A Proposed Analysis of the Ecosystem Integrity of Small Aquatic Ecosystems Local to the Amherst, Massachusetts Area

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ABSTRACT

Small aquatic ecosystems are critical contributors to freshwater biodiversity and freshwater ecosystem services. Ponds in particular house more rare and unique species than any other small freshwater ecosystem. However, little research has been done into measuring the ecosystem integrity of small aquatic ecosystems due to few evaluations in the effects of anthropogenic activities on these ecosystems. In this proposal, we aim to evaluate the ecosystem integrity of small aquatic ecosystems local to the Amherst, Massachusetts area by (1) determining their flora biodiversity, (2) measuring their quality of the matter economy, and (3) identifying sustainable architecture structures around them. We will use Simpson's biodiversity index as a simple measure of plant biodiversity, use soil core samples as a timeline of the matter economy, and we will compare the number of current sustainable architecture structures with previous numbers. With this data, we will determine if the priority of green architecture in local

construction developments have followed the same upward trend observed on a national scale. Without research into these ecosystems, we risk losing valuable oases of biodiversity and the opportunities to identify anthropogenic factors that may threaten ecosystems on a global scale.

SPECIFIC AIMS

Overall objective: to identify and analyse the architectural, biodiversity, and sedimentary factors contributing to the health of local aquatic ecosystems and to propose methods of bioremediation and architectural solutions to improve their health.

Specific Aim 1. Identify the number of plant species around the Campus Pond, Puffer's Pond, Pomery pond, Echo hill pond, . We will measure the biodiversity of these bodies of water by counting the number of different plant species around them via a systematic approach. We will use this measurement as the first parameter of ecosystem health.

Specific Aim 2. Take core samples of the soil around the previously listed bodies of water. We will analyze the core samples for sediment layer width in order to evaluate the level of runoff around the body of water as layer width is inversely proportional to the amount of runoff. We will use this measurement as the second parameter of water body health.

Specific Aim 3. Identify green architecture aimed at reducing runoff already present around the previously listed bodies of water. We will count the different structures that serve to reduce runoff around the bodies of water listed prior and identify their ability to reduce runoff. Though these data will not give direct information about the health of a small aquatic ecosystem, they will inform us about the priority level of green architecture in local construction projects.

Specific Aim 4. Identify and propose methods of bioremediation and architectural solutions to improve the health of local bodies of water. We have previously identified methods of bioremediation and architectural design such as planting more native flora, building new green roofs, and implementing bioretention/biofiltration materials as possible solutions to poor ecosystem health. Based on the evaluations developed in Aims 1, 2, and 3 we will propose the most salient solutions to improve local aquatic ecosystem health.

BACKGROUND

Small aquatic ecosystems and wetlands are critical contributors to both freshwater biodiversity and ecosystem services (Williams et al., 2004; Verdonschot et al., 2011). In fact, ponds contribute the most to freshwater biodiversity, housing more species, more unique species, and more rare species than other small aquatic ecosystems (Williams et al., 2004). Only recently has this evidence surfaced, and with it has come a growing need to explore anthropogenic effects on small aquatic ecosystems, in order to prevent future damage to these oases of biodiversity (Biggs et al. 2016). The University of Massachusetts Amherst collaborated with the MA Department of Environmental Protection (MassDEP), MA Office of Coast Zone Management (MassCZM), and the Environmental Protection Agency (EPA) on a project to assess and monitor local aquatic ecosystem integrity. The project was focused on forested wetlands, coastal salt marshes, and wadable fresh streams (McGarigal et al., 2013) and was designed to show that indices of biotic integrity (IBIs) could be developed directly from the empirical data (McGarigal et al., 2013). In this proposal we concentrated our research on ponds as their contribution to local biodiversity and anthropogenic stressors affecting their health have not yet been studied.

We chose plant diversity as our first measure of ecosystem health due to it being a strong component of the biotic diversity parameter found in the ecosystem integrity (EI) framework (Müller, 2005) used by the European branch of the international long-term ecological research (ILTER) network to determine ecosystem health (Haase et al., 2018). In addition,the Group on Earth Observations Biodiversity Observation Network (GEO BON) that uses essential biodiversity variables (EBVs) (Haase et al., 2018) to monitor changes in biodiversity on a global scale uses plant diversity as a key taxonomic parameter to measure community diversity (Schmeller et al., 2018). Moreover, measuring plant biodiversity can be done fairly simply via Simpson's biodiversity index (Simpson, 1949). Thus, since plant diversity is a point of intersection between the two major frameworks that aim to determine ecosystem health, it is likely to serve as a strong indicator of the health of the small aquatic ecosystems that are the focus of this study.

We chose soil samples as the second measure of ecosystem health as it is an indicator of the quality of the matter economy of an ecosystem (Müller, 2005), an important part of the abiotic factors considered in the EI framework (Haase et al., 2018). Soil cores of the soil around the ponds will provide a timeline of the rate of sedimentary deposition around local aquatic ecosystems. These timelines allow insight into soil input and output quantities as well as sediment quality around the ponds of interest, which are valuable parameters in determining ecosystem integrity (Haase et al., 2018). In addition, runoff has been linked to water eutrophication, the process by which excessive nutrients cause dense plant growth and the death of animal life due to lack of oxygen. Knowing the rate of runoff around an aquatic ecosystem will help us determine the risk of eutrophication in local small aquatic ecosystems (Zhao et al., 2013). Therefore, since soil cores are a good indicator of the matter economy and give a timeline of the sedimentary deposition around an aquatic ecosystem, they are another strong measure of ecosystem integrity.

Lastly, we chose to identify the green architecture already present around our focal bodies of water, such as green roofs, as a measure of the importance of green architecture in local construction projects. The hydrological environment of urban areas is markedly different from natural catchments, and is generally characterised by faster runoff process, shorter travel time for rainwater, and increased runoff volume (Sokac, 2019). Green roofs have served as the primary method employed to attempt to bring the hydrologic characteristics of urban environments closer to their natural counterparts (Freeborn, 2007). However, even though green roofs are often used to control runoff, their effectiveness has not been intensively researched (Berndtsson, 2010). Thus, we aim to document sustainable architecture structures around local small aquatic ecosystems: firstly, in order to have another indirect measurement of their integrity, and secondly, to determine whether local construction projects follow the trend of erecting green buildings largely apparent in the construction market, due to the growing importance of sustainability (Ahn & Pearce, 2007).

One way of addressing a potential lack in flora diversity around local small aquatic ecosystems has been to plant non-invasive, sustainable species as per the recommendations of the EBVs employed by GEO BON (Haase et al., 2018). In order to remedy deficiencies in the matter economy, ILTER's EI framework has suggested that sustainable ecosystem conditions could be reestablished by reducing excess runoff and subsequently abnormal levels of nutrients and other molecules like phosphate, nitrate, and ammonia (Haase et al., 2018). Green architecture has been used as a way of bringing an aquatic ecosystem closer to its natural hydrological conditions by creating structures that reduce anthropogenic impact on ecosystem hydrology

(Freeborn, 2007). Some of these sustainable architecture developments include: green roofs, green streets, permeable paving, and the use of bioretention/ biofiltration materials and spaces (Freeborn, 2007; Davis, 2009). As these methods have been previously applied to reduce anthropogenic effects on ecosystem integrity, they are good candidates for potential ways of ameliorating the health of local small aquatic ecosystems.

RESEARCH DESIGN

Identifying the number of plant species

Our aim is to count the number of different plant species found around a series of small, local aquatic ecosystems.

We intend to limit the radius within which we count the number of plant species to 2 metres into and 2 metres out of the pond or waterbed edge. Starting at an arbitrary point and marking it, the radius will be subdivided into 2 metre wide plots circling the entirety of the pond. This will be done in order to ensure accuracy of counting and to prevent backtracking. Within each of these plots, the number of plant species visible to the naked eye and the number of individuals of that species will be counted. Then, the counts for each species from each of the plots will be aggregated into a series of totals.

The data will be analysed by generating a Simpson biodiversity index for each area of study. This is a statistical tool described by the following equation:

$$D = 1 - \frac{\Sigma n(n-1)}{N(N-1)}$$

Where n is the number of individuals of each species and N is the total number of individuals of all species, and D represents the biodiversity index. The higher D is, the higher the biodiversity of a particular area.

We expect the results to show the level of biodiversity around small, local aquatic ecosystems in order to inform us about one aspect of the ecosystems' integrities. As there is no data on the biodiversity of these ecosystems, we will have no point of comparison for our data.

Obtaining soil core samples

Our aim is to acquire core samples of the soil around the aforementioned small aquatic ecosystems in order to generate a timeline of the rate of sedimentation around these ecosystems. By proxy, these samples will provide information about the rate of runoff around these aquatic ecosystems, giving us an idea of the quality of their matter economy.

We will subdivide the outer edge of the pond into 2 metre by 2 metre plots, within each of which we will take one core sample. We will analyze the samples by categorizing different layers of soil qualitatively based on average particle size.

We expect deviations in particle size to be the result of changes in runoff rate. We also expect that shifts from coarser layers to finer layers will denote an increase in runoff rate. We will use this measurement as an index of ecosystem integrity indicative of the quality of the matter economy around the pond.

Identifying green architecture

We will identify the green architecture structures aimed at reducing runoff around the small aquatic ecosystems we intend to study. This data will provide us with an index of the importance of sustainable architecture in local construction developments.

We will count the number of instances of green roofs, green streets, permeable paving, and bioretention/biofiltration areas within a 500 metre radius of the aquatic ecosystem.

We will analyze this data by correlating it to the biodiversity and matter economy data also to be collected. We will compare the number of sustainable architecture structures currently around local small aquatic ecosystems with the number present in the previous five years to see if there has been an increase in the priority of green architecture in local construction projects. We will identify sustainable architecture by using google earth to note the structures surrounding local pond ecosystems at different time periods.

Proposing methods of bioremediation and sustainable architecture solutions

Based on Simpson's biodiversity index, the evaluation of the soil core samples, and the green architecture comparative data, we will propose the most appropriate solutions to improve the health of local small aquatic ecosystems.

If the ecosystem shows a lack of biodiversity, we will suggest planting flora from native taxa in order to increase diversity around the ecosystem. If the ecosystem shows a weak matter economy possibly due to increased runoff we will advise planting flora from native taxa and increasing nearby runoff management structures in order to reduce runoff rate and decrease runoff volume. Similarly, if the data show there hasn't been an increase in the priority of green architecture in local construction projects, then we will recommend building more runoff management structures.

We expect that biodiversity around the Campus Pond will be the lowest of all for the bodies of water due to poor management and we expect to suggest planting more native flora around there relative to the pond size. It is also likely that the Campus

Pond has a weak matter economy, and we expect to suggest planting flora and building structures to remediate the effects of increased runoff. However, we also expect there to be the greatest density of sustainable architecture around the Campus Pond and thus do not anticipate that we will need to advise building new green structures. We expect there to be the highest biodiversity around the bodies of water furthest from urbanization, but they will likely have the fewest structures to manage runoff. As such, we expect to propose the construction of sustainable structures around these bodies of water, but it will likely not be necessary to increase their flora biodiversity.

SIGNIFICANCE

Ponds contribute more to biodiversity and ecosystem processes than any other small aquatic ecosystems. Preliminary research has shown that they house the most species, the most unique species, and the most rare species of all small aquatic ecosystem types. This information has only been identified recently, so there is a need for research into pond biodiversity and possible dangers to this ecosystem's integrity. Scientists have suggested from early research that these small aquatic ecosystems are highly valuable in terms of biodiversity and ecosystem use. Without further research into these ecosystems, we pose a risk of losing oases of species diversity whose full value has yet to be understood. This loss could prove a crippling blow to species diversity on a global scale. With this in mind, we aim to determine the health of local pond ecosystems that have yet to be studied in order to prevent such catastrophic loss.

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