			
Brook stickleback			
Yellow Perch			

Notes: Please only note things that are useful for data entry or necessary to understand the data for the day

(B)

FISH				
Filled in by (Fish Instructor):		Data entered by:	Entry checked by:	Trip #:
Date:	AM / PM / Eve	Sample Location:		Net #:

Otter Trawl		*Protocol: Trawl moving on the bottom for 10 min*	
Latitude: N		Longitude: W	
Start time:	End time:	Start depth *(ft)*:	End depth *(ft)*:

SPECIES INFORMATION					
☐ No fish caught ☐ Trawl not successful			*Photos of species on iNaturalist*		
Species	**Total count**	**# with spots**	**O = Otter TR= Traps**	**NOTES:** *Use back if needed*	
					☐
					☐
					☐
					☐
					☐

Notes:

[update: 03/2020 rjr]