Understanding Ecosystem Services Adoption by Resource Managers and Research Ecologists

by

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Abstract

Ecosystem Services (ES), or the benefits people obtain from ecosystems, have gained much prominence in natural resource management over the past two decades as a relatively comprehensive approach to decision-making and policy design. However, to date we know little about whether and how natural resource practitioners, from ecologists to resource managers, have adopted the ES paradigm into their respective work. Here, I address this knowledge gap by asking resource managers and research ecologists about whether and how they integrate ES into their respective work.

I conducted a survey of federal, state, provincial and tribal resource managers in the Great Lakes region to gather information on their perception and use of ES as well as the relevance of specific services to their work. Although results indicate that fewer than 31% of the managers said they currently consider economic values of ES, 79% of managers said they would use economic information on ES if they had access to it. Additionally, managers reported that ES-related information was generally inadequate for their resource management needs. I also assessed managers by dividing them into identifiable groups (e.g. managers working in different types of government agencies or administrative levels) in order to evaluate differential ES integration. Overall, results indicate a desire among managers to transition from considering ES concepts to quantifying economic metrics, indicating a need for practical and accessible valuation techniques.

I also evaluated research ecologists' integration of the ES paradigm because they play an important role by contributing requisite ecological knowledge for ES models. I surveyed and interviewed ecologists from a scientific agency asking questions similar to those asked of managers. I then compared the two population's responses. Ecologists and managers almost unanimously agreed that it was appropriate to consider ES in resource management. Their answers also converged regarding the specific kinds of services most relevant to their work. However, ecologists appeared to overestimate the adequacy of ES-related information they provide, while managers reported the information was inadequate for their needs. This divergence may reflect a need to hire economists in this system who can aid in translating ecological models into estimates of human well-being.

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Chapter 1

Resource Management in the Great Lakes Region: Integration of Ecosystem Services into Decision-Making

Abstract

Ecosystem services (ES) have gained much momentum among natural resource managers over the past two decades. To date, however, it is uncertain how and to what extent knowledge of ES actually contributes to resource management and decision-making. I conducted a survey of federal, state, provincial and tribal resource managers in the Great Lakes region to gather information on the background of resource managers, their familiarity with ES, and the relevance of ES to their work. Results indicate several themes: 1) Although 74% of resource managers are at least moderately familiar with the concept of ES, only 36% are at least moderately familiar with methods for quantifying ES; 2) Only 30% of resource managers currently consider economic values of ES, but 79% said they would use economic information on ES if they had access to it; and 3) ES-related information was generally considered inadequate for managers' needs. Additionally, in order to evaluate similarities and differences in ES integration, I assessed managers by dividing them into self-identified groups (e.g. managers working in different types of government agencies or administrative levels). As one example, I found that managers representing tribal agencies considered ES to be more relevant to their work than managers representing other types of agencies. Analysis shows this is likely due to the high regard tribal managers hold for services relating to cultural values. Overall, my results indicate a desire among managers to transition from considering ES concepts to quantifying economic metrics in their decision-making, suggesting a need for practical and accessible valuation techniques.

Introduction

Ecologists and natural resource managers over the past two decades have become increasingly concerned with understanding ecosystem services (ES), the benefits people obtain from ecosystems (MA, 2005). Much has been written about ES, from defining and categorizing services (Lamarque et al., 2011; Boyd and Banzhaf, 2007; MA, 2005) to quantifying ES provisioning spatially, temporally, and economically (Kareiva et al., 2011). For example, Costanza et al. (1997) estimated that the value of all services provided by the world's ecosystems was $33 trillion per year.

This estimate has since been updated to nearly $125 trillion per year with a loss rate of $4.3-20.5 trillion per year due to land use change (Costanza et al., 2014). Yet most of this value falls outside of the global economic market, highlighting the importance of studying these services and their economic values for inclusion in analyses and decision-making.

To date, however, it is uncertain how and to what extent knowledge of ES actually contributes to resource management and policy design. Other studies on similar subject matter exist, but they focus on specific systems (Australian coastal zones, Marre et al., 2015; forests in developing nations, Ferraro et al., 2012) or populations (EPA wetland regulators; Arnold, 2013) that differ from this study. To further contribute to understanding the integration of ES in decision-making, I focus here on the Laurentian Great Lakes basin.

The Great Lakes basin is defined by watershed topography, regional effects of large lakes on climate and ecology, and human connectivity through transportation and resource extraction since pre-colonial times. One example of how ES are being used in Great Lakes ecosystem management is the biodiversity conservation strategy for Lake Erie developed by The Nature Conservancy and its partners (Pearsall et al., 2012). One chapter of their report was devoted to ES. In a survey, they asked respondents, primarily resource managers, to "rate the importance of ecosystem services to the people that benefit from Lake Erie and its coastal areas." Results signified that respondents believe services like the provision of habitat, recreation and tourism, and fresh water are the most important ES in the Lake Erie area. It is still unclear from this study, however, whether this information is being considered in practical biodiversity management for Lake Erie.

My goal, then, is to study whether knowledge of ES is actually being used in the management of natural resources in the Great Lakes region. The overarching question I address is: Do resource managers consider ES in decision-making and policy design? And if so, how? A follow up question, when asking about actual use, is: What kinds of information do managers need regarding ES in order to consider comprehensively the benefits derived from ecosystems? This project answers these questions by conducting a survey of resource managers in the Great Lakes region about their management jurisdictions, priorities, and use of information about ES in policy implementation. Through this, I develop a broader understanding of how managers currently integrate ES concepts and metrics into policy-design and decision-making, as well as elucidate needed changes in information provision to further integrate ES information. Ultimately, I hope this study contributes to more responsible and comprehensive management of our finite natural resources by protecting ecological processes while meeting human needs.

The ecosystem services paradigm has changed throughout the years. Initially, much ES work focused on conceptually identifying and defining the myriad ways people benefit from ecosystems (Chaudray et al., 2015). A well known example of conceptual-level consideration of ES is the Millennium Ecosystem Assessment which sought to assess the status of ecosystems as well as to define and categorize the services provided to humanity by those ecosystems (MA, 2005; West, 2015). More recently, however, the ES paradigm has transitioned into quantifying ES at a valuation level in which scholars assess the economic utility of a service(s) to users, often as a dollar value (Chaudray et al., 2015). For example, Barbier et al. (2008) examined ES at a valuation level; they assessed nonlinear wave attenuation and the tradeoffs between coastal protection and conversion to shrimp farming. By recognizing the nonlinear ecological functions, they determined that the greatest return resulted when a small area of coastal habitat was converted to aquaculture and the remainder of the ecosystem was preserved (Barbier et al., 2008). Thus, the ES paradigm has evolved, and in this study, I contrast how managers in the Great Lakes region are considering ES at the conceptual level and at the valuation level.

The paradigm of ecosystem services has been a largely academic discussion so far. It is unclear whether and how ES concepts and metrics are being integrated into resource management. Many authors have discussed strategies for implementing ES into decision-making (NRC, 2005; Daily et al., 2011; McKenzie et al., 2011; Borger et al., 2014; Sutton-Grier et al., 2014), but that still leaves the question: How are managers considering ES in practice for natural resource management?

Methods

Selecting Resource Managers

I defined resource managers as those who directly contribute to management or policy decisions regarding natural resources in the Great Lakes basin. The managers for this study were selected from 31 resource management agencies in the Great Lakes region representing federal, state, provincial, and tribal agencies. These agencies spanned the eight states and one province that share shoreline on one of the Laurentian Great Lakes.

I anticipated a response rate for the surveys of about 20%, and therefore calculated that at least 50 contacts were needed from each agency to allow enough power for statistical analysis. To establish a list of potential managers, I accessed all 31 of the agencies' websites and collected names and work email addresses of personnel (all publicly available information). If no individual resource manager contacts were provided online, I requested contact information from the agency, or contacted

previously known personnel within those agencies. When possible, only managers located within the Great Lakes Basin were considered. For example, only resource managers in Northern Ohio were included, whereas those located in Middle and Southern Ohio were excluded because they were outside of the basin.

I accessed the agencies' websites and found their personnel directories. For agencies that had fewer than 50 contacts, I included every individual in my sample pool. For larger agencies, I visually estimated the number of individuals in the personnel directory. Then I determined the percentage of individuals needed to obtain at least 50 contacts (e.g. 25% for an agency with about 200 individuals) and randomly selected that given proportion. In some cases, however, my estimate of the number of personnel was low, resulting in more than 50 contacts for some agencies, especially those with websites that contained easily accessible personnel directories. This led to over-representation of some agencies in the initial sample pool.

To minimize this bias, I conducted a stratified random sample within my initial sample pool. For the over-represented agencies, I randomly selected 50 resource managers for the final sample pool. This stratified random sample resulted in a pool of 1,041 resource managers. In this final sample pool, 16 of the 31 agencies were represented by exactly 50 resource managers whereas the remaining 15 agencies had fewer than 50 managers total. A small number of managers (n=2) were incidentally included in the sample pool even though their jurisdictions were outside of, but adjacent to, the Great Lakes basin. I included their responses in the results because they dealt with Great Lakes issues, and there are strong ecological and human connections between these jurisdictions.

In order to further dissect the factors influencing how resource managers integrate ES into decision-making, I asked them about different aspects of their jobs. Some of these were mutually exclusive categories, such as the manager's administrative level or the type of governmental organization their agency represents. Some other categorizations were not mutually exclusive because managers could select all options that applied to them, and these included their primary focus areas (e.g. biodiversity, fisheries, water quantity, etc.), the states or province their jurisdiction covers, the systems they work within (the Great Lakes and connecting waterways), and the ecosystems they study (e.g. open water, forests, dunes, etc.). These categories allowed us to group the managers and to evaluate for correlations between these groups and certain levels of ES integration.

Data Collection and Analysis

I used a web-based survey to collect responses from the final sample pool of 1,041 resource managers. The survey was designed using Qualtrics Research Suite (qualtrics.com, 2015) and distributed via email. Respondents were informed that the survey was voluntary and that all data would be kept anonymous by aggregating and de-identifying the information. Survey questions were designed to gather information on the background of managers, their jurisdictions and priorities, and the relevance of ES to their work (copies of survey instruments are in the Appendix). Most questions were closed-ended, while a few allowed the managers to respond with open-ended answers. I received 245/1041 responses from managers, a response rate of 23.5%. I believe this is a conservative estimate of my target audience representation because the sampling methods almost certainly led to some percentage of non-resource managers receiving an invitation to participate. Of these 245 respondents, 46.1% agreed to do the survey, self-identified themselves as a resource manager in the Great Lakes basin, and completed the survey, leaving a final sample size of 113 for analysis.

Data management and summary statistics were performed within Qualtrics Research Suite and Microsoft Office Excel (https://products.office.com/en-us/excel). For inferential statistical analysis, I used the statistical computing software R (R.Computer Software). Given the nature of the data, I used non-parametric statistical techniques. I assessed the significance of the association between categorical variables using Fisher's Exact Test of Independence because it is a robust analysis of contingency tables when small values are expected. I also used the Kruskal-Wallis test, a non-parametric parallel to the ANOVA, to compare the pattern of a continuous variable (e.g., relevance of ES) across the mutually exclusive categories of independent variables (e.g. different types of government like federal, state, provincial, and tribal). Some categorical independent variables were non-mutually exclusive; for example, some managers' jurisdictions covered more than one state. In these cases, I analyzed the relationship between these independent variables and continuous dependent variables using a linear model with the non-mutually exclusive categorical answers specified by a series of binary variables.

Results

Here I review the responses to survey questions using simple summary statistics and explain how the responses to each question provide insight into the current integration of ecosystem services into resource management in the Great Lakes region. Next, I specify categories of managers and analyze how their responses differed.

Summary of Responses to Questions

Asked to Consider Ecosystem Services? Managers were questioned on whether they were asked to consider ES in their management decisions. Just over half of the managers (57%) are asked to consider ES in their management decisions. When questioned about who expected them to use ES, many managers responded that the public, their peers (fellow resource managers, often superiors), and legislators were all asking them to consider ES when making resource management decisions.

Do you Consider Ecosystem Services? I asked managers whether they consider ecosystem services at a conceptual level (considering the types of ES provided but not actually quantifying them) as they make decisions and design policies. Eighty six percent (86%; 97/113) of respondents reported that, yes, they do consider ES conceptually in their work (Fig 1). I want to juxtapose that with the next question in which I asked managers whether they consider ES at an economic valuation level (assigning a specific dollar value to the service). Only 30% (34/113) of managers responded that, yes, they do consider ES valuation in their work (Fig 1).

This dynamic, in which most managers consider ES conceptually but less than half consider their valuation, indicates that currently ES are likely integrated into resource management conceptually, where desired services are identified—but in most cases they are not quantified economically. These responses associated well with questions regarding managers' familiarity with ES—most managers (74%; 84/113) were at least moderately familiar with the concept of ES whereas only 36% (41/113) were at least moderately familiar with ES valuation techniques. Perhaps fewer of them are considering valuation because most are not very familiar with the metrics and methods. Additionally, consideration of ES at the valuation level may be limited by availability of adequate economic information.

Would You Use Economic Information? Managers were also asked whether they would use economic valuation information regarding ES if they had access to it. Seventy nine percent (79%; 89/113) of resource managers said they would use such information, whereas 21% (24/113) said they would not. This indicates that, in general, managers likely want to consider ES valuation information as they make management decisions, but they may not be doing so currently (only 30% reportedly consider ES valuation) because they lack access to quantified economic information regarding services.

Is it Appropriate to Consider Ecosystem Services? In this survey, 96% (109/113) of managers reported that they think it is appropriate to consider ES when managing Great Lakes resources. This leaves little doubt that the ES paradigm may be one appropriate tool for managers to utilize.

Relevance of Ecosystem Services. In one series of questions, I gave the resource managers a list of 32 ES and asked them to rate the relevance of each service (ranging from 0=Strongly Unrelated to 4=Strongly Related) to their current work. This list of ES was adapted from the global list compiled by the Millennium Ecosystem Assessment (2005) and mirrored the list used in the survey of Lake Erie managers mentioned previously (Pearsall et al., 2012), albeit with a slightly different question.

I ranked the 32 services based on managers' reported relevance. The three ES that managers reported as being most relevant to their work were provision of habitat (median=3.49, mean=3.27, sd=0.90), recreation and tourism (median=3.42, mean=3.16, sd=0.92), and fresh water (median=3.10, mean=2.95, sd=1.17)—the same top three services as those reported in Pearsall et al. (2012), thereby indicating a high degree of consistency between managers in the Great Lakes region (Table 1). The fourth most relevant ES in this study was biological control (median=3.08, mean=2.85, sd=1.23), although it did not rank so highly on the survey by Pearsall et al. (2012). These top four ES represent the four main categories of services identified by the Millennium Ecosystem Assessment: supporting, cultural, provisioning, and regulating services. This may reflect that resource managers have diversified their interests in order to address the wide array of stakeholders in the Great Lakes basin. To illustrate the multitude of user groups managers are considering in regards to ES, I offer three examples. Many managers discussed their use of ES concepts as informing their management of fisheries for recreational purposes. Another manager described how his/her work in an urban community always considered air quality and stormwater management in decision-making. Lastly, a couple tribal managers noted their protection of treaty rights regarding natural resources and the connection between ecosystem integrity and tribal community integrity.

I also assessed managers' responses when asked about the relevance of the four general categories of ES assigned by the Millennium Ecosystem Assessment: supporting (services needed for the production of all other ES), provisioning (products obtained from ecosystems), regulating (benefits obtained from the regulation of ecosystems), and cultural services (non-material benefits obtained from ecosystems). Respondents rated each category on a scale from 0 (Strongly Unrelated) to 4 (Strongly Related). According to median responses, the four categories ranked as 1) provisioning (median=3.05, mean=2.90, sd=1.04), 2) regulating (median=3.04, mean=2.99, sd=0.83), 3) cultural

(median=3.02, mean=2.87, sd=0.91), and 4) supporting services (median=3.00, mean=2.87, sd=0.84). All four of the categories had nearly identical medians and means which leads us to believe that managers consider each of these categories to be relevant to their work. Once again, resource managers appear to be considering most of the myriad interests in the Great Lakes basin.

More generally, I aggregated each manager's response to the relevance of all four categories of ES in order to get an index of how relevant ES are overall to resource management. Based on this aggregation, I found that the median response for the relevance of ES in general (on the same continuous scale, 0=Strongly Unrelated to 4=Strongly Related) was 2.99 (mean=2.91, sd=0.60, max=4.00, min=0.93), indicating that managers consider ES to be fairly highly related to their work (Fig 2). A histogram of this distribution showed a skew in which most managers reported ES as being quite relevant to their work while a few managers in the tail of the histogram indicated that ES were rather irrelevant for that small group.

Adequacy of Ecosystem Services Information. I compare the relevance of ES to an additional question in which I asked managers to rate the adequacy of information provided to them on the same continuous scale (0=Greatly Inadequate to 4=More Than Adequate). Based on the median response of 1.60 (mean=1.64, sd=0.84), managers report that ES-related information was generally inadequate for their resource management needs (Fig 2).

Analysis of Manager Categories

In addition to assessing ecosystem services integration by managers as a whole, I broke it down further by analyzing how specific categories of managers differed in their ES implementation. I add a precautionary warning that small sample sizes in some categories and the binary nature of many questions may have skewed results (e.g. higher likelihood of Type I errors). Therefore, my representation of some of these managers may be misleading in some cases. I note below instances where low sample size may influence results.

Comparing Government Types. I looked at different types of government—federal, state, provincial, and tribal—and their reported relevance of ES to assess whether any of the managers differed in terms of how they integrated ES into decision-making and policy design. I found an unexpected and significant difference in responses across managers by government type. Tribal nations (all within Michigan; n=12) reported that ES are more highly relevant to their work (median=3.38, mean=3.36, sd=0.43) than did state/provincial (median=2.79, mean=2.81, sd=0.61) and federal agencies (median=3.04, mean=3.00, sd=0.50; Kruskal-Wallis: χ^2=10.255, p=0.0059). The

tribal managers also had much lower variance in their responses. Digging deeper, I discovered that most of this difference was due to judgments about how relevant cultural services were to their respective work—tribal nations reported that cultural services were very relevant (median=4.00, mean=3.76, sd=0.35) while managers in state/provincial (median=3.00, mean=2.72, sd=0.92) and federal agencies (median=3.03, mean=2.86, sd=0.80) reported less relevance (Kruskal-Wallis: χ^2=18.217, p<0.001; Fig 3). Tribal managers indicated that cultural services such as spiritual and religious values, knowledge systems, cultural diversity, and cultural heritage values were especially relevant to the work they perform.

Next I compared state and provincial agencies (n=14 to 51) to see whether they consider ES differently. No striking patterns emerged—it appears that managers in all eight of the Great Lakes states and Ontario are comparable in terms of how they are implementing ES concepts and metrics into their resource management strategies. The one exception to this was that managers from Wisconsin reported a slightly higher-than-average ES relevancy (WI mean=3.19, sd=0.49; all other states/provinces mean=3.03, sd=0.51). Although this is statistically significant, this may not be a meaningful result since Wisconsin did not stand out in other analyses.

Administrative Level. I analyzed resource managers' responses based on three self-reported levels of administrative duties: supervise supervisors (top-level supervisors; n=19), supervise employees (n=49), and not a supervisor (boots-on-the-ground resource managers; n=45). I assessed how these three groups differed in how they consider ES in their work. Figure 4 shows that all those who supervise supervisors report that they consider ES conceptually which is significantly more than those who do not supervise anyone (71%=32/45; Fishers Exact Test of Independence p<0.01). This pattern did not continue when managers were assessed on whether they consider ES valuation, and one possible reason may be that many of the top-level supervisors were not at all familiar with ES valuation methods (42%=8/19 of those who supervise supervisors were Not At All Familiar compared to 17%=8/49 of those who supervise employees and 16%=7/45 of those who do not supervise), thus making it difficult for them to consider ES valuation in their work.

The three administrative levels were further analyzed based on the reported relevance of ES to their current work. They showed an increasing trend of ES relevance and decreasing variance as the supervisory level increased (Fig 5). Once again, those who supervise supervisors rated ES as significantly more relevant (median=3.31, mean=3.30, sd=0.46) than those who don't supervise anyone (median=2.75, mean=2.68, sd=0.62; Kruskal-Wallis Test: χ^2=14.076, p<0.001).

One reason that these relationships within the management structures might exist is the difference in duties between the administrative levels. The top-level supervisors, who oversee many different projects, may be more attuned to the different types of ES at play in the system than the boots-on-the-ground manager who focuses on only one type of service such as fishery production. This may be the mechanism leading to top-level supervisors saying they consider ES conceptually more than others and reporting that ES are more relevant to their work. Conversely, it could also be that boots-on-the-ground managers, who are generally more familiar with ES valuation, are aware of the significant data requirements and unavoidable uncertainties in valuation methods, and thus consider ES less in their regular work.

Great Lakes Managers. I hypothesized that managers working in the Great Lakes proper (n=91) would integrate ES into their work differently than managers working in other systems within the basin (n=18) because there are so many users of the lakes for a variety of beneficial uses. I did in fact find that Great Lakes managers were significantly more familiar with ES, both conceptually (Kruskal-Wallis: χ^2=4.301, p=0.038) and in terms of economic quantification (Kruskal-Wallis: χ^2=4.954, p=0.026), but that is where differences ended. Great Lakes managers did not actually consider ES more frequently in their work, nor did they report ES as more relevant than non-Great Lakes managers.

Do Ecosystems Matter? The ecosystem in which managers work had varying relationships with how the resource managers integrated ES into their work (n=20 to 80). While managers working in some ecosystems, such as urban and agricultural areas, were more familiar than others with ES, managers in other ecosystems, such as open water and islands actually considered ES in their current work more frequently. Two ecosystems which did stand out were wetlands and nearshore zones. Managers working in wetlands were more familiar with ES, both conceptually and economically, than managers not working in wetlands; they also reported that ES-related information was less adequate than managers working in other ecosystems. Managers working in nearshore zones were also quite familiar with ES concepts and valuation, and, in addition, they reported being asked to consider ES more frequently than most other managers. Managers in almost all ecosystems in the Great Lakes region stood out in one way or another for how they are implementing ES thinking in their work, which may reflect the fact that people benefit from all ecosystems and their associated services on some level, and resource managers are trying to capture those benefits in their resource management strategies.

Education and Tenure. I evaluated ES integration by the managers' level of education (bachelor's, master's, or PhD) and length of tenure at their current agency and found that responses were not differentially characterized. Specifically, managers at all levels of education were equally familiar with ES concepts (Kruskal-Wallis: χ^2=2.523, p=0.283) and methods for quantifying ES (Kruskal-Wallis: χ^2=1.834, p=0.0.400). Moreover, I found no significant trend between education and the reported relevance of ES (Kruskal-Wallis: χ^2=4.768, p=0.0922). Additionally, increasing tenure did not correlate with reported ES relevance (Linear Model: estimate=0.0026, F-statistic=0.237, adjusted R^2=-0.0072, p=0.627). Thus, resource managers at all levels of experience appear to consider ES and report their relevance similarly.

Discussion

Reviewing managers' responses and assessing specific groups has allowed me to understand how managers are considering ecosystem services in practical resource management. The data I have presented thus far have been congruent with the findings of Marre et al. (2015) that although economic valuation of ES is used, its impact on policy is weak. In addition to closed-ended questions, I also asked open-ended questions on which I report in this section. Managers' open-ended responses led to interesting perspectives and provides context that deepens my understanding of their responses to closed-ended questions.

I recognize a few biases and assumptions in this study that will impact the interpretation of my results. First, I have surveyed only resource managers within the Great Lakes region, potentially limiting my ability to extrapolate to resource managers elsewhere. Similarly, my managers represented only individuals working in state, provincial, tribal, and federal government agencies, thus excluding individuals working at the local level or within non-governmental organizations. Additionally, my survey email used the phrase 'ecosystem services' in the subject line, and this could have biased responses towards individuals that are aware of the topic. Despite that, I believe that the diversity of individuals I received feedback from (25+ agencies) and their significant interactions with managers outside of the basin will result in their responses being representative of managers in general. Other studies (Pearsall et al., 2012; Ferraro et al., 2012; Arnold, 2013; Marre et al., 2015) also received similar responses on overlapping questions which lends further credibility to my results.

Generally speaking, although only about half of managers are being asked to consider ES in their work, they do consider them to be relevant to their resource management practices. Resource managers as a whole reported that provisioning of habitat, recreation and tourism, and fresh water are

the most relevant services. In addition, tribal managers specifically highlighted the relevance of cultural services such as knowledge systems.

Because of the relevance of ES, most managers reported considering ES at a conceptual level in their work by considering the types of services provided. When allowed to comment on how they consider these services, many of them highlighted how they use the ES paradigm to justify that their work is meaningful and beneficial to the public. Other managers stated that they use the comprehensive ES concepts to help them consider the whole ecosystem and to evaluate tradeoffs among potentially conflicting policies.

Despite managers' relatively high conceptual integration of ES, only a handful of managers consider the economic metrics of these services. This corroborates findings by Ferraro et al. (2012), Arnold (2013), and Marre et al. (2015) that rigorous valuation of ES is rare in other contexts as well. Those managers who do consider ES valuation cite that they quantify the value of particular services in order to (1) inform management policies and (2) conduct cost-benefit analyses. Many resource managers also said they were interested in the total economic impact certain services have on the region's economy (e.g. contribution of commercial and recreational fishing to Michigan's economy).

Although few managers purportedly calculate ES value, most of them report that they would use economic information regarding ES if they had access to the information, a finding supported by the work of Marre et al. (2015). This discrepancy suggests that one obstacle to managers integrating valuation is a lack of information (also found by Arnold, 2013), or perhaps the quality of information regarding the economic value of these services is not adequate for their resource management needs. When asked in open-ended questions about their greatest data deficiency, three types of responses predominated. First, many managers pointed out a lack of data on the value of specific services (or their loss), such as "what an intact floodplain is worth," "economic value of restoration," and "credible valuation of locally relevant ecosystem services." Along with that, managers also reported a desire for methods and tools to quantify the value of ES for themselves (a sentiment also reported by Arnold, 2013). Finally, many managers reported that they knew ES-related data existed, but they did not know how to get access to information relevant to their work. I believe this indicates a need for practical and accessible valuation techniques that can be catered to the focal services and scales of managers and other practitioners.

I anticipated one obstacle to ES integration might be that resource managers did not feel the ES paradigm was appropriate for managing natural resources, but this evidently is not the case because nearly all managers responded that ES concepts and metrics were a useful tool in managing

resources in the Great Lakes. I then asked the managers to comment on what they thought were benefits and drawbacks to considering ES in managing Great Lakes resources. For benefits, they pointed out that the ES paradigm was comprehensive and highlighted the interconnectedness of people and the environment. They also reported that ES language provided a common ground to communicate with developers, legislators, and even the public who function more regularly with dollar values. Some managers also thought that integrating ES into their arguments for natural areas could help people recognize the value of and aid in getting protection for natural spaces.

I also asked managers to articulate drawbacks to considering ES in resource management, and, interestingly, one of the most common responses was "none," suggesting an enthusiasm for the ES paradigm and that integrating ES into resource management may have few downsides. Other managers, however, highlighted concerns that aligned closely with those found in the literature (e.g. Norgaard et al., 1998; Boyd, 2011; Barnaud and Anton, 2014). Some respondents thought the ES paradigm was too anthropocentric and focused too much on dollar values, thus undermining the moral arguments for protecting ecosystems and practicing sustainability. These responses mirrored the controversy expressed by Norgaard et al. (1998); they are concerned that ecosystem structures or functions that form the foundation of life, such as water, should not be assigned a dollar value at all. Many managers also noted in open-ended responses that methods in ES valuation are fraught with uncertainty—ES concepts are complicated and not always well understood by policy makers who are making decisions regarding complex systems. These concerns reiterated the conclusion of Barnaud and Anton (2014) that there are still significant scientific uncertainties concerning causal relationships of ES production and that this has implications for policy development. Finally, several managers commented that, although the ES paradigm was powerful, there were limitations to its integration due to constraints on time, resources, and personnel availability. These controversies, uncertainties, and limitations associated with the ES approach have likely resulted in the slow and inconsistent implementation of ES in resource conservation.

Conclusion: Moving Forward

Because many managers perceived no drawbacks to considering ecosystem services in managing resources, I believe that finding ways to facilitate their integration into decision-making may be a worthwhile effort. Additionally, since I found that managers generally support the consideration of ES values but are limited by access to information, I conclude that managers need *both* training on, and access to, ES valuation models. Much academic literature is already devoted to how ES can be implemented in resource management and to developing tools for making this process

relatively straightforward for managers (Ash et al., 2010; Daily et al., 2011; Kareiva et al., 2011; McKenzie et al., 2011; Borger et al., 2014;Sutton-Grier et al., 2014). I highlight a few options for making these models available to resource management practitioners. In addition, I believe this will be of interest to a number of non-governmental organizations that are interested in ecosystems and human well-being.

Because managers are largely unfamiliar with ES valuation techniques, training would be beneficial, perhaps in the form of conference workshops or online classes. The Ecosystem Services Partnership (www.fsd.nl/esp) has a repository of online educational and training opportunities, many of which are free. These opportunities range from connecting ecosystems and businesses to sustainable land use management, from ecosystem based management tools for managers to a handbook explaining ES concepts to primary school students. Additionally The Economics of Ecosystems and Biodiversity (TEEB; teebweb.org) is a well-known international initiative with the goal of making nature's value visible. The TEEB website has substantial information regarding ES and provides many resources as well. These would be easily accessible to most managers, provided they had the time available for that learning.

Three specific resources may be helpful for evaluating ES and their associated values. Following the Millennium Ecosystem Assessment, Ash et al. (2010) published *Ecosystems and Well-Being: A Manual for Assessment Practitioners*. This manual was written as a guide for practitioners undertaking ecosystem assessments in which connections are made between environmental issues and people at scales relevant to decision-makers. The Natural Capital Project, based out of Stanford University, published *Natural Capital: Theory and Mapping of Ecosystem Services* (Kareiva et al., 2011) which introduces the InVEST model (Integrated Valuation of Ecosystem Services and Trade-Offs). The InVEST model is designed for resource managers who want to integrate ES valuation into their management practices, and it is made available at their website (naturalcapitalproject.org). Lastly, *A Field Guide to Economics for Conservationists* (Fisher et al., 2014) is a readable text that describes central economic principles and tools that are relevant to conservationists, even those with no background in economics. Again, this would require substantial time investment.

This study examines how the ES framework is currently being considered and implemented by resource managers in the Great Lakes basin. I discovered that although many managers expressed a desire to integrate ES valuation into management practices, they do not know how to use or access the information and tools that exist. Several resources are available for resource managers and others

to gain training and tools on ES valuation. These may assist practitioners as they perform their jobs of managing our limited natural resources.

Table 1: Top ranked most relevant ecosystem services (out of 32) to resource managers. Median score represents the score assigned by managers from 0=Strongly Unrelated to 4=Strongly Related. Category of Service is the primary category of the service based on the Millennium Ecosystem Assessment (MA, 2005).

Rank	*Ecosystem Service*	*Median Score*	*Category of Service*	*Examples*
1	Provision of Habitat	3.49	Supporting	Biodiversity support, habitat diversity
2	Recreation & Tourism	3.42	Cultural	Lake recreation, wild game, song birds, other wildlife
3	Fresh Water	3.10	Provisioning	Water supply
4	Biological Control	3.08	Regulating	Pest control, invasives
5	Primary Production	3.04	Supporting	Energy capture, food chain support, energy flow for fish, benthic food chain
6	Educational Values	3.02	Cultural	
7	Food	3.02	Provisioning	Wild game
8	Erosion Control	3.00	Regulating	
9	Water Regulation	3.00	Regulating	Flood mitigation
10	Aesthetic Values	3.00	Cultural	Aesthetics
11	Knowledge Systems	3.00	Cultural	Cultural, economic, and scientific knowledge

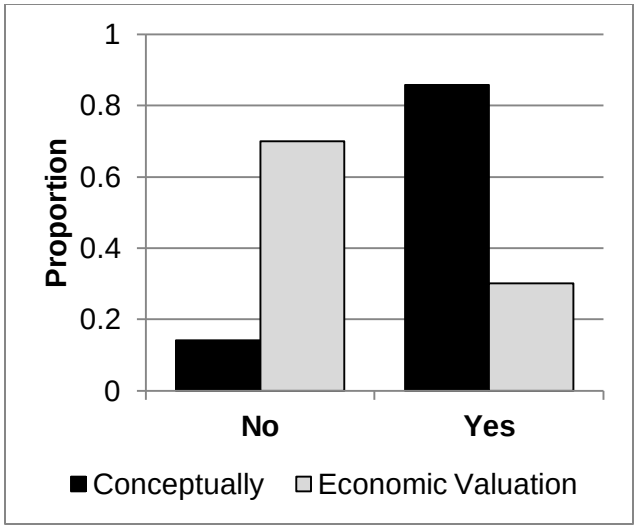

Figure 1: Ecosystem Services Consideration. Asked whether they consider ES conceptually, 86% said yes whereas 14% said no. Asked whether they consider ES economic valuation, 30% said yes whereas 70% said no.

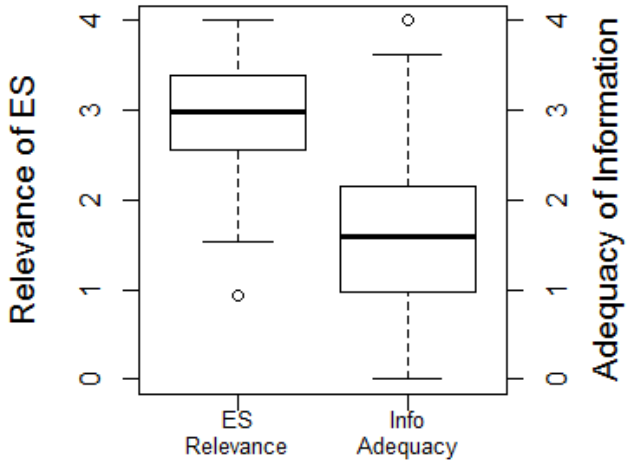

Figure 2: Relevance of Ecosystem Services and Adequacy of Ecosystem Services Information. Asked to rate the relevance of ES to their work on a scale from strongly unrelated (0) to strongly related (4), managers reported a median relevance of 2.99. Asked to rate the adequacy of ES-related information from greatly inadequate (0) to more than adequate (4), managers reported a median adequacy of 1.60. In the box and whisker plot, the bold line represents the median, the box represents the interquartile range (the middle 50% of data points), the whiskers represent the datum that is no more than 1.5 times the interquartile range, and the dots represent outliers (Tukey, 1997).

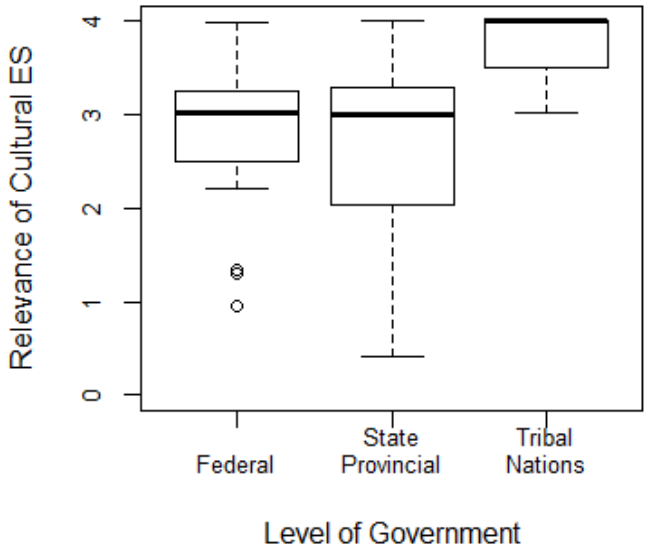

Figure 3: Type of Government Agency and Relevance of Cultural Ecosystem Services. Types of government agencies differed in how they rate the relevance of ES, particularly cultural services. Tribal nations reported higher relevance (median=4.00, mean=3.76, sd=0.35) than state/provincial (median=3.00, mean=2.72, sd=0.92) and federal agencies (median=3.03, mean=2.86, sd=0.80). Kruskal-Wallis Test: χ^2=18.217, p<0.001. Relevance of Cultural ES ranges from Strongly Unrelated (0) to Strongly Related (4).

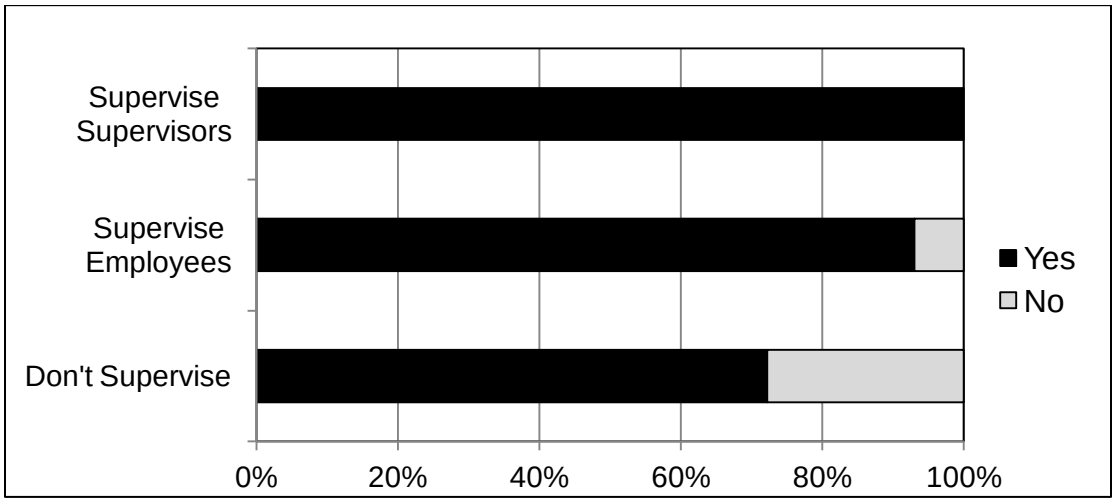

Figure 4: Administrative Level and Consideration of Ecosystem Services Conceptually. Managers with different administrative duties differed in how they consider ES conceptually—100% of those who supervise supervisors consider ES conceptually compared to only 72% of those who don't supervise anyone (Fishers Exact Test of Independence p<0.01).

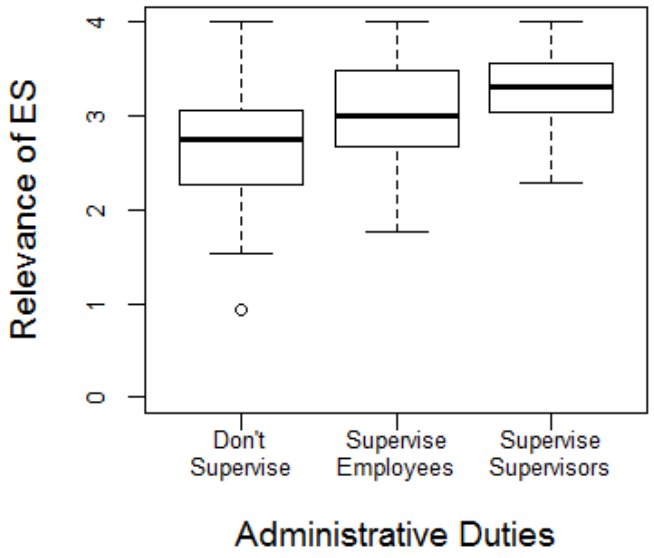

Figure 5: Administrative Level and Relevance of Ecosystem Services. Managers with different administrative duties differed in how they rate the relevance of ES. Don't Supervise median=2.75, mean=2.68, sd=0.62. Supervise Employees mean=3.00, mean=2.96, sd=0.55. Supervise Supervisors median=3.31, mean=3.30, sd=0.46. Kruskal-Wallis Test χ^2=14.08, p<0.01. Relevance of ES ranges from 0 (Strongly Unrelated) to 4 (Strongly Related).

Chapter 2

Research Ecologists and the Adoption of the Ecosystem Services Paradigm

Abstract

The ecosystem services (ES) paradigm has gained much traction as a resource management framework due to its comprehensive approach to resource management and ability to provide quantitative tools to improve decision-making. Research ecologists are in a unique position to contribute to the ES paradigm by providing requisite ecological knowledge. However, little work has been done to evaluate whether and how ecologists have adopted the ES paradigm into their work and how this aligns with resource management information needs. To address this, I surveyed and interviewed research ecologists from an agency within the Great Lakes region and compared their responses to those of resource managers. In this study, ecologists and managers almost unanimously agreed that ES were appropriate to consider in resource management. I also found that ES such as food, primary production, provision of habitat, and biological control are the services that are most relevant to ecologists' research, and this aligned nicely with the priority rankings for resource managers as well. However, a disconnect arose in terms of perceived adequacy of ES-related information: research ecologists deemed the information they provide regarding ES as adequate for management needs whereas managers disagreed. I believe this data deficiency could represent a gap in scientific coverage by ecologists, but it is more likely that it reflects a lack of economists in this natural resource management system to translate ecological knowledge of ES providers into models of human well-being.

Introduction

Ecosystem services (ES), or the benefits people obtain from ecosystems (MA, 2005), is a relatively young resource management paradigm. In this age of technology, it can be easy to forget that society depends on ecosystems for its very livelihood. Given growing global populations and rising consumption in many developing nations, ecosystems and their natural resources are being stressed, beyond capacity in many cases. The ES paradigm is in a unique position to change this narrative. This framework takes a comprehensive approach to natural resource management and provides quantitative tools to improve decision-making so that benefits drawn from ecosystems can be conserved as economies

continue to develop (Daily and Matson, 2008; Daily et al., 2011; Tallis and Polasky, 2011). But this begs the question: How much do we really know about how ES concepts and tools are being used by applied ecologists and resource managers?

The ES paradigm has made great progress in developing models for determining economic values of ES since its inception nearly two decades ago. Much of the early work in this field entailed only qualitative descriptions of the types of services from which people were benefitting (Baskin, 1997; Daily, 1997; MA, 2005) with only a few crude estimates of the monetary value of the services provided by natural systems (e.g. Costanza et al., 1997 estimated the global ES value was $33 trillion/year while global gross national product was $18 trillion/year). The early work in this field was stymied by a lack of rigorous assessment tools ready for use by scientists and managers (MA, 2005; Daily and Matson, 2008).

Over the last decade, however, many tools have been developed for practitioners to facilitate the adoption of the ES paradigm into resource management. For example, the InVEST model (Integrated Valuation of Ecosystem Services and Tradeoffs) by the Natural Capital Project (Kareiva et al., 2011; naturalcapitalproject.org/InVEST) is a spatially-explicit tool that allows practitioners to assess quantified tradeoffs (e.g. dollar values, tradeoff curves) in different management scenarios and to determine locations where investment in natural capital can enhance both conservation and development.

Ecosystem services models require that practitioners understand the functioning of ecosystems. Ecologists are in a unique position to contribute to the ES paradigm by providing requisite ecological knowledge. Their studies can help develop ecological production functions, or models in which ecosystem structures and functions are translated into flows of ES (Kremen, 2005; Daily et al., 2008; Mäler et al., 2008; Daily et al., 2011; naturalcapitalproject.org/InVEST). These ecological production functions then feed into economic models that connect the provisioning of the service(s) to the benefits people derive from the natural system in question (often communicated in monetary terms; Daily et al., 2008; Mäler et al., 2008; Daily et al., 2011). Thus, the ES paradigm is inherently interdisciplinary, and ecologists play a crucial role in connecting ecological state to societal value.

Thus far, however, only a handful of publications have systematically asked whether practitioners are considering ES in practical applications. Two projects studied resource managers. Those include Marre et al. (2015), who surveyed decision-makers in Australian coastal zones, and my previous survey of resource managers in the Great Lakes region (chapter 1). In both cases, researchers found that even though some managers are considering ES valuation, overall these techniques are weak contributors to

resource management. A third study by Arnold (2013) examined U.S. EPA wetland regulators, and he found that these regulators use monetary estimates of wetlands' societal values relatively infrequently.

Each of the previous studies ignored ecologists, effectively writing only part of the story for the ES paradigm. Therefore, I am interested in whether and how ecologists have adopted the ES paradigm into their research, especially now that the field is relatively well known and assessment tools are available. Have ecologists taken up the call to investigate ES in their study systems? Do they think about ES, and are ES ideas incorporated into their study plans? These are the overarching questions of this project as I study how ecologists have adopted the ES paradigm into their research.

To focus my efforts, I have limited my study region to the Laurentian Great Lakes and one particular research agency within the Great Lakes region (described further in methods section). I have asked the research ecologists at the agency whether and how they are adopting ES into their research practices: Are they familiar with ES concepts and valuation techniques? And which ES are most relevant to their research? Additionally, I am interested in the extent to which the information provided by ecologists overlaps with the information needs identified by resource managers (chapter 1). I compare the ecologists' responses to those of managers to determine whether these two groups have adopted the ES paradigm similarly. This study will aid in understanding how ecologists consider ES in their work and how that influences the information they provide to resource managers. Ultimately, I intend for this project to shed light on the role ecologists play in the adoption of the ES paradigm and possible avenues for improving the management of our limited natural resources.

Methods

Research Ecologist Sample Pool

To assess how ecologists are adopting the ES paradigm, I collaborated with a research science agency that represents a subset of research ecologists. This particular agency operates within the U.S federal government and focuses on many aspects of aquatic ecology (e.g. fisheries surveys, beach health, coastal wetland restoration, invasive species assessments, etc.). It is a medium size laboratory with 100-150 employees, of which 38 were considered research ecologists at the time of this study. Personnel are distributed in multiple offices with one primary headquarters and six different field stations spanning much of the United States' portion of the Laurentian Great Lakes basin.

Because of the relatively small size of this population, I tried to conduct a census of all of the ecologists by asking them via an interview and a follow-up survey about their research and how it may or

may not involve ES. Of the 38 individuals with the title of research ecologist, 37 consented to the interview, giving us 97% coverage of the agency's research ecologists on the interview questions. However, some interviewees self-identified as not practicing research ecologists and were excluded from analysis, leaving a final sample size of 33 interviews. I sent the follow-up survey to 36 ecologists (one ecologist was incidentally omitted in the survey distribution), of which 32 responded for a response rate of 89%. Of these, 7 individuals declined to complete the survey, self-identified as a non-research ecologists, or did not complete the survey, leaving a final sample size of 25 completed surveys.

Data Collection and Analysis

I used two methods for collecting data about my study subjects: interviews and surveys. Interviews were conducted in person (except two that were done via phone) in a one-on-one setting and took around 15-40 minutes depending on the length of the respondent's answers. There were 15 questions most of which were closed-response questions, while six left room for open responses. All interviews were conducted by the same interviewer. The online surveys were designed in Qualtrics Research Suite (qualtrics.com) and distributed via email to the scientists following the interview. I kept survey responses anonymous and therefore could not connect individual responses between the interview and survey. Similar to the interview, the survey had primarily closed-response questions with a few questions where respondents could clarify responses in an open-ended format. I designed questions to gain information regarding the type of research the ecologist performs, how ES might relate to their research and their perspective on integrating ES into resource management.

In one series of questions important to my analysis, I presented a list of 32 ES to the ecologists and asked them to rate the relevance of each ES from 0 (Strongly Unrelated to their research) to 4 (Strongly Related). In this particular question, I used a tool on Qualtrics called a slider bar which allowed the respondents to select any decimal from 0 to 4 down to the hundredths place, thus making it a functionally continuous variable. I adapted this list of ES from a list developed by the Millennium Ecosystem Assessment (2005). I then ranked the services from most relevant to least relevant based on the relevance reported by the ecologists.

I carried out data management and summary statistics in Qualtrics Research Suite, NVivo 10 for Windows (www.qsrinternational.com), and Microsoft Office Excel (https://products.office.com/en-us/excel). Summaries of the data including counts, proportions, means, standard deviations, and medians helped us understand the themes in the data and response distributions.

I performed inferential statistical analysis using the statistical computing software R (R.Computer Software). I used Analysis of Variance to compare the pattern of continuous and ordinal variables (e.g., relevance of ES) across the mutually exclusive categories of independent variables (e.g. tenure of their service at the agency).

I also compared the research ecologists' responses to those of resource managers from chapter 1. Managers in that project represented 25+ resource management agencies in the Laurentian Great Lakes basin, including Canadian, Tribal and U.S. agencies. I compared responses between these two groups on their familiarity with ES, the relevance of ES to their respective work, and the perceived adequacy of ES related information. These variables were ordinal and continuous in nature, and, therefore, I tested for a difference in mean between the two groups using the two-sample t-test. For all tests, an alpha of 0.05 was assumed.

Results

I begin by reviewing survey question responses with simple summary statistics and offer some interpretations of what the responses mean about how and why ecologists in my study agency are adopting the ES paradigm in their research. Next, I compare responses between ecologists and resource managers to determine if they view ES applications differently.

Summary of Responses to Questions

Appropriate to Consider Ecosystem Services? Because research ecologists play an important role in resource management by providing information to decision-makers, I asked the ecologists whether they thought it was appropriate to consider ES in the management of Great Lakes resources. Every ecologist stated that, yes, it is appropriate to consider ES. However, there were varying degrees to which respondents supported their general agreement.

Some ecologists suggested that considering ES in resource management is more than just appropriate. In fact, one ecologist even said "I don't think 'appropriate' is the right word. I think it's essential." Ecologists agreeing with this position responded that it was hard to manage natural resources responsibly without considering the goods and services those resources present because benefits to people are part of the definition of resource management. Additionally, I offer that our economy is highly dependent on natural resources, and the ES paradigm provides a connection between these two fields.

On the other hand, a few ecologists were hesitant about including ES in resource management despite their agreement that it is appropriate to consider ES. These ecologists cited problems with quantifying the value of ES—sometimes the valuations are incomplete or do not consider the temporal nature of ES provision. They are further concerned that if an ecosystem is calculated as having a low value, it might be deemed better suited for another use, such as a factory. However, I want to point out once again that all ecologists reported thinking ES are an appropriate tool in resource management, and that will shape much of my discussion going forward.

Familiarity with Ecosystem Services. I asked the ecologists about how familiar they were with ES on a five-point scale from Not At All Familiar to Very Familiar. When asked about how familiar they were with the concept of ES, 68% (17/25) reported that they were at least moderately familiar (Fig 1). In contrast, when asked about how familiar they were with methods for quantifying the economic value (e.g. dollar value) of ES, only 36% (9/25) reported they were moderately familiar, and none reported they were very familiar (Fig 1). This dynamic in which the ecologists seem to be familiar with ES concepts but much less familiar with the ES economic valuation likely reflects their training. Ecologists are trained in how ecosystems function and are well aware of how people benefit from ecosystems, but they are likely not trained in developing economic valuation functions that express societal benefits from ecosystems in quantifiable terms, often dollars.

Relevance of Ecosystem Services. To assess which specific ES ecologists thought were most relevant to their research, I provided them with a list of 32 ES and asked them to rate the relevance of each one on a scale from 0 (Strongly Unrelated) to 4 (Strongly Related). This list was adapted from a list of ES developed by the Millennium Ecosystem Assessment (2005).

Among the list of 32 ES, the six most relevant services, which stood out from the rest, were food (median=3.32, mean=3.00, sd=1.27), primary production (median=3.04, mean=2.81, sd=1.28), provision of habitat (median=3.03, mean=2.69, sd=1.34), biological control (median=3.02, mean=2.48, sd=1.37), recreation and tourism (median=3.00, mean=2.70, sd=1.29), and knowledge systems (median=3.00, mean=2.66, sd=1.23; Table 1). These results are likely highly influenced by the mission of the study agency which tends to be known for its work on aquatic systems, fish in particular.

To evaluate more broadly which kinds of ES were most relevant to ecologists' research, I asked them to rate the relevance of the four categories of ES designated by the Millennium Ecosystem Assessment (2005): supporting (services needed for the production of all other ES), provisioning (products obtained from ecosystems), regulating (benefits obtained from the regulation of ecosystems),

and cultural services (non-material benefits obtained from ecosystems). Based on ratings from ecologists, the four categories ranked as follows: 1) provisioning (median=3.03, mean=2.96, sd=0.97), 2) cultural (median=2.88, mean=2.40, sd=1.05), 3) regulating (median=2.81, mean=2.44, sd=1.18), and 4) supporting services (median=2.67, mean=2.43, sd=1.16). Provisioning services being ranked as the most relevant category of ES likely reflects the high relevance of food to the work of ecologists.

I also aggregated the responses regarding the previous four categories of ES to get an index of how relevant ES are in general to the research conducted by the ecologists in my project. I found that the median aggregated response on the continuous scale was 2.52 (mean=2.56, sd=0.69; Fig 2), indicating that ecologists generally thought ES were relevant to their work, but not strongly so. A histogram of this data is right skewed showing most ecologists reported ES as relevant to their work, but a few in the tail thought the paradigm was irrelevant.

Conducting Research on Ecosystem Services? In addition to asking scientists about their perceptions of and familiarity with ES, I wanted to know whether or not ecologists are actually considering ES in their research. Are ES concepts and metrics part of their research design? So I asked the ecologists in an interview whether, in their judgment, they were conducting research on ES in the Great Lakes basin. Eighty eight percent (88%; 29/33) of ecologists affirmed that they do conduct research on ES, but this proportion may be a bit misleading. A number of the scientists that I interviewed pointed out that they do not actually study these services directly, but rather indirectly. In many cases, the ecologists are studying the ecosystem functions (e.g. provisioning of habitat for fish spawning) that are then valued by people, but they are not actually studying or quantifying the amount of service these functions provide.

I also provided the research ecologists with the list of 32 ES again in an interview and asked them to tell us which of these they were directly conducting research on (as opposed to indirectly; Note: scientists could select more than one ES). Once again, I wanted an explicit tally of which services these ecologists were addressing in their research. The top 6 most studied services were primary production (66% of scientists; 22/33), food (61%; 20/33), provision of habitat (52%; 17/33), biological control (52%; 17/33), knowledge systems (37%; 12/33), and recreation and tourism (33%; 11/33; Table 2). These are the same top 6 ES as the relevance ranking, which adds credibility to those results. However, there are cautions in these data about how different ecologists interpreted the term ‘directly.’ Many respondents, despite affirming that they directly study a specific service, would then describe a process that was decidedly indirect (e.g. determining the biomass of prey fish that supports a recreational fishery, but not

actually translating that into the amount people are benefitted). In either case, this ranking provides us with an idea of which ES are most directly addressed by ecologists at this agency.

Adequacy of Information. In order to determine if ecologists thought they were contributing to the ES paradigm in resource management, I asked the ecologists to rate the adequacy of the ES-related information provided by them and their research relative to resource managers' information needs. On a scale from 0 (Greatly Inadequate) to 4 (More Than Adequate), the median rating by ecologists was 3.01 (mean=2.67, sd=0.94). They gave almost the exact same response about their organization as a whole with a median rating of the ES-related information as 3.01 (mean=2.71, sd=0.95). This indicates that even though ecologists on average report thinking that ES are only moderately related to their work, they believe they are providing information regarding these ES that is adequate, or nearly so, for the resource managers' information needs.

Comparison with Resource Managers

In the previous study, I found that resource managers in the Great Lakes basin had a strong desire to use ES information, and, in fact, they are already considering ES concepts in their decision-making and policy design (chapter 1). Managers did, however, describe some obstacles to integrating ES economic valuation into resource management practices, including the availability and adequacy of ES-related information (chapter 1). Here, I want to compare research ecologists' and resource managers' responses on their perception of ES and the adequacy of ES-related information to determine whether the managers and ecologists are on the same page. Are they similarly familiar with ES, and are they interested in the same types of services? Is their perception of the adequacy of ES information congruent?

Appropriate to Consider Ecosystem Services? Both resource managers (96%; 109/113; chapter 1) and ecologists (100%; 33/33) responded that it was appropriate to consider ES in their work. No analysis is needed to show that ecologists and managers likely have very similar perspectives on this subject.

Familiarity with Ecosystem Services. As with the ecologists, I asked managers how familiar they were with ES on a five-point likert scale from Not At All Familiar to Very Familiar. I compared the difference in means between the two populations for their familiarity with ES concepts and found no difference (Two sample t-test: t=0.4928, p=0.6253; Fig 3)—both ecologists and managers reported being moderately familiar with ES concepts. I also compared the two populations for their familiarity with methods for quantifying the economic value of ES and, once again, found no difference (Two sample t-test: t=0.2699, p=0.7877; Fig 4)—both managers and ecologists are vaguely familiar with methods for

quantifying the dollar value of ES. This is a strong indicator that neither group is more familiar with the ES paradigm than the other.

Relevance of Ecosystem Services. I compared the rankings of ES relevance between the ecologists and managers to determine whether their priority areas aligned. Looking at the top six most relevant ES for ecologists, I found that four of those were also reflected in the top six ES for managers: primary production, provision of habitat, biological control, and recreation and tourism (Table 3). The similarities in these rankings show a high degree of overlap between ecologists and managers regarding priority ES, thus leading me to believe that ecologists and managers are likely focusing on some similar issues in their respective work.

However, several misalignments in these rankings do exist. Food is one example, which ranked first for ecologists (median=3.32) and seventh for managers (median=3.02). I suspect that the difference in the ranking for food was a result of different perceptions of how game fish are utilized—many scientists cited their fisheries studies as contributing to food services, whereas managers likely cited these same services as recreation and tourism because the recreational fishery in the Great Lakes is several times bigger than the commercial fishery and receives more attention from the public. Another interesting discrepancy surrounded the service of fresh water supply which ranked 10 among ecologists (median=2.00) and 3 (median 3.10) among managers in terms of relevance. This may illuminate a gap in scientific coverage by my study agency, but more likely reflects a difference in priority issues—the study agency is comprised primarily of ecologists, rather than hydrologists, and thus issues like water levels and water scarcity are not prominent in their research (although these issues are addressed extensively by other agencies in the region).

In some cases, however, some of the misalignments in rankings could be misleading. As an example, knowledge systems as a service was ranked 6 for ecologists and 11 for managers, but both parties reported a median relevance of 3.00. This identical rating may mean that both groups actually consider the service of knowledge systems as similarly relevant to their respective work, even though managers may place it lower on their priority rankings. The same situation of different rankings but similar ratings applies to genetic resources which ecologists ranked as 8 (median=2.01) and managers as 21 (median=2.04). A different example is nutrient cycling which ranked 9 for ecologists (median=2.00) and 15 for managers (median=2.83)—despite a higher ranking by ecologists, their reported median relevance was actually lower than that that of managers. Given the way this study was designed, it is difficult to tease out exactly what the disparity in these rankings and ratings may reveal about differential

integration of ES by ecologists and managers. Some of the differences may be a result of the narrow field in which these ecologists work (representing one agency) compared to the diverse fields in which the managers work (representing 27 agencies).

I then compared the reported relevance of ES overall between managers and ecologists to see whether they perceived ES in general as being of similar relevance to their work. I did find a statistically significant, although not large, difference (Two sample t-test: t=2.1541, p=0.03487; Fig 2). On a scale from 0 (highly unrelated) to 4 (highly related), ecologists reported ES as being less relevant to their work (median=2.52, mean=2.56, sd=0.69) than did managers (median=2.99, mean=2.91, sd=0.60). This indicates that research ecologists consider the benefits people obtain from ecosystems to be less relevant to their work than do resource managers. This is not surprising because of the difference in their respective roles—managers make decisions about managing resources for peoples' utility whereas ecologists provide knowledge that can help inform those decisions. Therefore, managers, who work more directly with people, could be more professionally interested in the benefits those people derive.

I did the same analysis with the top six ES for ecologists and compared their responses with those of managers to assess for differences in reported relevance (e.g. relevance of provisioning of habitat for both groups). Interestingly, ecologists and managers, from their very different perspectives, agree remarkably well—none of the comparisons revealed significantly different means. It is worth pointing out that the difference between these two populations regarding the provisioning of habitat was nearly significant (Two sample t-test: t=1.986, p=0.05646). It is interesting to note that ecologists and managers differ in regards to the relevance of ES overall (above) but not with regards to the top six most relevant ES. Once again, this likely reflects that ecologists and managers have similar perspectives regarding the priority ES but differences begin to arise beyond the ecologists' focus areas which results in divergent perspectives about ES overall.

To dig deeper, I compared the ecologists with resource managers from the five management agencies with which they worked most regularly: the Environmental Protection Agency, U.S. Fish and Wildlife Service, the Great Lakes Fishery Commission, the Michigan Department of Natural Resources, and the Ontario Ministry of Natural Resources. The top five most relevant ES for ecologists' were the exact same as the top five ES for these specific management agencies (although they were in a different order), compared to a four out of five match between ecologists and all of the management agencies. This indicates that research ecologists' views may be increasingly consistent with the agencies with which they work most closely.

Adequacy of Information. One of the greatest differences between ecologists and resource managers was in their perception of the adequacy of ES-related information. While ecologists thought the information they provide was generally adequate (median=3.01 on a scale from 0=Greatly Inadequate to 4=More Than Adequate), managers thought the information was generally inadequate (median=1.60), a difference that is both statistically significant (Two sample t-test: $t=-4.2727$, $p<0.001$) and meaningful. Ecologists clearly perceive that the information that they are providing is enough for managers to consider ES when managing natural resources. On the other than hand, resource managers report being unsatisfied with the ES-related information and expressed a desire for more economically quantified metrics for ecosystem services.

Discussion

Summary of Findings

Assessing research ecologists has allowed us to gain insight into their perception and adoption of ES into their research. I discovered that research ecologists overwhelmingly thought it was appropriate, even essential in some cases, to adopt the ES paradigm into management practices. I also found that most ecologists are at least moderately familiar with ES concepts—many of them articulated how their research provides information about specific services—but only a small proportion of ecologists were moderately familiar with ES valuation methods. This was consistent with the findings of Marre et al. (2015) and myself (chapter 1) that ES valuation is rarely considered in many contexts. Arnold (2013) also concluded that lack of expertise in valuation methods was one of the main obstacles to ES value estimates. Most ecologists confirmed that they do conduct research on ES, but often this was an indirect relationship as they provided information about certain services but did not quantify benefits. I also discovered that ES, especially food, were quite relevant to ecologists' research. This is similar to the finding that in Australian coastal ecosystems, commercial fisheries (a common source of food) was the context in which ES valuation was used most frequently (Marre et al., 2015). Lastly, ecologists in this study thought they were providing adequate information for resource management needs.

Comparing ecologists' responses to those of resource managers in the study from chapter 1 allowed us to assess the relative adoption of the ES paradigm in their respective work. Both groups almost unanimously thought the ES paradigm was appropriate for resource management, and they were similarly familiar with ES concepts and valuation methods. Several of the high priority services were given comparable relevancy rankings by both groups— primary production, provision of habitat, biological control, and recreation and tourism—which indicates a high degree congruency between the

two populations. Ecologists, however, assigned a lower relevancy score to ES in general. Additionally, ecologists reported a higher score for the adequacy of ES-related information relevant to management needs. Therefore, I conclude that in many ways research ecologists and resource managers are both considering ES in similar ways, but their perceptions about which services are most important and the adequacy of information represent slight departures from this trend.

Potential Biases

I do want to note a few biases and assumptions in this study that will influence the interpretation of my results. First, I have surveyed only a small sub-population of research ecologists (n=25 survey respondents and 33 interviewees). Therefore, my analysis is subject a moderately small sample size and my extrapolation to other individuals is limited by my inclusion of ecologists working in a narrow field. I elected to exclude certain individuals from the research ecologist population because they did not self-identify as such, but this may bias my results because some these excluded individuals still have significant impact on study directions and designs. I also acknowledge that non-respondents may have different perceptions of the ES paradigm than those in this survey. Nevertheless, I was able to interview 97% of the agency's research ecologists and had an 89% response rate on the surveys, well above normal rates in this field. Although this population may represent a narrow sub-set of ecologists, I suspect that their diverse backgrounds and significant interactions with other research agencies has made their perception of the ES paradigm quite representative of ecologists in general.

I recognize that my results could also be influenced by a social desirability bias (a desire to adhere to cultural expectations; Crowne and Marlowe, 1960) or the Hawthorne Effect (a modification of behavior due to the awareness of being observed; McCarney et al., 2007), especially in the case of interviews. Because of the presence of an interviewer or the fact that the "ecosystem services paradigm" is a potentially charged subject, respondents may have felt compelled to answer in a certain way. Given that this was an ecosystem services study, these biases could lead respondents to overestimate certain factors such as their familiarity with ES or the relevance of ES to their work. Perhaps this partially explains why ecologists think their work provides great ES-related information, but managers think otherwise. I did my best to minimize these biases by maintaining neutral language in the questions, asking about a wide variety of ES, and keeping the surveys and interviews anonymous.

Implications

One of the main critiques of the ES paradigm is that there is not enough information to reliably include ES values in decision-making and policy design (Seifert-Dähnn et al., 2013; Sutton-Grier et al., 2014; Marre et al., 2015; Volk, 2015). Research ecologists are in a unique position to alleviate some of these information needs by studying ecosystem structures and functions, also known as ES providers (Kremen and Ostfield, 2005), and developing ecological production functions. In this study, I learned that most research ecologists in my population are addressing this weakness by directly or indirectly conducting research on ES providers, but few are directly connecting their findings to societal utility. I believe this is representative of scientists in general who are trending towards connecting their work to tangible benefits for society, even if it is simply increasing knowledge of a given subject.

All ecologists that I interviewed reported that ES were appropriate in resource management. In order to assess how they envisioned the ES paradigm contributing to this field, I asked interviewees in an open ended format what they thought were some benefits and drawbacks to considering ES. The most common benefit mentioned was the comprehensiveness of the ES paradigm compared to old management practices. Managing ecosystems and resources for human benefit is not new (Mooney and Ehrlich, 1997)—wild game, timber, etc. have been managed since antiquity—but the myriad benefits in the MA's (2005) list of 32 services is a more modern focus. Benefits such as nutrient cycling, biological control, and cultural heritage values are more recent inclusions, and ecologists reported that this is a strength of the ES paradigm. Ecologists also pointed out that the people-centered nature of the ES paradigm is helpful in management since maximizing benefits to people is the overarching focus of resource management as well. Lastly, many ecologists in this study said that the framing their research in terms of ES and the quantifiable utility of ecosystems is helpful in justifying the work they do, especially in getting funding.

In addition to asking about benefits, I asked ecologists to comment on the drawbacks they saw with the ES paradigm. The most common concern was competing user groups and their conflicting interests. For example, whose values are most important when it comes to making decisions about shipping and the risk of introducing invasive species? Ecologists also pointed out that many ES evaluations are incomplete because there is not enough information to consider all the services that an ecosystem offers which echoes the concerns expressed by other scholars in the literature (e.g. Seifert-Dähnn et al., 2013; Sutton-Grier et al., 2014; Marre et al., 2015; Volk, 2015). Others respondents stated that valuations are complex and difficult which correlates with my finding that ecologists in general

testify to being only vaguely familiar with methods for quantifying values of ES. Lastly, however, some ecologists saw no drawbacks to the ES approach and, thus, indicated that they had little hesitancy in adopting the ES paradigm as *one* tool for resource management.

By comparing the responses of ecologists to those of resource managers, I discovered that these two populations interact with the ES paradigm in many similar ways, with a few noted exceptions. These two groups were similarly familiar with ES concepts and metrics and had much overlap in terms of which services were most relevant to their work. Moreover, ecologists' rankings of services were even more consistent with the agencies that they worked with most closely. Thus, there seems to be strong alignment between ecologists and managers regarding high priority areas within the ES paradigm. This likely reflects good communication between these two groups and represents a willingness and interest among ecologists to respond to resource management agencies.

Unfortunately, this alignment does not appear to result in the generation of adequate information for managers to fully utilize the ES paradigm. Although ecologists and managers agreed on priority services in my study, managers still report that the information provided to them is not adequate for their management needs, a finding that is consistent with conclusions of Seifert- Dähnn et al. (2013). It could be that even though ecologists study a service that is highly relevant to managers, the specific questions they are addressing may not provide immediately useful information. For example, an ecologist studying factors influencing harmful algal blooms may not quite answer the questions of a water quality manager trying to minimize the impact of microcystin toxin on drinking water. This is not to say the ecologist's work is unimportant, but rather to point out it may not be directly applicable in some management scenarios. It may be that this disconnect between priority area alignment and information adequacy is a result of ecological studies that are not coordinated with the precise data gaps of managers.

In my previous study (chapter 1), managers reported that they would use economic information regarding ES if they had access to that information, but based on my questions regarding familiarity with valuation methods, it appears that neither ecologists nor managers are fit to provide that economic information. From this finding, an additional possible explanation for the aforementioned disconnect in information adequacy arises. Perhaps a critical step in the ES paradigm is missing.

Multiple scholars have noted that incorporating the ES paradigm into natural resource management takes at least three groups: ecologists to provide the ecological production functions; economists to translate the production functions into economic valuation functions; and managers to make decisions about the conservation and/or use of natural resources and ES providers in light of the valuation

functions. (Kremen, 2005; Daily et al., 2008; Mäler et al., 2008; Daily et al., 2011; naturalcapitalproject.org/InVEST). For the resource management system that I have studied in the Great Lakes region, the critical step that seems to be missing is the economists. Given the complexity of developing economic models that calculate societal benefits from nature, I believe this may be where ES-related data gaps originate. Including trained ecological economists may provide the important connection between ecological research and resource management information needs and may allow managers to more fully adopt the ES paradigm as a reliable tool to aid in managing our finite natural resources.

Conclusion

Here I have studied how research ecologists have adopted the ecosystem services paradigm and how well this aligns with resource managers in the Great Lakes region. All the ecologists I interviewed reported that ES were appropriate to consider in resource management and services such as food and primary production were ranked as highly relevant to their research. Both of these findings matched reasonably well with reports from resource managers in the region. Ecologists and managers diverged, however, in terms of ES-related information adequacy: ecologists thought the information on ES that they provide was adequate for resource managers' needs whereas managers deemed it inadequate. This disconnect in information adequacy may reveal a gap in scientific coverage, but I believe it is more likely that it represents a need for economists in the Great Lakes resource management system who can translate ecological production functions into economic valuation functions that inform managers about societal value.

Table 1: Top ranked most relevant ecosystem services (out of 32) to research ecologists. Median score represents the score assigned by managers from 0=Strongly Unrelated to 4=Strongly Related. Category of Service is the primary category of the service based on the Millennium Ecosystem Assessment (MA, 2005).

Rank	*Ecosystem Service*	*Median Score*	*Category of Service*	*Examples*
1	Food	3.32	Provisioning	Wild game
2	Primary Production	3.04	Supporting	Energy capture, food chain support, energy flow for fish, benthic food chain
3	Provision of Habitat	3.03	Supporting	Biodiversity support, habitat diversity
4	Biological Control	3.02	Regulating	Pest control, invasives
5	Recreation & Tourism	3.00	Cultural	Lake recreation, wild game, song birds, other wildlife
6	Knowledge Systems	3.00	Cultural	Cultural, economic, and scientific knowledge
7	Educational Values	2.58	Cultural	
8	Genetic Resources	2.01	Provisioning	
9	Nutrient Cycling	2.00	Regulating	Nutrient Storage
10	Fresh Water	2.00	Provisioning	Water Supply
11	Sense of Place	2.00	Cultural	
12	Cultural Heritage Values	2.00	Cultural	

Table 2: Top ranked ecosystem services (out of 32 total) directly studied by ecologists. Vote tally is the number of ecologists who reported directly studying that service. Note: 33 ecologists were asked, and they could select more than one service.

Rank	*Ecosystem Service*	*Vote Tally*
1	Primary Production	22
2	Food	20
3	Provision of Habitat	17
4	Biological Control	17
5	Knowledge Systems	12
6	Recreation and Tourism	11
7	Genetic Resources	8
8	Educational Values	6
9	Nutrient Cycling	6
10	Aesthetic Values	6

Table 3: Comparative Rankings of Ecosystem Services for Ecologists and Managers. Rankings and median scores for the top twelve ES in terms of relevance to ecologists' research (on a scale from 0=Highly Unrelated to 4=Highly Related; left). The median scores and rankings for managers are shown for comparison (right). The list had 32 ES in total.

Ecologists		*Ecosystem Services*	*Managers*	
Rank	Median Score		Median Score	Rank
1	3.32	Food	3.02	7
2	3.04	Primary Production	3.04	5
3	3.03	Provision of Habitat	3.49	1
4	3.02	Biological Control	3.08	4
5	3.00	Recreation & Tourism	3.42	2
6	3.00	Knowledge Systems	3.00	11
7	2.58	Educational Values	3.02	6
8	2.01	Genetic Resources	2.04	21
9	2.00	Nutrient Cycling	2.83	15
10	2.00	Fresh Water	3.10	3
11	2.00	Sense of Place	2.95	12
12	2.00	Cultural Heritage Value	2.62	16

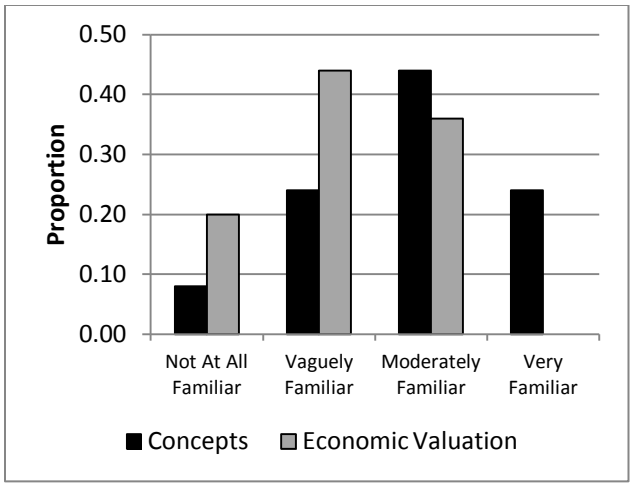

Figure 1: Familiarity with Ecosystem Services. Asked how familiar they were with concepts of ES (black), 8% said not at all, 24% said vaguely, 44% said moderately, and 24% said very familiar. Asked how familiar they were with methods for quantifying the economic value of ES (gray), 20% said not at all, 44% said vaguely, 36% said moderately, and 0% said very familiar.

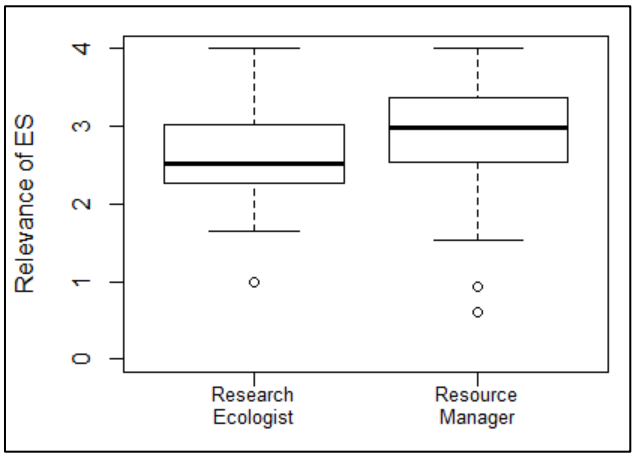

Figure 2: Relevance of Ecosystem Services. The reported relevance of ES in general to research ecologists (median=2.52) and resource managers (median=2.99; Two sample t-test: t=2.1541, p=0.03487). Relevance of ES ranges from 0 (Strongly Unrelated) to 4 (Strongly Related). In the box and whisker plot, the bold line represents the median, the box represents the interquartile range (the middle 50% of data points), the whiskers represent the datum that is no more than 1.5 times the interquartile range, and the dots represent outliers (Tukey, 1997).

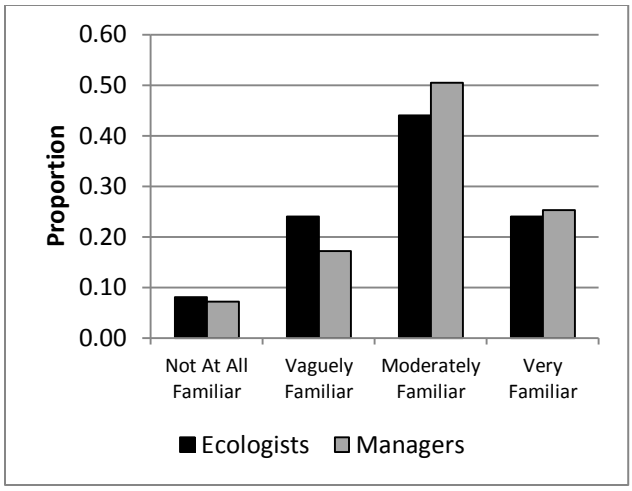

Figure 3: Familiarity with Ecosystem Services Concepts. Ecologists (black) and managers (gray) were asked how familiar they were with concepts of ES. A two sample t-test comparing the difference of means showed no difference between the two populations (t=0.4928, p=0.6253).

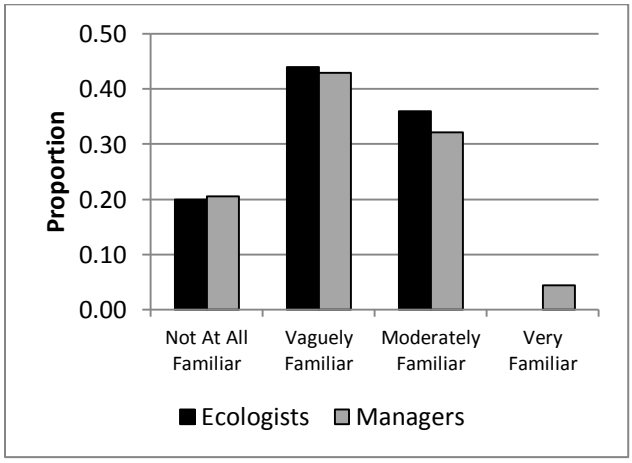

Figure 4: Familiarity with Ecosystem Services Economic Valuation. Ecologists (black) and managers (gray) were asked how familiar they were with methods for quantifying the economic value of ES. A two sample t-test comparing the difference of means showed no difference between the two populations (t=0.2699, p=0.7877).

Appendix

Great Lakes Resource Managers Online Survey

Principal Investigator: Dan Engel, Master's candidate, School of Natural Resources and Environment, University of Michigan
Faculty Advisory: Bobbi Low, Professor of Natural Resources, University of Michigan School of Natural Resources and Environment
Committee Member: Jeff Schaeffer, Fisheries Biologist, USGS Great Lakes Science Center
Committee Member: Michael Moore, Professor of Environmental Economics and Associate Dean, University of Michigan School of Natural Resources and Environment
Science Advisor: Mary Anne Evans, Research Ecologist, USGS Great Lakes Science Center.

The purpose of this research study is to evaluate the science program at the Great Lakes Science Center (hereafter GLSC) in the context of understanding ecosystem services. Thus, this survey is designed to gather background information and develop an empirical basis for analyzing whether the needs of resource managers in relation to ecosystem services are being met by the science conducted at the Great Lakes Science Center (hereafter GLSC). Data will be collected from both Great Lakes resource managers (U.S. and Canada) and GLSC scientists in relation to their consideration of ecosystem services in their respective work. Analysis will compare the information needs of resource managers and the information provided by GLSC scientists, and matches and mismatches will be highlighted.

I am interested in how resource managers are thinking about ecosystem services as they design policy and make decisions regarding resources in the Great Lakes Basin. With that in mind, please answer these questions with respect to **the work you are currently doing** as a **resource manager** in the Great Lakes Basin.

1. Do you agree to take part in the survey?
   a. ____ Yes b. ____ No

Part 1: Agency Work

The first section of the survey asks questions that try to determine what kind of work you are doing as a **resource manager** in the Great Lakes basin.

1. In your current work, do you directly contribute to management or policy decisions regarding natural resources in the Great Lakes Basin?
   a. ___ Yes
   b. ___ No
2. Which agency do you currently work for? _____
3. What is your position (e.g. wildlife biologist, etc.)? _____
4. Choose the category that describes your administrative duties.
   a. ___ I don't supervise employees
   b. ___ I supervise employees
   c. ___ I supervise others who supervise employees
5. In comparison with other agencies that your agency works with, how frequently does your agency currently work with the Great Lakes Science Center?
   a. ___ Frequently
   b. ___ Occasionally
   c. ___ Rarely
   d. ___ Never
   e. __ Don't know
6. In which state(s)/province(s) do you currently work? (Check all that apply)
   a. ___ Illinois
   b. ___ Indiana
   c. ___ Michigan
   d. ___ Minnesota
   e. ___ New York
   f. ___ Ohio
   g. ___ Pennsylvania
   h. ___ Wisconsin
   i. ___ Ontario
7. Pick the category that best describes the primary focus of your current work. (Check all that apply)
   a. ___ Biodiversity management
   b. ___ Fisheries management
   c. ___ Forest resources management
   d. ___ Mineral resources management
   e. ___ Water quality management
   f. ___ Water quantity management
   g. ___ Wildlife management
   h. ___ Recreation
   i. ___ Other _____
8. In which of the following systems do you currently work? (Check all that apply)
   a. ___ Lake Erie
   b. ___ Lake Huron
   c. ___ Lake Michigan
   d. ___ Lake Ontario
   e. ___ Lake Superior
   f. ___ Inland lakes
   g. ___ Huron-Erie corridor
   h. ___ Rivers and streams
   i. ___ Other connecting channels
   j. ___ Other _____

9. In which of the following ecosystems in the Great Lakes Basin do you currently work? (Check all that apply)
    a. ___ Great Lakes coastal wetlands/marshes
    b. ___ Great Lakes islands
    c. ___ Great Lakes nearshore zone
    d. ___ Great Lakes open water
    e. ___ Agricultural land
    f. ___ Dunes
    g. ___ Forests
    h. ___ Inland lakes
    i. ___ Inland streams and rivers
    j. ___ Prairies
    k. ___ Urban areas
    l. ___ Other _____

Part 2: How do you as a resource manager consider ecosystem services?

This section asks questions that try to determine how you as a **resource manager** are considering ecosystem services while making decisions and designing policies in the Great Lakes Basin.

1. How would you rank your familiarity with the concept of ecosystem services?
    a. ___ Very familiar
    b. ___ Moderately familiar
    c. ___ Vaguely familiar
    d. ___ Not at all familiar
    e. ___ Don't know
2. How would you rank your familiarity with the methods for quantifying the economic value (e.g. dollar value) of ecosystem services?
    a. ___ Very familiar
    b. ___ Moderately familiar
    c. ___ Vaguely familiar
    d. ___ Not at all familiar
    e. ___ Don't know
3. How would you describe your familiarity with the methods for quantifying ecosystem services spatially and temporally (e.g. mapping, ecological production functions, etc.)?
    a. ___ Very familiar
    b. ___ Moderately familiar
    c. ___ Vaguely familiar
    d. ___ Not at all familiar
    e. ___ Don't know
4. How would you define ecosystem services?
    a. (Open ended)

For consistency, I will use the Millennium Ecosystem Assessment's (MA) definition of ecosystem services as "the benefits people obtain from ecosystems." Please keep this definition in mind while answering the following questions.

5. In your current work, do you consider ecosystem services at a conceptual-level (take into account the benefits people obtain from ecosystems but without necessarily assigning a specific dollar value) as you make decisions and design policies?
    i. ___ Yes ii. ___ No
    b. If Yes to question 5 (concept-level), how do you consider ecosystem services at a concept-level as you make decisions and design policies?
        i. (Open ended)
6. In your current work, do you consider ecosystem services at an economic valuation-level (assigning a specific dollar value) as you make decisions and design policies?
    i. ___ Yes ii. ___ No
    b. If Yes to question 6 (valuation-level), how do you consider ecosystem services at an economic valuation-level as you make decisions and design policies?
        i. (Open ended)
    c. If Yes to question 6 (valuation-level), which of the following valuation methods do you use as you quantify the economic value of ecosystem services? (Check all that apply)
        i. ___ Avoided cost
        ii. ___ Replacement cost
        iii. ___ Travel cost
        iv. ___ Factor income
        v. ___ Hedonic pricing
        vi. ____ Contingent valuation
        vii. ___ Option and insurance values
        viii. ___ Choice experiments (conjoint analysis)
        ix. ___ Other _____
    d. If No to question 6 (valuation-level): If you had access to economic valuation information about ecosystem services, would you use that information?
        1. ___ Yes 2. ___ No
        ii. If Yes to 6d, how would you use ecosystem services economic valuation information?
            1. (Open ended)
7. Within the past five years, has a resource management decision appeared that you think would have benefitted from ecosystem valuation techniques?
    a. ___ Yes
    b. ___ No

The MA classifies ecosystem services according to four categories: 1) *supporting services* (services needed for the production of all other ecosystem services), 2) *provisioning services* (products obtained from ecosystems), 3) *regulating services* (benefits obtained from the regulation of ecosystems), and 4) *cultural services* (non-material benefits obtained from ecosystems). The purpose of the following questions is to find out what ecosystem services are important to **resource managers** in the Great Lakes basin.

8. On a scale from Strongly Unrelated to Strongly Related, how would you rate the following Ecosystem Services in their relation to your work as a **resource manager**? (Slide the bar to select the appropriate rating)

Ecosystem Services	**Strongly Unrelated** **Strongly Related**	**I don't know (IDK)**
Supporting Services (services needed for the production of all other ecosystem services)	0 ---------- 2 ---------- 4	IDK
Provisioning Services (products obtained from ecosystems)	0 ---------- 2 ---------- 4	IDK
Regulating Services (benefits obtained from regulation of ecosystems)	0 ---------- 2 ---------- 4	IDK
Cultural Services (Non-material benefits obtained from ecosystems)	0 ---------- 2 ---------- 4	IDK

9. On a scale from Strongly Unrelated to Strongly Related, how would you rate the following *supporting services* in their relation to your research? (Select the appropriate rating)
   Supporting Services – services needed for the production of all other ecosystem services

Ecosystem Services	Strongly Unrelated Strongly Related	I don't know (IDK)
Soil Formation and Retention (soil renewal, renewal of soil fertility)	0 ---------- 2 ---------- 4	IDK
Production of Atmospheric Oxygen	0 ---------- 2 ---------- 4	IDK
Water Cycling (soil moisture storage)	0 ---------- 2 ---------- 4	IDK
Nutrient Cycling (nutrient storage)	0 ---------- 2 ---------- 4	IDK
Primary Production (energy capture, food chain support, energy flow for fish, benthic food chain)	0 ---------- 2 ---------- 4	IDK
Provision of Habitat (biodiversity support, habitat diversity)	0 ---------- 2 ---------- 4	IDK

10. On a scale from Strongly Unrelated to Strongly Related, how would you rate the following *provisioning services* in their relation to your research? (Select the appropriate rating)
    Provisioning Services – products obtained from ecosystems

Ecosystem Services	Strongly Unrelated Strongly Related	I don't know (IDK)
Fresh Water (water supply)	0 ---------- 2 ---------- 4	IDK
Food (wild game)	0 ---------- 2 ---------- 4	IDK
Fuel/energy (Hydro-electricity)	0 ---------- 2 ---------- 4	IDK
Genetic Resources	0 ---------- 2 ---------- 4	IDK
Ornamental Resources (beach glass jewelry, household decorations)	0 ---------- 2 ---------- 4	IDK
Biochemical, Natural Medicines, and Pharmaceuticals (medicines)	0 ---------- 2 ---------- 4	IDK
Fiber (timber production)	0 ---------- 2 ---------- 4	IDK

11. On a scale from Strongly Unrelated to Strongly Related, how would you rate the following *regulating services* in their relation to your work as a **resource manager**? (Slide the bar to select the appropriate rating)

    Regulating Services - benefits obtained from the regulation of ecosystems

Ecosystem Services	Strongly Unrelated Strongly Related	I don't know (IDK)
Pollination	0 ---------- 2 ---------- 4	IDK
Regulation of Human Diseases	0 ---------- 2 ---------- 4	IDK
Biological Control (pest control, invasives)	0 ---------- 2 ---------- 4	IDK
Air Quality Maintenance (air purification, visibility)	0 ---------- 2 ---------- 4	IDK
Storm Protection	0 ---------- 2 ---------- 4	IDK
Erosion Control	0 ---------- 2 ---------- 4	IDK
Water Regulation (flood mitigation)	0 ---------- 2 ---------- 4	IDK
Climate Regulation (carbon storage, moderation of weather extremes)	0 ---------- 2 ---------- 4	IDK
Water Purification and Waste Water Treatment (water quality, waste assimilation, groundwater quality)	0 ---------- 2 ---------- 4	IDK

12. On a scale from Strongly Unrelated to Strongly Related, how would you rate the following c*ultural services* in their relation to your work as a **resource manager**? (Slide the bar to select the appropriate rating)

    Cultural Services - non-material benefits obtained from ecosystems

Ecosystem Services	**Strongly Unrelated** **Strongly Related**	**I don't know (IDK)**
Recreation and Tourism (lake recreation, wild game, song birds, other wildlife)	0 ---------- 2 ---------- 4	IDK
Aesthetic Values (aesthetics)	0---------- 2 ---------- 4	IDK
Sense of Place	0 ---------- 2 ---------- 4	IDK
Educational Values	0 ---------- 2 ---------- 4	IDK
Inspiration	0 ---------- 2 ---------- 4	IDK
Cultural Heritage Values	0 ---------- 2 ---------- 4	IDK
Social Relations	0 ---------- 2 ---------- 4	IDK
Cultural Diversity	0 ---------- 2 ---------- 4	IDK
Knowledge systems (cultural, economic, scientific knowledge)	0 ---------- 2 ---------- 4	IDK
Spiritual and Religious Values	0 ---------- 2 ---------- 4	IDK

13. To what extent is available ecosystem services-related information adequate for your resource management needs? (Slide the bar to select the appropriate rating)

	Greatly Inadequate **More Than Adequate**	**I don't know (IDK)**
Adequacy of ecosystem services-related information for management needs	0 ---------- 2 ---------- 4	IDK

14. What is your greatest data-deficiency in terms of ecosystem services-related information?
    a. (Open ended)
15. In your opinion, is it appropriate to considering ecosystem services when managing Great Lakes resources?
    a. ___ Yes b. ___ No
16. What do you think are some <u>benefits</u> to considering ecosystem services when managing Great Lakes resources?
    a. (Open ended)
17. What do you think are some <u>drawbacks</u> to considering ecosystem services when managing Great Lakes resources?
    b. (Open ended)
18. In your experience, are resource managers currently being asked to consider ecosystem services in their management decisions?
    c. ___ Yes d. ___ No
    c. If yes, by whom?
        i. (Open ended)

Part 3: Demographic Information

The last few questions ask about some demographic characteristics.

1. What is the highest level of education that you have attained?
    a. ____ Undergraduate degree c. ____ Doctorate degree
    b. ____ Master's degree d. ____ Other _____
2. What is your gender?
    a. ____ Male b. ____ Female
3. How long have you been working with your current agency? _____
4. Do you have any additional comments that you would like to share?
    a. (Open ended)

GLSC Scientist Online Survey

Principal Investigator: Dan Engel, Master's candidate, University of Michigan School of Natural Resources and Environment
Faculty Advisory: Bobbi Low, Professor of Natural Resources, University of Michigan School of Natural Resources and Environment
Committee Member: Jeff Schaeffer, Fisheries Biologist, USGS Great Lakes Science Center
Committee Member: Michael Moore, Professor of Environmental Economics and Associate Dean, University of Michigan School of Natural Resources and Environment
Science Advisor: Mary Anne Evans, Research Ecologist, USGS Great Lakes Science Center.

The purpose of this research study is to evaluate the science program at the Great Lakes Science Center (hereafter GLSC) in the context of understanding ecosystem services. Thus, this survey is designed to gather background information and develop an empirical basis for analyzing whether the needs of resource managers in relation to ecosystem services are being met by the science conducted at the Great Lakes Science Center (hereafter GLSC). Data will be collected from both Great Lakes resource managers (U.S. and Canada) and GLSC scientists in relation to their consideration of ecosystem services in their respective work. Analysis will compare the information needs of resource managers and the information provided by GLSC scientists, and matches and mismatches will be highlighted.

I am interested in how scientists are thinking about ecosystem services as they conduct scientific investigations in the Great Lakes basin. With that in mind, please answer these questions with respect to **the research you are currently conducting** as a **research scientist** with the GLSC.

Part 1: Your research in the Great Lakes Basin

This section asks questions that try to determine what kind of scientific research you are conducting in the Great Lakes Basin as a **research scientist** for the GLSC.

1. Are you a research scientist for the GLSC?
   a. ___ Yes b. ___ No

2. As an employee for the GLSC, how frequently would you estimate that you currently work with the following resource management agencies?

Agencies	Not at All	Occasionally	Frequently	I don't know
Michigan Department of Natural Resources				
Wisconsin Department of Natural Resources				
Minnesota Department of Natural Resources				
Illinois Department of Natural Resources				
Indiana Department of Natural Resources				
Ohio Depart of Natural Resources				
New York Department of Environmental Conservation				
Pennsylvania Department of Conservation and Natural Resources				
Pennsylvania Game Commission				
Pennsylvania Fish and Boat commission				
Michigan Department of Environmental Quality				
Ohio Environmental Protection Agency				
NOAA Great Lakes Environmental Research Laboratory				
Natural Resources Conservation Service				
Great Lakes Indian Fish and Wildlife Commission				
Chippewa/Ottawa Resource Authority				
Bay Mills Indian Community				
Grand Traverse Band of Ottawa and Chippewa Indians				
Little River Band of Ottawa Indians				
Sault Ste Marie Tribe of Chippewa Indians				
Great Lakes Commission				
National Park Service				
U.S. Fish and Wildlife Service				
Great Lakes Fishery Commission				
International Joint Commission				
Environment Canada				

3. At which GLSC station do you currently conduct research? (Check all that apply)

a. ___ Ann Arbor
b. ___ Cheboygan Vessel Base
c. ___ Hammond Bay Biological Station
d. ___ Lake Erie Biological Station
e. ___ Lake Michigan Ecological Research Station
f. ___ Lake Ontario Biological Station
g. ___ Lake Superior Biological Station
h. ___ Tunison Laboratory of Aquatic Sciences
i. ___ Other _____

4. In which of the following systems do you currently conduct research? (Check all that apply)
    a. ___ Lake Erie
    b. ___ Lake Huron
    c. ___ Lake Michigan
    d. ___ Lake Ontario
    e. ___ Lake Superior
    f. ___ Inland lakes
    g. ___ Huron-Erie corridor
    h. ___ Rivers and streams
    i. ___ Other connecting channels
    j. ___ Other _____
5. In which of the following ecosystems in the Great Lakes Basin do you currently conduct research? (Check all that apply)
    a. ___ Great Lakes coastal wetlands/marshes
    b. ___ Great Lakes islands
    c. ___ Great Lakes nearshore zone
    d. ___ Great Lakes open water
    e. ___ Agricultural land
    f. ___ Dunes
    g. ___ Forests
    h. ___ Inland lakes
    i. ___ Inland streams and rivers
    j. ___ Prairies
    k. ___ Urban areas
    l. ___ Other _____

Part 2: Research on Ecosystem Services

The second section of the survey asks questions that try to determine what kind of research results and related information on ecosystem services you are providing to Great Lakes resource managers.

1. How would you define ecosystem services?
    a. (Open ended)
2. How would you describe your familiarity with the concept of ecosystem services?
    a. ___ Very familiar
    b. ___ Moderately familiar
    c. ___ Vaguely familiar
    d. ___ Not at all familiar
    e. ___ Don't know
3. How would you describe your familiarity with the methods for quantifying the economic value (e.g. dollar value) of ecosystem services?
    a. ___ Very familiar
    b. ___ Moderately familiar
    c. ___ Vaguely familiar
    d. ___ Not at all familiar
    e. ___ Don't know

4. How would you describe your familiarity with the methods for quantifying ecosystem services spatially and temporally (e.g. mapping, ecological production functions, etc.)?
    a. ___ Very familiar
    b. ___ Moderately familiar
    c. ___ Vaguely familiar
    d. ___ Not at all familiar
    e. ___ Don't know

For consistency, I will use the Millennium Ecosystem Assessment's (MA) definition of ecosystem services as "the benefits people obtain from ecosystems." The MA further classifies ecosystem services according to four categories:

1) *Supporting Services* – services needed for the production of all other ecosystem services
2) *Provisioning Services* – products obtained from ecosystems
3) *Regulating Services* – benefits obtained from the regulation of ecosystems
4) *Cultural Services* – non-material benefits obtained from ecosystems

The purpose of the following questions is to find out what ecosystem services are important to **GLSC research scientists**.

5. On a scale from Strongly Unrelated to Strongly Related, how would you rate the following Ecosystem Services in their relation to your research? (Slide the bar to select the appropriate rating)

Ecosystem Services	**Strongly Unrelated** **Strongly Related**	**I don't know (IDK)**
Supporting Services (services needed for the production of all other ecosystem services)	0 ---------- 2 ---------- 4	IDK
Provisioning Services (products obtained from ecosystems)	0 ---------- 2 ---------- 4	IDK
Regulating Services (benefits obtained from regulation of ecosystems)	0 ---------- 2 ---------- 4	IDK
Cultural Services (Non-material benefits obtained from ecosystems)	0 ---------- 2 ---------- 4	IDK

6. On a scale from Strongly Unrelated to Strongly Related, how would you rate the following *supporting services* in their relation to your research? (Slide the bar to select the appropriate rating)

   Supporting Services – services needed for the production of all other ecosystem services

Ecosystem Services	Strongly Unrelated Strongly Related	I don't know (IDK)
Soil Formation and Retention (soil renewal, renewal of soil fertility)	0 ---------- 2 ---------- 4	IDK
Production of Atmospheric Oxygen	0 ---------- 2 ---------- 4	IDK
Water Cycling (soil moisture storage)	0 ---------- 2 ---------- 4	IDK
Nutrient Cycling (nutrient storage)	0 ---------- 2 ---------- 4	IDK
Primary Production (energy capture, food chain support, energy flow for fish, benthic food chain)	0 ---------- 2 ---------- 4	IDK
Provision of Habitat (biodiversity support, habitat diversity)	0 ---------- 2 ---------- 4	IDK

7. On a scale from Strongly Unrelated to Strongly Related, how would you rate the following *provisioning services* in their relation to your research? (Slide the bar to select the appropriate rating)

   Provisioning Services – products obtained from ecosystems

Ecosystem Services	Strongly Unrelated Strongly Related	I don't know (IDK)
Fresh Water (water supply)	0 ---------- 2 ---------- 4	IDK
Food (wild game)	0 ---------- 2 ---------- 4	IDK
Fuel/energy (Hydro-electricity)	0 ---------- 2 ---------- 4	IDK
Genetic Resources	0 ---------- 2 ---------- 4	IDK
Ornamental Resources (beach glass jewelry, household decorations)	0 ---------- 2 ---------- 4	IDK
Biochemical, Natural Medicines, and Pharmaceuticals (medicines)	0 ---------- 2 ---------- 4	IDK
Fiber (timber production)	0 ---------- 2 ---------- 4	IDK

8. On a scale from Strongly Unrelated to Strongly Related, how would you rate the following r*egulating services* in their relation to your research? (Slide the bar to select the appropriate rating)

   Regulating Services - benefits obtained from the regulation of ecosystems

Ecosystem Services	**Strongly Unrelated** **Strongly Related**	**I don't know (IDK)**
Pollination	0 ---------- 2 ---------- 4	IDK
Regulation of Human Diseases	0 ---------- 2 ---------- 4	IDK
Biological Control (pest control, invasives)	0 ---------- 2 ---------- 4	IDK
Air Quality Maintenance (air purification, visibility)	0 ---------- 2 ---------- 4	IDK
Storm Protection	0 ---------- 2 ---------- 4	IDK
Erosion Control	0 ---------- 2 ---------- 4	IDK
Water Regulation (flood mitigation)	0 ---------- 2 ---------- 4	IDK
Climate Regulation (carbon storage, moderation of weather extremes)	0 ---------- 2 ---------- 4	IDK
Water Purification and Waste Water Treatment (water quality, waste assimilation, groundwater quality)	0 ---------- 2 ---------- 4	IDK

9. On a scale from Strongly Unrelated to Strongly Related, how would you rate the following c*ultural services* in their relation to your research? (Slide the bar to select the appropriate rating)

   Cultural Services - non-material benefits obtained from ecosystems

Ecosystem Services	Strongly Unrelated Strongly Related	I don't know (IDK)
Recreation and Tourism (lake recreation, wild game, song birds, other wildlife)	0 ---------- 2 ---------- 4	IDK
Aesthetic Values (aesthetics)	0 ---------- 2 ---------- 4	IDK
Sense of Place	0 ---------- 2 ---------- 4	IDK
Educational Values	0 ---------- 2 ---------- 4	IDK
Inspiration	0 ---------- 2 ---------- 4	IDK
Cultural Heritage Values	0 ---------- 2 ---------- 4	IDK
Social Relations	0 ---------- 2 ---------- 4	IDK
Cultural Diversity	0 ---------- 2 ---------- 4	IDK
Knowledge systems (cultural, economic, scientific knowledge)	0 ---------- 2 ---------- 4	IDK
Spiritual and Religious Values	0 ---------- 2 ---------- 4	IDK

10. Relative to the information needs of resource managers, how adequate is the ecosystem services-related information provided by **you and your research**?

	Greatly Inadequate More Than Adequate	I don't know (IDK)
Adequacy of ecosystem services-related Information provided by you	0 ---------- 2 ---------- 4	IDK

11. Relative to the information needs of resource managers, how adequate is the ecosystem services-related information provided by the **GLSC**?

	Greatly Inadequate **More Than Adequate**	**I don't know (IDK)**
Adequacy of ecosystem services-related Information provided by the GLSC	0 ---------- 2 ---------- 4	IDK

Part 3: Demographic Information

The last few questions ask about some demographic characteristics. Category-specific responses will not be reported unless there are more than 10 responses in the given category in order to avoid reporting information that can identify individuals.

1. What is your gender?
    a. ___ Male
    b. ___ Female
2. What is the highest level of education that you have attained?
    a. ___ Undergraduate degree
    b. ___ Master's degree
    c. ___ Doctorate degree
    d. ___ Other _____
3. How long have you been working with the GLSC?
    a. ___ 0-4 years
    b. ___ 5-9 years
    c. ___ 10-14 years
    d. ___ 15-20 years
    e. ___ 20+ years
4. Do you have any additional comments that you would like to share?
    a. (Open ended)

GLSC Research Scientist & Ecosystem Services

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Faculty Advisory: Bobbi Low, Professor of Natural Resources, University of Michigan School of Natural Resources and Environment

Committee Member: Jeff Schaeffer, Fisheries Biologist, USGS Great Lakes Science Center

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Science Advisor: Mary Anne Evans, Research Ecologist, USGS Great Lakes Science Center.

Introduction

The purpose of this research study is to evaluate the science program at the Great Lakes Science Center (hereafter GLSC) in the context of understanding ecosystem services. Thus, this interview is designed to gather background information and develop an empirical basis for analyzing whether the needs of resource managers in relation to ecosystem services are being met by the science conducted at the GLSC. Data will be collected from both Great Lakes resource managers (both U.S. and Canada) and GLSC scientists in relation to their consideration of ecosystem services in their respective work. Analysis will compare the information needs of resource managers and the information provided by GLSC scientists, and matches and mismatches will be highlighted.

I am interested in how GLSC scientists are thinking about ecosystem services as they conduct scientific investigations in the Great Lakes basin. With that in mind, please answer the following questions with respect to the work you are currently doing as a **research scientist** with the GLSC.

Participation in this interview is designed to take about 30 minutes and is completely voluntary. All the answers that you provide will be kept confidential and de-identified, and once the answers are transcribed, the digital copy will be deleted. You may terminate the interview at any time, and your data will be discarded.

Consent

1. Do you agree to take part in this interview?
   a. ____ Yes b. ____ No
2. Do you agree to allow the interview to be audio-recorded for transcription purposes?
   a. ____ Yes b. ____ No

3. This interview will also be audio-recorded for later transcription into a Word document. Anonymous quotations in written form may be used for the purposes of this study—analysis, reporting, etc. Do you agree to allow anonymous quotations from this interview to be used?
    a. ___ Yes b. ___ No

Part 1: Your research in the Great Lakes Basin

This section asks questions that try to determine what kind of scientific research you are conducting in the Great Lakes Basin as a **research scientist** for the GLSC.

1. Are you a research scientist for the GLSC?
    a. ___ Yes b. ___ No
2. What resource management agencies and stakeholders do you work with and how regularly? (Open ended)
3. At which GLSC station(s) is your research based? (Check all that apply)
    a. ___ Ann Arbor Station
    b. ___ Lake Erie Biological Station
    c. ___ Lake Ontario Biological Station
    d. ___ Lake Superior Biological Station
    e. ___ Lake Michigan Biological Station
    f. ___ Hammond Bay Biological Station
    g. ___ Tunison Laboratory of Aquatic Sciences
    h. ___ Cheboygan Vessel Base
4. In which of the following ecosystems in the Great Lakes Basin do you currently conduct research? (Check all that apply)
    a. ___ Open Water
    b. ___ Nearshore Zone
    c. ___ Coastal wetlands/marshes
    d. ___ Islands
    e. ___ Rivers and Streams
    f. ___ Forests
    g. ___ Dunes
    h. ___ Inland Lakes
    i. ___ Prairies
    j. ___ Urban Areas
    k. ___ Agricultural land
    l. ___ Other _____
5. In which of the following systems do you currently conduct research? (Check all that apply)
    a. ___ Lake Superior
    b. ___ Lake Huron
    c. ___ Lake Michigan
    d. ___ Huron-Erie Corridor
    e. ___ Lake Erie
    f. ___ Lake Ontario
    g. ___ Rivers and Streams
    h. ___ Inland Lakes
    i. ___ Other connecting channels
    j. ___ Other _____

6. Please tell me a little bit about the research questions you are investigating in the Great Lakes basin?
   (Open ended)

Part 2: Research on Ecosystem Services

The second section of the survey asks questions that try to determine what kind of research results and related information on ecosystem services you are providing to Great Lakes resource managers.

For consistency, I will use the Millennium Ecosystem Assessment's (MA) definition of ecosystem services as "the benefits people obtain from ecosystems." The MA further classifies ecosystem services according to four categories:

1) *Supporting Services* – services needed for the production of all other ecosystem services
2) *Provisioning Services* – products obtained from ecosystems
3) *Regulating Services* – benefits obtained from the regulation of ecosystems
4) *Cultural Services* – non-material benefits obtained from ecosystems

The purpose of the following questions is to find out what ecosystem services are being addressed in your research as a **GLSC research scientist**.

12. In your judgment, are you conducting research on ecosystem services in the Great Lakes Basin?
    a. ___ Yes b. ___ No
13. On which of the following *Supporting Services* do you directly conduct research? (Check all that apply)

Ecosystem Services	**Conduct Research on…**
<u>Supporting Services</u> – services needed for the production of all other ecosystem services	
Soil Formation and Retention (e.g. soil renewal, renewal of soil fertility)	
Production of Atmospheric Oxygen	
Water Cycling (e.g. soil moisture storage)	
Nutrient Cycling (e.g. nutrient storage)	
Primary Production (e.g. energy capture, food chain support, energy flow for fish, benthic food chain)	
Provision of Habitat (e.g. biodiversity support, habitat diversity)	

14. On which of the following *Provisioning Services* do you directly conduct research? (Check all that apply)

Ecosystem Services	Conduct Research on…
Provisioning Services – products obtained from ecosystems	
Fresh Water (e.g. water supply)	
Food (e.g. wild game)	
Fuel/energy (e.g. Hydro-electricity)	
Genetic Resources	
Ornamental Resources (e.g. beach glass jewelry, household decorations)	
Biochemical, Natural Medicines, and Pharmaceuticals (e.g. medicines)	
Fiber (e.g. timber production)	

15. On which of the following *Regulating Services* do you directly conduct research? (Check all that apply)

Ecosystem Services	Conduct Research on…
Regulating Services – benefits obtained from the regulation of ecosystems	
Pollination	
Regulation of Human Diseases	
Biological Control (e.g. pest control, invasives)	
Air Quality Maintenance (e.g. air purification, visibility)	
Storm Protection	
Erosion Control	
Water Regulation (e.g. flood mitigation)	
Climate Regulation (e.g. carbon storage, moderation of weather extremes)	
Water Purification and Waste Water Treatment (e.g. water quality, waste assimilation, groundwater quality)	

16. On which of the following *Cultural Services* do you directly conduct research? (Check all that apply)

Ecosystem Services	Conduct Research on…
Cultural Services – non-material benefits obtained from ecosystems	
Recreation and Tourism (e.g. lake recreation, wild game, song birds, other wildlife)	
Aesthetic Values (e.g. aesthetics)	
Sense of Place	
Educational Values	
Inspiration	
Cultural Heritage Values	
Social Relations	
Cultural Diversity	
Knowledge systems (e.g. cultural, economic, scientific knowledge)	
Spiritual and Religious Values	

    a. Choose one ecosystem service from the previous lists and explain how it relates to your research (if applicable).
    (Open ended)

17. In your opinion, are any additional ecosystem services important to the management of Great Lakes resources?
    (Open ended)
18. In your opinion, is it appropriate to consider ecosystem services when managing Great Lakes resources?
    a. ___ Yes b. ___ No
19. What do you think are some benefits to considering ecosystem services when managing Great Lakes resources?
    (Open ended)
20. What do you think are some drawbacks to considering ecosystem services when managing Great Lakes resources?
    (Open ended)
21. Comments?

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