Het gebruik van informatie over ecosysteemdiensten voor milieu-besluitvorming

The Use of Ecosystem Services Information for Environmental Decision-Making

Thesis

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Samenvatting

Dit proefschrift is een verkenning van het gebruik van informatie over ecosysteemdiensten in het beleid. Onderzoekers gaan vaak uit van de veronderstelling dat informatie over ecosysteemdiensten een wijze van definiëren en waarderen van de functies van ecosystemen is het belang van milieubescherming beter laat doorklinken in de beleidsontwikkeling. In het onderzoek werd nagegaan hoe waarden van ecosysteemdiensten kwalitatief en kwantitatief begrepen worden, en hoe deze waarden duurzame maatschappelijke transformaties kunnen beïnvloeden. Daarbij gaat het niet alleen om de uiteindelijke beleidsbeslissingen zelf, maar ook om de beslissingsondersteunende methoden die daarbij gebruikt worden. Een centraal begrip in dit onderzoek is 'sustaining ecosystem services', de meetbare ecologische condities en uitkomsten die relevant zijn voor het nut van de belanghebbenden. De centrale vraag is of het gebruik daarvan effectievere sociaal-economische strategieën van milieubescherming oplevert: en zo ja, welke besluitvorming daar het meest gebaat is.

De methoden van onderzoek worden besproken in hoofdstuk 1. Aktieonderzoek werd toegepast in een samenwerking met een deel van de milieumanagers van het Nationaal Estuarien Programma in de VS (NEP). De populatie voor dit onderzoek bestond uit managers van 28 geografisch gedefinieerde programma's. Estuarine beheersprogramma's hebben met succes gebruik gemaakt van methoden voor de waardering van ecosysteemdiensten, kwalitatief en kwantitatief, voor het stellen van doelen voor milieubescherming en -herstel, en voor de communicatie met belanghebbenden.

De hoofdstukken 2 en 3 gaan over de verschillende methoden om ecosysteemdiensten te waarderen, en de analytische kaders waarmee de waarde van ecosystemen in de besluitvorming ingebracht kan worden. Waardering kan zich richten op zowel een locatie als op stromen van economische hulpbronnen (of beiden). Er werd een onderscheid gemaakt tussen objectieve, marktwaarden en waarden in subjectieve voorkeuren. Het continuum van kwalitatieve en kwantitatieve besluitvormingsmethoden werd besproken die relevant zijn voor maatschappelijke transities naar duurzaamheid. Dit continuum laat zien dat voorkeuren voor duurzaamheid voortkomen uit waarden, en dat besluitvormingsmethoden mogelijkheden bieden om resultaten te waarderen ook al zijn velen daarvan moeilijk kwantitatief meetbaar. Het integreren van ongelijksoortige informatie en percepties (en waarden) bleek het nuttigst te zijn in conteksten diverse belanghebbenden, en uiteenlopende belangen. Die conteksten komen vaak voor als het gaat om natuurlijke hulpbronnen en duurzaamheidsproblemen, waarvan vaak gedacht wordt dat ze om een vorm van afruil (milieu versus economie) vragen.

In hoofdstuk 3 (gepubliceerd in een peer reviewed journal) worden de methoden in kaart gebracht waarmee waarden op een transparante manier tot uitdrukking kunnen komen in besluitvorming over duurzaamheid. Empirische, normatieve en andere besluitvormingsmethoden worden besproken aan de hand vvan een architectuur die ontleend is het de idee van Aristoteles over Episteem, Techne en Phronesis. De toepassing van en de beperkingen aan de besproken methoden in de objectieve analyse voor besluitvorming wordt verkend door de bespreking van 'wicked' en 'tame' problemen (het schema dat vaak gehanteerd wordt bij de bespreking van waarderingsmethoden en 'post-normal science'). Een belangrijke conclusie is dat beleidsmakers

gestuurd worden door geïnternaliseerde waarden – normatieve, paradigmatische, mathematische of andere. Het concept phronese wordt gebruikt om in kaart te brengen hoe deze waardeoriëntatie van belang is in het denken over en het beoordelen van kwantitatieve informatie over afruil in complexe systemen; dat geldt in het bijzonder voor beslissingen die gaan over een balangs tussen milieu-, maatschappelijke en economische uitkomsten (duurzaamheid).

In hoofdstuk 4 komen de bevindingen aan de orde uit het aktieonderzoek met de 'Association of National Estuary Programs (ANEP), en presenteert de resultaten van de NEP enquete (gepubliceerd in een peer reviewed journal). Met de enquete werd verkend hoe het concept ecosysteemdiensten getypeerd is, en gebruikt ter ondersteuning van de besluitvorming en ter bevordering van het succes van strategieën voor milieubescherming en het beheer van estuaria. Het ging in dit onderzoek vooral om de ervaren baten van het identificeren van de waarde van ecosysteemdiensten in verschillende functies van estuaria. Het waarderen van ecosysteemdiensten werd het meest toegepast om beleidsissues in te kaderen, en een basis te leggen voor gesprekken over waarden die belangrijk zijn voor belanghebbenden. Managers van estuaria die zelf rechtstreeks ervaring hadden met het de waardering van ecosysteemdiensten vonden deze benadering twee maal zo vaak nuttig als collega's die het begrip alleen kenden. Andere conclusies zijn:

- Estuarine beheersprogramma's heben succesvol gebruik gemaakt van methoden voor de waardering van ecosysteemdiensten, zowel in kwalitatieve als in kwantitatiee zin, om doelen voor milieubescherming en -herstel te formuleren and daarover te communiceren met belanghebbenden.
- Het gebruik van informatie over ecosysteemdiensten is nuttig voor beleidsmakers en heeft een positieve invloed op het bereiken van de gestelde doelen.
- Informatie over ecosysteemdiensten kan gebruikt worden om het belang van ecologische gezondheid en de integriteit van ecosystemen duidelijk te maken aan belanghebbenden en de samenleving.
- Inzicht in hoe informatie over ecosysteemdiensten benut kan worden voor communicatie met belanghebbenden en het stellen van prioriteiten van beheer en investeringen leidt tot een grotere waardering bij beleidsmakers voor deze benadering. Het leidt ook tot een grotere bereidheid om informatie te verzamelen over de waardering van ecosysteemdiensten en deze informatie daadwerkelijk te benutten.

De theorie die gebruikt werd om de data uit het onderzoek te evalueren en te interpreteren was die van Jürgen Habermas, de 'theory of communicative action'. Daarnaast werd ook de theorie van ecologische modernisering gebruikt, en in mindere mate de theorie van institutionele verandering. Deze theorieën worden besproken in hoofdstuk 5. Ze werden vooral gebruikt om te onderzoeken of en hoe een kwalitatief bewustzijn van ideeën in de samenleving de adoptie kunnen ondersteunen van kwantitatieve methoden voor het evalueren van de resultaten van besluitvorming. Een belangrijke bevinding in de NEP enquete was dat de gebruikte informatie over ecosysteemdiensten vooral kwalitatief van aard was, en tegen lage kosten verworven. Daar tegenover staat dat de informatie van de meeste veldonderzoekers kwantitatief van aard is, en tegen hoge kosten verkregen. De theorie ondersteunt de conclusie dat een toenemend gebruik van kwalitatieve informatie over ecosysteemdiensten in de samenleving kan leiden tot steun voor meer kwantitatieve informatie. Daarmee kunnen belangrijke milieurelevante beslissingen ondersteund worden, zoals in de ruimtelijke ordening.

Een andere belangrijke conclusie uit dit onderzoek: het waarderen van ecosysteemdiensten – als een methode voor de waardering van de functies van ecosystemen – is een belangrijke strategie om informatie in te brengen in processen van besluitvorming over milieubescherming. De inkadering van die besluitvorming, en de daarbij gehanteerde methode zijn dat echter ook. Het interpreteren van de bevindingen van het onderzoek met de theorie van communicatieve actie ondersteunde de hypothese dat het gebruik van kwalitatieve concepten van ecosysteemdiensten, tegen lage kosten, leidt tot steun – sociaal en institutioneel – voor meer kwantitatieve waarderingssystemen voor ecosysteemdiensten, maar wel tegen hogere kosten.

Tot slot een theoretische conclusie: Informatie over ecosysteemdiensten, met de drie dimensies van ecologische functies, maatschappelijke waarden en economische 'value accounting', kan een brug vormen tussen de normatieve, kwalitatieve wereld en de positivistische, rationaliserende dominante factor in institutionele kwantitatieve besluitvormingsprocessen. Het inbedden van kwalitatieve en kwantitatieve informatie over ecosysteemdiensten kan een brug zijn tussen de normatieve belief systems in de samenleving en de analytisch-deliberatieve processen (zoals kostenbatenanalyse) die instituties gebruiken bij besluitvorming. Daarmee ontstaat een vorm van cognitieve harmonie. Dit staat in contrast met de cognitieve dissonantie die ontstaat bij sociale idealen die haaks staan op de resultaten van eerdere beslissingen. De drie dimensies van ecosysteemdiensten is consistent met de drie dimensies breed toegekend worden aan duurzame ontwikkeling. Het kan goed zijn dat het gebruik van informatie over ecosysteemdiensten leidt tot de toename in het gebruik van methoden voor duurzame besluitvorming. Het omgekeerde geldt ook: het toenemende gebruik van methoden voor duurzame besluitvorming leidt tot een bredere toepassing van informatie over ecosysteemdiensten.

Summary

This thesis explored the use of ecosystem services information in environmental decision-making. The research questioned the presumption held by researchers in this field that ecological service valuation, as a means to define and value the function of ecosystems, offers an improved means for delivering information about the importance of environmental protection to decision-making processes. The research examined how value is understood, both quantitatively and qualitatively, in making decisions about how we use or preserve our natural environment. Also explored is how the understanding of value can influence sustainable societal transformations not only through the resulting decisions, but also through choices of the frameworks used to support decision-making. The research sought to explore whether the concept of *sustaining* ecosystem services (characterized as measurable ecological conditions/outcomes providing utility defined by stakeholders) is useful information to promote the success of socio-economic strategies for environmental protection; and if so, what decisions might best benefit from the information.

Research methods are discussed in Chapter 1. Action research methods were employed to work directly with a sample population of environmental managers in the U.S. National Estuary Program (NEP). The study population was comprised of 28 geographically defined programs. Estuary management programs have used ecosystem service valuation successfully, both quantitatively and qualitatively, to set environmental protection and restoration objectives, and to communicate to stakeholders.

Chapters 2 and 3 focused on different approaches to the valuation of ecosystem services, and frameworks that can represent the value of ecosystem services in decision-making. Value assessments may focus on place or economic resource flows, or both. A distinction was made between objective, market-based values, and values that are subjective preferences. A continuum of quantitative to qualitative decision-making methods was discussed as relevant for including different types of information important for the transition to more sustainable societal patterns. The continuum is an acknowledgement that sustainability preferences are driven by values, and that decision-making methods provide a means to value outcomes, many of which may be difficult to quantify. The integration of disparate information and perceptions (and values) has been demonstrated to be the most useful in settings with a variety of stakeholders who may value different outcomes. Such conditions are typical in natural resource and sustainability problems where trade-offs are often perceived.

In Chapter 3, a published literature review explored methods for transparently incorporating values in sustainability decision-making. Empirical, normative and other decision-making methods were discussed using a conceptual architecture borrowed from the Aristotelian ideas of Episteme, Techne and Phronesis. The application and limits to positivist reasoning for decision-making is explored through discussions of wicked and tame problems, the analytic-deliberative framework that characterizes most assessment methods, and post-normal science. A conclusion was that decision-makers are guided by internalized values – normative and paradigmatic, mathematical or otherwise. The concept of phronesis is introduced to describe how this value orientation is key to the judgement used in deliberating on quantitative information for resolving

the tradeoffs in complex systems, and in particular sustainability decisions balancing environmental, social and economic outcomes.

Chapter 4 reports on the findings from the action research with the Association of National Estuary Programs (ANEP), and presents the results of the NEP survey research, as published in a peer-reviewed journal. The survey research explored how the concept of ecosystem services has been characterized and used to aid decision-making, and to promote the success of environmental protection strategies in the management of estuaries. The research examined the perceived benefits from articulating the value of ecosystem services in various NEP functions. The most widespread use of ecosystem service valuation information was to frame issues and to ground discussions in values that are important to stakeholders. NEP managers who had some direct experience with the use of ecosystem service valuation were nearly twice as likely to assert "ecosystem services information is useful" as those who were merely alert to the concept. Other significant conclusions included:

- Estuary management programs have used ecosystem services valuation successfully, both quantitatively and qualitatively, to set environmental protection and restoration objectives and to communicate to stakeholders.
- Use of ecosystem services valuation information is useful to decision-makers and promotes achievement of environmental protection objectives.
- Ecosystem services valuation information can be successfully employed to communicate the importance of ecological health and ecological systems' integrity to society or stakeholders.
- A qualitative awareness of how ecosystem services information can be used to communicate with stake- holders, and aid in prioritization of operations or investment, appears to lead to a stronger appreciation in managers for the use of ecosystem services valuation information, and a greater willingness to collect and use ecosystem services valuation information.

The primary analytical theory relied upon to interpret and evaluate data was Jürgen Habermas' Theory of Communicative Action. The Theory of Ecological Modernization is also used, and to a lesser degree, Institutional Change Theory. These theories are discussed in Chapter 5, and are used in major part to examine the significance of qualitative awareness of ideas in society supporting the eventual adoption of quantitative methods for evaluating environmental outcomes of decisions. A prominent finding in the NEP survey research conducted was that ecosystem services information relied upon by NEPs was largely qualitative – and low cost. In comparison, the ecosystem services information being generated by most field researchers is quantitative, and can be expensive to obtain. The theories support a conclusion that increased qualitative use of ecosystem services information in society can lead to support over time for its more quantitative use to inform important environmental decisions, such as land-use.

Another key conclusion of this research is that ecological service valuation, as a means to define and value the function of ecosystems, is an important strategy to provide information about the importance of environmental protection to decision-making processes, but that the framework for decision-making, itself, is also an important dimension contributing to the success of the outcome. Interpreting the research findings through the Theory of Communicative Action supported a hypothesis that the use of qualitative ecosystem services concepts, at low cost, will lead to support, both socially and institutionally, for more quantitative ecosystem service valuation metrics that require greater investment.

Finally, a theoretical conclusion is that ecosystem services information, with the three dimensional structure of ecological function, societal values, and economic value accounting can bridge between the normative, qualitative social world and the positivist, rationalization dominant in quantitative institutional decision processes. The incorporation of reinforcing and complementary qualitative and quantitative information from ecosystem services can bridge between society's normative belief systems and the analytical-deliberative processes (e.g. cost-benefit analysis) used by institutions in decision-making, to foster cognitive harmony. This is in contrast to the prevalent cognitive dissonance fostered by social ideals at odds with the widespread result of cumulative decisions. The three dimensional structure of ecosystem services is also consistent with the analytical structure widely espoused to describe sustainable development. This suggests that the use of ecosystem services information will be reinforced through adoption of sustainability decision-making frameworks; and the inverse, that sustainability frameworks will be well-served by information on ecosystem services.

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AAAS – American Association for the Advancement of Science
ANEP – Association of National Estuary Programs
BIOMOT – Motivational strength of ecosystem services and alternative ways to express the value of biodiversity
CCMP – Comprehensive Conservation and Management Plan
CICES – Common International Classification of Ecosystem Services
CO_2 – Carbon Dioxide
CoP – Community of practice
CWA – U.S. Clean Water Act
EPA – U.S. Environmental Protection Agency
ESA – U.S. Endangered Species Act
ES – Ecosystem Services
ESV – Ecosystem service valuation
FEGS – Final Ecosystem Goods and Services
MAUT – Multi-Attribute Utility Theory
NAAQS – National Ambient Air Quality Standards
NEA – National Economic Accounts
NESCS – National Ecosystem Services Classification System
NEP – National Estuary Program
PES – Paying for Economic Services
PM – Particulate Matter
PNAS – Proceedings of the National Academy of Sciences
PNS – Post-normal Science
RA/ RM – Risk Assessment and Risk Management
SEEA – System of Integrated Environmental and Economic Accounting
TCA – Theory of Communicative Action
TEEB – The Economics of Ecosystems and Biodiversity (a project administered by the United Nations Environment Programme)
TEV – Total Economic Value
TMDL – Total Maximum Daily Load
SES – Social-Ecologic Systems
UNEP – United Nations Environment Program
VoI – Value of Information

Nature, in its ministry to man, is not only the material, but is also the process and the result.
- Ralph Waldo Emerson

1. Introduction

This thesis was an exploration of the nexus between ecosystem services as information for decision-making, values as expressed quantitatively and qualitatively in decision making, and how decision making frameworks could be used to advance sustainable societal transformations.

Environmental decision-making is supported by assessments of value. A distinction is made between objective, market-based values, and those that are subjective preferences based on personal values. Environmental value assessments focus on place or resource flows, or both. This is as true for mining bauxite to support global aluminum demand as it is for finding a place to rest in the shade. Environmental decision-making can be contentious when there are competing ideas for how the environment should be used or valued. If your shade tree is valued by someone else for firewood there is competition for that tree's service. Not all environmental decisions reflect competition, but they all entail an assessment and optimization of values, both objective and subjective. Objective environmental value has been most readily accounted for as income from use or extraction of resources from the environment. This is a commodified type of ecosystem service that is easily and routinely quantitatively valued (monetized).

Thus, an ecosystem service is a concept for describing how the natural environment is used and valued by people and society. An ecosystem service is something we need, want or value about the natural environment. The term "ecological services" was first used in the 1960s, in reference to the benefits ecosystems provide (Irwin & Ranganathan, 2007). Implicit in the term "ecosystem service" is something of value (or service) produced by an ecosystem. The connection of the service to an ecosystem is an essential analytical dimension of the concept because it establishes a reasoned linkage between the production function of the ecosystem and the service to society. Although the term "ecosystem service" is used loosely and inconsistently in the literature (Landers and Nahlic, 2013), it can be defined for specific purposes or be used loosely to facilitate general discussion – much like alternative usages of the term sustainability.

Ecosystem service valuation has been proposed as a tool to improve the outcome of environmental decision-making (MEA, 2005; TEEB, 2010b). While there have been decades of valuation evidence produced with the explicit objective of helping policy-makers take better account of environmental benefits and costs when making decisions, this evidence has largely not been translated into tangible improvements in terms of environmental outcomes (Kenter et al., 2015).

The conviction none-the-less remains that including information on ecological services, including valuation, offers an improvement of the design, measure and success of strategies for environmental decision-making. Ecosystem service valuation research was/is conducted with the belief that knowledge about the value (economic or otherwise) of ecological services will help characterize the benefits to society from the protection of ecological systems, particularly in comparison with the monetized benefits from economic development (Costanza, et al, 1997). This belief was predicated on rational decision-making, and on the presumption that additional

information about the value of ecosystem services will improve the representation of environmental protection outcomes in discussions of the merit of economic development of natural resources (Wegner & Pascua, 2011, Irwin & Ranganathan, 2007; Farber et al, 2002).

The primary objective of the author of this thesis was to improve the understanding of how knowledge of the consequences to ecosystem services from use of the environment can affect environmental management decisions; also if such knowledge may be better suited to informing certain types of decisions.

A second, related area of inquiry developed as a result of the literature review on decision science, sustainability science and the Theory of Communicative Action. This inquiry focused on whether the ecosystem services concept, as an input to decision-making, can enhance sustainable development or the adoption of sustainability as a framework for decision-making. Sustainability is a concept linked with protection of the environment – in conjunction with advancing social justice and economic equity (UN, 1987).

Inquiry into how defining and valuing ecosystem services can make useful contributions to environmental decision-making is important for two reasons:

> Firstly, as the search of the ecosystem services literature revealed, significant research focus and funding have been dedicated to developing data and analytical tools to support the use of ecosystem services. The dedication of scientific careers and research budgets have an opportunity cost.
>
> Secondly, environmental decision-making is a wide field of endeavor, ranging from dedication of habitat for endangered species and the siting of roads and buildings, to the establishment of priorities for land restoration and clean-up of contaminated sites. The use of ecosystem services may be more advantageous for some decisions and less for others. It would be prudent to target ecosystem services research and valuation tools to those decisions that would most benefit and most effectively demonstrate proof of the concept's utility.

1.1. Thesis outline

This dissertation is organized into seven chapters. Chapters one and two introduce the research and the concept of ecosystem services. Chapter three introduces the sustainability concept from the literature review and includes a published article titled: *Incorporating values into sustainability decision-making*. The article investigated issues and concepts in decision making relevant to the dissertation topic, but also discussed the implications of the values represented by use of sustainability science for environmental decision making. The sustainability theme arose from recognition that the explicit purpose of using ecosystem services reflected intent by ecosystem service researchers and advocates to better incorporate environmental conservation and protection values into land-use decisions and other economic, social and environmental decision making, in an effort to better sustain the health of the natural environment.

This thesis researcher asserted that ecosystem services and sustainability share a common essential structure that integrates environmental, social and economic dimensions. The question of how to incorporate values in decision making, specifically those values that advance the idea of sustainability, became a central theme for this research that affected the choice of research methods, guided the literature review, and animated the conclusions. Other elements of the literature review appear throughout the dissertation. Chapter four presents the empirical research that was conducted and includes a published article titled: *The use of ecosystem services information by the U.S. National Estuary Programs*. This article provides detailed description of the research methods used, discussion of results, and conclusions from that research. Chapter five presents the results of the analysis and discussion of the empirical research, employing context from the literature review, and also introduces the theoretical interpretations of the results to expand upon the empirical conclusions drawn in Chapter four. Chapters six and seven present conclusions and reflections on the research questions, methods and findings, with recommendations for future research.

1.2. Research questions for this thesis

The thesis research explored how the concept of ecosystem services has been characterized and used to inform environmental decision-making in a sample population of environmental managers. The empirical research was designed to examine how ecosystem services information was used to promote the success of estuary protection strategies in selected estuaries of the United States. This included informing program planning priorities, communication with stakeholders, and evaluation of trade-offs between ecological preservation and economic development (e.g. cost-benefit analysis).

The purpose of the empirical research was to survey and to assess the perspectives and experiences of environmental managers on the use of ecosystem service valuation in the planning and management of estuary resources in order to learn if the use of ecosystem services information resulted in any of the positive outcomes for environmental protection expected by those who assert its utility. The preliminary research questions used to frame this thesis research were:

- Does information on ecosystem service valuation provide value to decision-makers and does it increase progress in achieving environmental protection objectives?

- Is communication of ecosystems' economic service values to societal stakeholders a demonstrated successful technique for communicating the importance of ecological health and ecological systems' integrity?

- In what ways did the communication of ecosystem services influence environmental decision-making outcomes in market arbitrated decisions within the sample population?

The preliminary research questions are addressed in Chapter 4. The theoretical inquiry and literature review provided contextual understanding and informed responses to the above

research questions, but also led to formulation of new questions. The following supplemental research questions provided both a finer level of detail and a broader perspective for examining the use of ecosystem services for decision-making. The following research questions below were addressed in Chapters two, three and five.

- Can the concept of ecosystem service have a value in decision-making regardless of whether quantified values are assigned to the services?

- Can the framework for decision-making have effects on the influence of ecosystem services information in the decisions that are made?

- Is there relevance in the similarity of analytical dimensions between ecosystem services and sustainability (i.e. environmental, societal, economic)?

1.3. Research methods, research strategy and theoretical approach

The Research Methods

The research methods used to support this thesis research included action research, two surveys, expert elicitation, a comprehensive literature review, and reflection on Jürgen Habermas's Theory of Communicative Action (Habermas, 1984 & 1987). The action research was conducted with the U.S. Environmental Protection Agency (EPA) National Estuary Program (NEP) managers, who helped to define the scope of the overall research and shaped the survey research.

Action Research

Action Research was characterized by Reason and Bradbury in the "Handbook of Action Research" (2001) as "research with, rather than on practitioners… in effect action research bypasses the traditional, constructed separation between research and application."[1] Action research was selected as a research method because it provided a rich, engaging and contextual means to understand the types of decisions made in NEPs. It also provided a process to gain an understanding of how some NEP managers had come to an awareness of ecosystem services as an information resource, and thus, how best to appeal to NEP managers as participants in the survey research. The contextual understanding of NEP's decision making processes and program objectives helped in the interpretation of the empirical information collected by survey.

This thesis researcher engaged with managers of NEPs who were early adopters of ecosystem services concepts to assess how to explore the use of ecosystem services information by the larger population of NEP managers. These NEP managers advocated for the use of the ecosystem service information by their colleagues, because they believed that use of the information can improve environmental decision making. In addition to the direct communications with select managers, the action research also included conference presentations about ecosystem services to NEP managers and interaction within a semi-structured community of practice.

[1] See page pg. xxv.

Initial conversations held with managers from the Tampa Bay, Narragansett, and Delaware Bay Estuary NEPs (early adopters), and with EPA employees who worked with NEPs, were focused upon the varying levels of awareness and use of ecosystem services information within NEPs. The conversations resolved that awareness of ecosystem services concepts could be advanced through educational sessions at twice-annual Association of National Estuary Program (ANEP) meetings. A more detailed examination of NEP managers' ideas about how ecosystem services information was used helped inform decisions on how to frame questions in subsequent surveys and structured interviews. This researcher then contacted NEP leadership and proposed workshops on the use of ecosystem services valuation for decision making at two national NEP meetings in 2008. This researcher worked closely with NEP managers who were early adopters to shape the presentations so they would be useful to NEP managers who were unfamiliar with, or minimally aware of ecosystem service concepts. This researcher discussed with the early adopters if a community of practice[2] would be a constructive means to allow other interested NEP managers to follow up on interest expressed at the ANEP meeting presentations. It was agreed that the community of practice model had features that would be desirable. The model required no more time than participants chose to give, and allowed for varying degrees of participation.

Following the November 2008 NEP meeting this researcher discussed with the ANEP Executive Director, Mr. Berman,[3] about creating an opportunity for a committee of the ANEP to self-select to advance the discussion of ecosystem services among NEPs. The ANEP Board agreed to the formation of a self-selected "community of practice" and Mr. Berman notified the ANEP membership of the opportunity. The community of practice is further described in Chapter 4 (Methods, Section 2.2).

Draft research questions were then formulated by this researcher and discussed with the early adopters and select EPA staff colleagues. The questions were validated and refined. The choice of various research strategies, including case studies, interviewing and surveys were discussed. The decision to use a survey research method was made based upon a general agreement that the less time required by NEP managers to participate, the better would be the participation rate. The NEP early adopters and EPA colleagues agreed that the research study would make a useful contribution to the subject literature.

Action research has been criticized as non-objective, and too tailored to unique and non-reproducible circumstances to be of any transferable value. The question of objectivity is addressed in Chapter 3, and the conclusion made that social science is of greatest value when it provides information that helps people to understand how best to serve the interests of society. The research conclusions presented in Chapter 6 were made to serve that objective.

This researcher wove the concept of sustainability throughout this dissertation. Sustainability is not an idea solely dependent on objective, positivist knowledge; insofar as it is highly contextual

[2] A Community of Practice (commonly abbreviated as CoP) is increasingly recognized as both an informal and a formal means for shared learning and information communication.
[3] The 2008 ANEP Executive Director was Dan Berman (Morro Bay, CA).

on a dynamic interplay between environmental, social and economic conditions. There is no final and universal state of sustainability; and this was also discussed in the context of sustainability science in Chapter 3. Action research has its own scientific rigor, and a tenet is reasoned explanations of why actions are taken. It is distinctive for its purpose in advancing a desired outcome, and not only seeking to discover new facts of knowledge. In this dissertation the purpose of employing action research was to improve the outcomes of environmental decision making through the incorporation of information regarding relevant ecosystem services.

The Survey Research

This thesis researcher prepared a survey questionnaire in 2009 with input from several members of the community of practice, including members of the ANEP board. The information collected was used by the community of practice to inform agendas for two follow-up conversations convened by this researcher that occurred in 2010. Subsequently, a final presentation was made to the ANEP at their December 2010 annual meeting on applications for coastal assessment of ecological services. A final survey was administered in 2011 to the members of the ANEP community of practice by phone interview. The managers of the other NEP member organizations of the ANEP were contacted by email on three separate occasions over a period of four weeks in August and September 2011. They were requested to respond to an on-line web survey. Greater detail on survey methods is included in the published research, which is included in Chapter 4.2.

Expert Elicitation

Experts were identified following completion of the survey research, and their opinions sought on survey design and the conclusions of this researcher drawn from survey responses. The elicitation was an internal check on the reasonableness of this researcher's interpretations and conclusions from the NEP survey responses. More detail on expert elicitation is provided in Chapter 4.3.

Literature Review

The literature review followed a methodical strategy to gain understanding of approaches and methods for decision making. The relevance of decision science to this dissertation is easily understood, but the focus on sustainability science requires explanation. Sustainability science was understood by this researcher as a framework to inform decision making that shared a structure similar to the analytical dimensions of ecosystem services. The similarity is based upon both ideas' integration of environmental, social, and economic attributes, which is explored in greater detail in Chapter five. This decision opened an important investigation of reciprocal reinforcement between sustainability decision making and the ecosystem services concept; specifically, how can the use of ecosystem services valuation advance the utility of sustainability as a decision-making framework, as well as can the use of sustainability as a decision-making framework advance the utility of ecosystem services valuation?

Theoretical Framework

Extended reflection on Habermas's Theory of Communicative Action was used as an important methodological strategy for interpreting and extrapolating the findings of the surveys and action research from the specific to the general. The explanatory power of communicative action was employed in shaping the inquiry into sustainability as a decision-making framework, for developing conclusions, and formulating recommendations for further research.

Research strategy and theoretical approach

This dissertation evolved from initial questions concerning whether the application of ecosystem services information to environmental decision-making improves environmental outcomes. It progressed from a literature review, and formulation of research questions, to a theoretical framework for analysis, and to the assemblage of findings in the literature review with interpretation of research results, from which the author developed conclusions.

This dissertation was developed following the tenets of action research (Reason and Bradbury, 2001), and sustainability science (Kates, 2011). They share a common approach to problem definition and study that is dedicated to purposeful societal outcomes. This is consequential for two reasons. First, these approaches allowed this thesis author the opportunity to reexamine and refine the research objectives and questions as information framing the issue or problem was discovered. The reliance of this researcher on interaction with representatives from the study population advanced the evolution of the inquiry. New study questions arose as this researcher considered the survey results in the context of Habermas's Theory of Communicative Action, which are discussed in Chapter five. Conclusions stemming from the new questions were derived from insights from the study population and from the nexus of empirical and theoretical study, and are presented in Chapter six.

Secondly, societal outcomes following from decisions – both personal and institutional are influenced by desires, and thus values. The central question in this research was whether putting a value (monetary or otherwise) on the environment can have an influence on the outcome of decisions that result in environmental impacts (e.g. whether to convert a wetland into a parking lot). These values are highly variable based on what value society places on wetlands vs. parking lots (the ratio changes over time and place). However, values are philosophical pre-dispositions that affect decisions. The subjective or normative predisposition of the decision-maker, or institutional context for the decision is a factor in how information is used (or valued), and thus affects the outcomes. For example, a neo-classical economist may choose to discount the value of an ecosystem service because s/he believes that it is essentially substitutable at the right price point.

Values are a driver in societal outcomes that can be characterized qualitatively and measured quantitatively (Martin, 2015). Values are a dynamic factor in decision-making and societal outcomes, in that they can change through time and place, and with different decision-makers, resulting in different outcomes. Understanding how to account for the significance of values in the use of information for decision-making was unanticipated, but became a lengthy and fruitful area of study in this dissertation. It led to an examination of how the value foundation of a decision framework could influence the choice of incorporating ecosystem services, or not. This is addressed further in Chapter 3.

Study Population.

The U.S. EPA National Estuary Program (NEP) was the sample population for the survey and action research. The NEP is comprised of 28 geographically defined programs on all coasts of

the continental United States formed around community partnerships. The NEPs were created expressly as public-private partnerships to engage all elements of society in a place-based approach to the protection of estuaries and associated watersheds. The study population is heterogeneous, but is clearly demarcated by subscription to EPA's National Estuary Program.[4] The EPA established the NEP to protect and restore the water quality and ecological integrity of estuaries of national significance pursuant to the 'Estuaries and Clean Waters Act of 2000 under Section 320 of the 1987 Clean Water Act Amendments. Individual NEPs were created to foster development of community partnerships for the protection of an area's specific estuary and watershed. The individual NEPs are managed through local decision-making processes that rely heavily on stakeholder involvement, interaction and consensus. The collaborative decision-making process relies on the effective diffusion, transparency, and use of information to substantiate and define objectives, as well as to manage operations and to assess performance. The NEPs were considered to be an ideal population for studying the significance of improved ecological information on environmental management decision-making because of the organizational emphasis placed on use of information for rational objective setting and program operations. Further detail on the NEPs is provided in Chapter 4.

1.4. Environment, nature and ecosystems

People have a normative sense of their natural environment conditioned by their experience and the traditions of their culture. Environment means different things to different people. Traditional peoples in the cold circumpolar region, such as the Yupik, Inuit, and Unangam understand natural cycles of weather, wildlife and seasons intimately because their survival depends upon this knowledge. Similarly, fishermen know their local waters and weather well, because their livelihood is dependent on their knowledge of place. Rural folks the world over also tend to be knowledgeable of the natural areas they inhabit because features such as wildlife and weather are prominent in their daily life. The environment is our physical world, of which there are both natural and built elements. In western societies, the majority of the population now lives in an urban built environment, and their experience of the natural environment is primarily recreational. Weather is for the most part an optional experience, except in the event of extreme storms. This differs markedly from how earlier, more rural, generations experienced their environment. Since the 1970s, for many people the environment has become a sort of basket of indicators describing the quality of air, and water as regulated under environmental statutes. We are informed that our surface water quality is good when dissolved oxygen, nitrogen levels, and a host of other chemical and physical conditions are within prescribed limits, and that our air is healthy to breathe on "code green" days. In general, however, most people now are sufficiently removed from their natural environment, so as to take the living conditions it supports for granted.

In the 19th and early 20th centuries, the American romanticists characterized the environment as a sort of transcendent *nature*. Emerson, a leading romanticist, in his short book, NATURE (Emerson, 1903), made a distinction in how people perceive the *environment* that is highly relevant to the discussion of ecosystem services. The first two chapters of NATURE are titled

[4] http://water.epa.gov/type/oceb/nep/index.cfm Accessed on 9-30-17

respectively, Nature, and Commodity. The distinction made between nature and commodity reflects a key difference between how ecosystem services are valued, as either an intrinsic quality or a denominated commodity. This distinction also mirrors a very deep divide in how people think about what they know – qualitatively, based on subjective and normative values, or quantitatively with learned precision. These are important themes for this dissertation and are discussed further in later sections.

With regard to 'Nature,' Emerson wrote:

> Nature never became a toy to a wise spirit. The flowers, the animals, the mountains, reflected the wisdom of his best hour, as much as they had delighted the simplicity of his childhood. When we speak of nature in this manner, we have a distinct but most poetical sense in the mind. We mean the integrity of impression made by manifold natural objects. It is this which distinguishes the stick of timber of the wood-cutter, from the tree of the poet. The charming landscape which I saw this morning, is indubitably made up of some twenty or thirty farms. Miller owns this field, Locke that, and Manning the woodland beyond. But none of them owns the landscape. There is a property in the horizon which no man has but he whose eye can integrate all the parts, that is, the poet. This is the best part of these men's farms, yet to this their warranty-deeds give no title. To speak truly, few adult persons can see nature.

With regard to 'Commodity,' Emerson wrote:

> Under the general name of 'Commodity,' I rank all those advantages which our senses owe to nature. This, of course, is a benefit which is temporary and mediate, not ultimate, like its service to the soul. Yet although low, it is perfect in its kind, and is the only use of nature which all men apprehend. Nature, in its ministry to man, is not only the material, but is also the process and the result. All the parts incessantly work into each other's hands for the profit of man. The wind sows the seed; the sun evaporates the sea; the wind blows the vapor to the field; the ice, on the other side of the planet, condenses rain on this; the rain feeds the plant; the plant feeds the animal; and thus, the endless circulations of the divine charity nourish man.

Emerson distinguished between commodity and nature, but recognized that both experiences of the environment reflect a sense of value. Commodity is easily valued in the marketplace, or by individual utility; and nature is valued in the eye of the beholder. The valuation of ecological services relies heavily on commodity, but is designed to more clearly articulate the full import of *nature* to the welfare of society. Some values captured by the beholder can now also be represented in market assessments, as is demonstrated through hedonic valuation of properties adjoining water features (Restore America's Estuaries, 2008).

Environment and ecosystem are terms that are sometimes used interchangeably. Unquestionably, ecosystems, collectively, make up at least a part of anyone's perception of their environment. However, the idea of ecosystem is a defined part of the larger environment based on a structure and function brought into focus by the study of ecology. This idea is an anthropological construct for organizing how to think about our environment in a scientific way, to better comprehend the

working of the natural world. However, the natural environment seamlessly transitions between structures and functions, and thus our ideas of ecosystems are driven by our need to understand differences. The boundaries we define for ecosystems are not arbitrary, but do reflect a utilitarian need to understand how what we observe affects us for better or worse. How the world affects us is conditioned by our needs, which in turn is conditioned, at least in part, by our values.

The idea of ecosystem function can serve as a lens for defining the ecosystem bounds, since logically, the function determines the service. Ecosystem services are built upon ecological understanding of structure and function as the basis for how services are created, and the factors that influence their flows of benefits. Ecosystem service valuation is a systematic exploration of how nature and landscape functions provide services and products that support society and civilization. Ecosystem service valuation also draws on the theory and literature of sociology, and particularly economics, to create a penetrating understanding of how nature and human volition provide benefits to the larger society.

Ecosystem service valuation is a useful concept for characterizing the quality of "the environment" and how it contributes to the welfare of society. In addition, some of the poetic qualities of a landscape in Emerson's time have yielded to the ecologist's study and are now understood to offer services of significant value to society, though often difficult to monetize. Advocates of studying ecosystem services valuation perceive it as useful to quantify the value of the environment, to demonstrate the value of preserving what Emerson termed "landscape," and what the ecologist thinks of as intact and functioning ecosystems. Efforts to quantify and monetize these services highlight "the relative importance of ecosystem services and the potential impact on our welfare of continuing to squander them" (Constanza et al. 2017).

Others have been more critical of the approach to monetize ecology, arguing that this methodology conforms to and perpetuates a utilitarian, reductionist and instrumental view of nature. Much has been made of this criticism. O'Hara (1996) was sympathetic to this position, but extended it further, observing that "even expanded economic valuation methods remain firmly embedded in the very conceptual framework which causes the inadequate representation of ecosystems qualities and functions in the first place." This critique arises from recognition that a conceptual – or decision-making framework that is intrinsically inimical to value propositions such as ecological whole systems, is unlikely to constructively integrate the information with recognition of its appropriate full value. Importantly, O'Hara distinguished between how nature is valued (monetized or in some other non-quantitative way) and the conceptual framework in which it is evaluated. The difference is both insightful and consequential. If ecological service information were effectively monetized such that it better represented the full value of ecosystems in cost-benefit decisions the resulting improvement to a decision could not be denied. However, when the decision-making (or conceptual) framework is itself biased against the intrinsic values of the ecological system it is a delusional belief that the information will have the significance with which it was intended. Given that prevailing decision-making frameworks that consider the environment have externalized costs to the environment (e.g. global warming), one must acknowledge a strong argument that the dominant conceptual frameworks appear poorly suited to understanding or valuing ecological services.

Constanza et al. (2017) responded to the criticism that ecosystem services represent an anthropocentric and utilitarian view of nature arguing that the perspective simplifies ecosystem services, and instead they should be recognized as implying that "humans depend for their wellbeing and their very survival on the rest of nature…". They assert "rather than implying that humans are the only thing that matters, the concept of ecosystem services makes it clear that the whole system matters…". While this response to critics of the ecosystem services concept may be seen to address the concerns that the ecosystem service concept is an intellectual transgression against ecology, it does not address the fate of ecosystem service information in a conceptual framework which as O'Hara asserts "causes the inadequate representation of ecosystems qualities and functions in the first place" (O'Hara 1976). This concern is an issue that is woven throughout this thesis, and is a concern addressed in the conclusions.

The sometimes elusive and difficult to quantify subjective and normative values that individuals and social groupings (i.e. communities, regions, nations, and cultures) place on their environment is a confounding feature of ecosystem services. Values are both irregular and inconsistent, varying over time and location. Shifting perceived values can be just as consequential for environmental decision-making as physical changes or monetary conditions. Thus, in addition to the ecological and economic dimensions of ecosystem services, there is a need to examine the sociological dimensions of ecosystem services. How accurately these difficult to quantify values can be measured is a central issue for the characterization of ecosystem services and is addressed in subsequent sections of this thesis.

2. Ecosystem Services Are Measurable Indicators of Value

The concept of ecosystem service captures the idea that "ecosystems are a source of extraordinary wealth and value." (Irwin & Raganathan, 2007). With the use of the term service, there is an implicit intention to acknowledge value. The concept of ecosystem services is imbued with the value accorded to it for its utility – or significance, to users. Important components for understanding ecosystem services value include:
1. Who does the service benefit?
2. What is the nature of the value, qualitative or quantitative, and (how) is it measured?
3. Is monetary benefit incorporated into financial accounting?
4. Are social benefits from services equitably distributed?
These questions point to important aspects of how information on ecosystem services can be used to analyze social welfare outcomes.

<u>Values are critical to valuing ecosystem services</u>
Values are assignable to a continuum of 'held' or 'assigned;' where held values are the beliefs we hold as important – typically qualitative, while assigned values is the *valuation* placed on things – typically quantitative (Rokeach, 1973). This conceptualization of values is presented as a continuum because held values inform our situational understanding (or "appreciation") of discrete ecosystem services, which in turn will inform our assignment of value to any particular service. It is difficult to pinpoint when subjective appreciation turns into commodity value, but one does grade into the other along a continuum. For example, a held "value" that all forms of life are ecologically important and interdependent would inform a situational understanding that

conservation of natural habitat should be "valued;" which might in turn result in a high monetary "value" placed on wildlife habitat as an ecosystem service.

Assigned valuation of ecosystem services facilitates comparable indicators of value (e.g. monetary) and enables analyses such as ranking or cost-benefit. Normative social values, in contrast, underlie our assignment of values to services, and are not often referenced or made visible. However, normative "held" values provide clarity on the shared social values underlying resource valuations. Clarity about shared social values is considered essential for decision-makers to assess the social impacts of policy and to manage natural resources (Kenter et al., 2015).

Understanding the difference and the relationships between held and assigned values provides insight to ecosystem services that are easily assigned monetary values, and those for which such valuation is elusive or highly uncertain. As Emerson noted, some natural attributes are less easily perceived. These are aspects of Nature that may not have assigned ownership or book transactions in a market, and do not lend themselves to commodification or measurement. They are often '*common good*'[5] resources, which are important to public welfare even when they are unidentified. Examples are natural areas with permeable surfaces for groundwater recharge and stormwater control, or that condition and provide good air quality, or function to preserve biodiversity. When such services are functioning well, or are plentiful, they may only be acknowledged, and not accorded any particular value so long as they are provided. Thus, values are linked to knowledge. Services may be taken for granted because they are only observed and valued when they are threatened. The degree to which they are recognized has implications for how or if they are valued.

Users of ecosystem services valuation tools seek to make services visible, and to link the management of underlying resources to the social benefits they provide. For example, a populated region that is heavily dependent on clean groundwater needs to understand the hydrologic implications of up-gradient land-use, and the consequences of development vs conservation in the watershed. This sort of knowledge is gained from the study of ecology, a multi-disciplinary science built upon information from many different disciplines, including physics, chemistry, geology, hydrology, climatology and biology. The interlocking web of processes that constitute ecological functions can be perceived by the trained eye as the landscape referred to by Emerson in his description of Nature. The deeper our knowledge of ecology, the better we're able to comprehend the services provided by the "landscape."

When the value of non-market landscape services is captured, it usually occurs in a regulatory framework associated with public or national policy to protect and preserve it (Kepner, et al., 2010). Examples are wetland mitigation banking in the United States (NAS, 2001) and the European carbon trading market (UN, 1998). The European trading market for CO_2 emissions is instructive because it illustrates how value can be assigned by institutional order. No such value

[5] '*Common goods,*' are those where it is impossible to prevent people who have not paid for them from having free access if the consumption of the good by one person precludes its consumption by another. https://en.wikipedia.org/wiki/Common_good_(economics)

for CO_2 exists in most other parts of the world because the governments there do not yet sufficiently acknowledge the value of reducing CO_2 emissions.

Ecosystem values are assigned individually, societally, and institutionally based on desires, knowledge and perceptions. Institutions create an economic market context for many ecological services, and are subject to market fluctuations based on supply, demand, and other variables such as substitutability[6]. For services that are a common good, or less tangible, the value may be difficult to quantify unless they become scarce or their necessity is better understood ecologically. In such circumstances when society comes to value an ecological service as a common good, its institutions may develop regulatory frameworks to protect and preserve it, creating a "market value" by order, such as with the wetland mitigation banking in the U.S. Other ecological services, may only be identified through social science research using tools such as revealed preference[7], and may not have fungible cash value.

Values are not static; they shift over time as a result of processes like innovation, social discussion of events, and societal debate. Kenter et al. (2015) described deliberative valuation literature as distinguishing three different processes: economization, where preferences may be become more informed and lead to monetization; moralization, where transcendental values become established or evolve; and democratization through communicative action ("Habermasian debate") that shapes societal and institutional rational preferences. This is an important observation because it identifies subjective and social processes that have explanatory power for how awareness of the ecosystem services concept can affect individual and social values, but also how user's value of ecosystem services is key to their valuation, and how that can change over time with the values of the users.

The decision-making framework is key to assigning values

The complexity of how normative and subjective values inform the assigned value of ecosystem services creates a rich, if opaque, substrata of social drivers and motivations underlying whatever assigned values might be employed for decision-making. This awareness focuses attention on the important issue of the framework used to frame questions and inform decisions, because the choice of framework will affect the analysis of value complexity. The focus on framework context for decision-making is prominent with the work of The Economics of Ecosystems and Biodiversity (TEEB) project administered by the United Nations Environment Programme. The principal objective of TEEB "is to mainstream the values of biodiversity and ecosystem services into decision-making at all levels."[8] The TEEB approach to valuing ecosystem services (in which biodiversity is accorded primary importance) recognizes the complexity and importance of tailoring the selection of value to the decision context. Table 2.1 summarizes the TEEB 3-tiered approach. It is notable for its context appropriate focus on the valuing of ecosystem

[6] Substitute goods are goods that can be used in activities designed to satisfy the same needs, one in the place of another. The buyer carries out an actual and conscious process of choice about them, which leads the buyer to prefer one to another. http://www.economicswebinstitute.org/glossary/substitute.htm (accessed 5/5/17)
[7] Revealed preference is a means to study consumer choice and preference, and can be applied to both market and non-market goods and services. https://web.stanford.edu/~asahoo/ValuationMethods.pdf (accessed 5/5/17)
[8] http://www.teebweb.org/about/ (accessed 5/24/17)

services, recognizing that economic valuation is one among several effective strategies for valuing services.

Ecosystem services are measurable indicators of value. Whatever objective, quantifiable value services may have is built upon prevailing subjective and normative values that establish the context for that value. Moreover, the decision-making framework used for assessment and evaluation also creates a context for what values are allowable. These two meta-factors have significant influence over if (and how) value is measured, whose benefits are counted, the equity of their distribution, and whether monetary benefit is incorporated into fiscal accounting. The following two subsections examine in greater detail the quantitative and qualitative value of ecosystem services as both economic and social indicators.

Table 2.1 Tiers in the TEEB framework for valuing ecosystem services
(adapted from TEEB, 2010b)

Tier	Action	Description
Recognizing Value	Identify and assess the full range of ecosystem services affected and the implications for different groups in society.	Recognizing value in ecosystems is sometimes sufficient to ensure sustainable use. Where the spiritual or cultural values of nature are strong, as with sacred places in some cultures, natural areas are protected, without the need to place a monetary value on the 'services' provided. Protected areas such as national parks were established in response to a sense of shared cultural or social value being placed on treasured landscapes, charismatic species and natural wonders.
Demonstrating Value	Estimate and demonstrate the value of ecosystem services.	Demonstrating value in economic terms is often useful for reaching decisions that consider the full costs and benefits of a proposed use of an ecosystem, rather than just those costs or values that enter markets in the form of capital and private goods. Monetary valuation is best applied for assessing the consequences of changes resulting from alternative management options, rather than for attempting to estimate the total value of ecosystems. The demonstration of economic value can aid in the more efficient use of natural resources for delivery of ecosystem services; and clarifies the costs of achieving environmental goals. Economic valuation can enable decision-makers to manage trade-offs in a rational manner, and correct bias favoring private wealth and physical capital.
Capturing Value	Articulate the value of ecosystem services and incorporate information into decision-making to	The final tier involves the introduction of incentives and price signals to incorporate ecosystem service value into decision making. This can include payments for ecosystem services,

	overcome the undervaluation of ecosystems.	reforming environmentally harmful subsidies, introducing tax breaks for conservation, or creating new markets for sustainably produced goods and ecosystem services. Calculating prices for natural assets and ecosystem services is not always necessary; and such valuation does not imply that all ecosystem services must necessarily be privatized and traded in the market.

2.1. Ecosystem services as an economic indicator of value

The monetary valuation of ecosystem services has been described as a strategic tool to convey the importance of ecosystems and biodiversity to policy-makers (MEA, 2005; TEEB, 2010b). Monetary valuation can provide important information for some decisions, such as the efficient and cost-effective budgeting of programs to protect and restore ecosystems. Characterizing the economic value of ecosystem services can also provide insight into preferences and values held by the users, shape decisions about allocating resources between competing uses, and promote the integration of ecologically informed values into national accounting systems (de Groot et al., 2012).

The valuation of ecosystem services requires an evaluative framework. Uniformity and reproducibility are desirable features. There has also been a call for the development of economic indicators that are relevant to both natural sciences and to social welfare that can address policy questions requiring linked natural and social science analysis (Boyd et al., 2015). Ecosystem services science is well suited to this function because it explicitly requires data, models, and analyses that link ecological conditions to social welfare. A rigorous classification system for ecosystem services is imperative if it is to be used to inform policy development and decision-making (Landers and Nahlic, 2013).

There are two major "valuation paradigms," biophysical methods, and preference-based methods (TEEB, 2010a). The biophysical approach has two notable and widely known models, emergy, pioneered by Howard Odem (1996), and the Ecological Footprint advanced by Mathias Wackernagel et al. (1999) and the Global Footprint Network.[9] Biophysical models are predicated on the intrinsic properties of objects, and measure underlying physical parameters. Emergy measures and provides a framework for the accounting of embodied energy in resource stocks and flows. The Ecological Footprint measures the amount of ecological production necessary to support annual economic activity, and is communicated as the number of Earths required to meet global demand for renewable resources.[10] In 2016, the Global Footprint Network calculated 1.6 Earths were necessary to support global demand for resources without consuming the non-renewable capital stocks. The 1.6 Earth footprint indicates that global demand exceeds the renewable resource base by 60%. The biophysical models can provide vivid and detailed information about the value of ecosystem services that can be incorporated into decision-making

[9] http://www.footprintnetwork.org/ accessed 5/19/17
[10] http://www.overshootday.org/newsroom/press-release-english/ accessed 5/19/17

processes. Such information can effectively provide visibility to the importance of ecological functions and highlight their contribution to welfare. However, the biophysical models stand alone, and do not directly correlate with the methods and classification schemes commonly used for economic analysis.

Preference-based methods, in contrast, are designed to correspond with ecosystem services classification systems that are consistent with national accounting methods. Thus, the preference-based framework is a practical choice for valuing ecosystem services economically. Standard economic valuation, however, may not capture all the intrinsic values of ecosystems. Some authors have challenged that the utilitarian and instrumental perspective advanced by economic (e.g. cost-benefit) analysis can undermine moral motivations for conservation that are better captured in non-economic valuation (TEEB, 2010a). However, Constanza (2006) proposed that different valuation frameworks can provide different insights and can be used simultaneously. The respective valuation units used in different frameworks may be incommensurable, but can often be integrated through a framework such as multi-criteria decision analysis as discussed in Chapter 3 (Linkov & Moberg 2012).

Several classification schemes have been introduced in response to the recognized need for economic indicators that are relevant to both natural sciences and to social welfare (MEA, 2005; Wallace, 2007; Fisher and Turner, 2008b; Haines-Young and Potschin, 2013; Staub et al., 2011; U.S. EPA, 2015). An early and influential framework for valuing ecosystem services was the Millennium Ecosystem Assessment (MEA) in 2005 (MEA, 2005). The Millennium Assessment provided an examination of the condition and global trends in 24 natural systems and the services they supply. The 24 natural systems were presented as representative of four categories of services:

- Provisioning (e.g. food, fuel, fiber…)
- Regulating (e.g. climate, hydrology, nutrient cycles…)
- Cultural (e.g. recreational, aesthetic, spiritual…)
- Supporting (e.g. primary production, soil formation…)

The Millennium Ecosystem Assessment was influential in shaping perspectives on ecosystem services, but as an early examination of the field, was overly generic in their definition of services (Boyd and Banzhaf, 2007). Efforts to standardize accounting units for ecosystem services were subsequently targeted more specifically toward informing decisions such as management of environmental quality by institutions, and the management of national accounts reflecting environmental public goods and market goods known as "green GNP."[11] This is reflected in the design of classification schemes to be compatible with economic accounting methods. Two important examples are the Common International Classification of Ecosystem Services (CICES) developed under contract to the European Environment Agency, and the National Ecosystem Services Classification System (NESCS) developed by U.S. EPA.

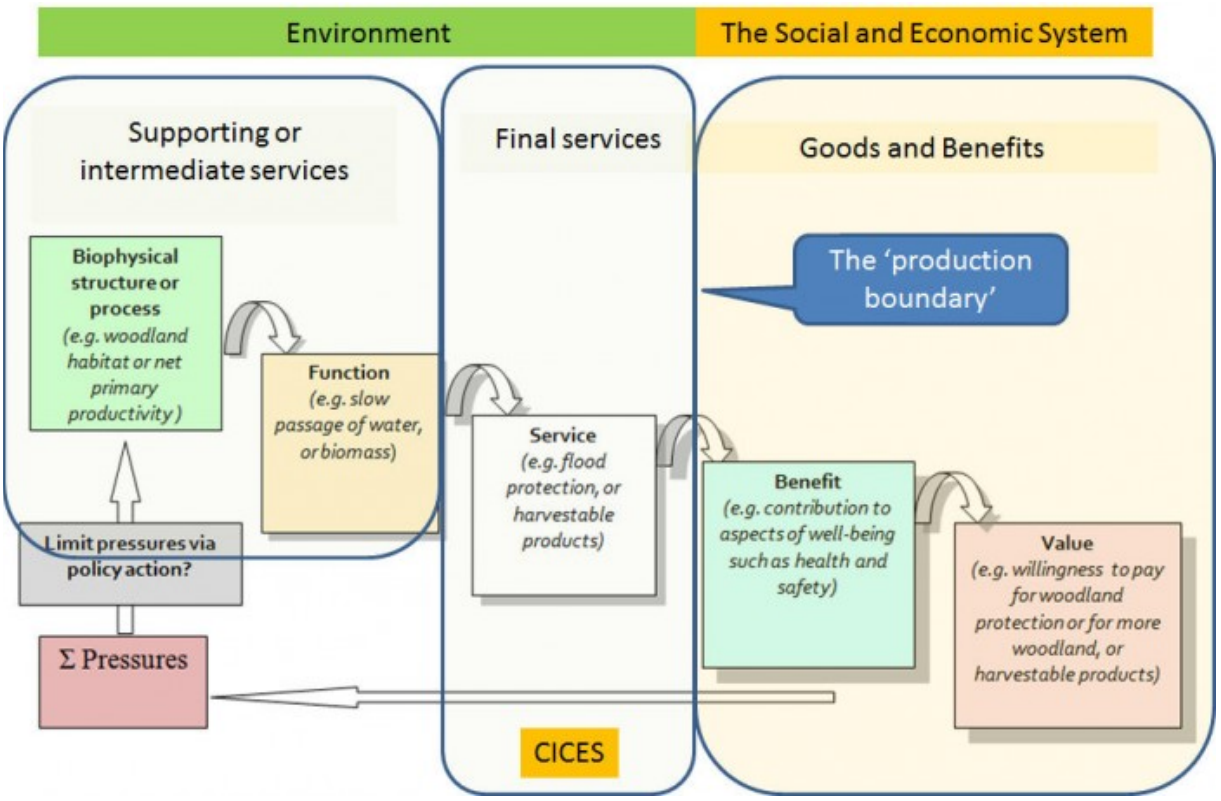
CICES uses the Cascade Model (see Figure 2.1) to frame one of the major points of contention in development of accounting frameworks for ecosystem services – the point at which a service

[11] Green GNP is an accounting for the services of ecosystems advanced by Mäler (1991), and others.

becomes receivable as a value, referred to in the figure as the "production boundary". This model is useful for describing the order from which value is created. Values originate from biophysical structure and function in the environment, and become valuable within the socio-economic system. The model also illustrates that demand for services within the socio-economic system creates a feedback to a change in pressure (understood as stress or liability) on the environment. Pressures, in turn, influence primary production from biophysical structure and function. Thus, the Cascade Model describes not only the creation of ecosystem values, but also traces the conventional understanding of how demand for and use of materials from the environment result in stresses to the environment from depletion of resources, waste and pollution.

The Cascade Model's primary focus is on the communication of how ecosystem services result in human and social benefits. The "production boundary" in the Cascade Model separates the provision of services from the perception of value, signifying that the value accruing from services is only recognized once the benefits of those services is acknowledged. Some have criticized this aspect of the Cascade Model as distinction without a difference, meaning that services are benefits by definition whether or not they are acknowledged (Costanza et al., 2017).

Figure 2.1 The Cascade Model linking ecological production to social goods and benefits
Excerpted from: https://cices.eu/supporting-functions/
After: Potschin, M. and R. Haines-Young (2011): Introduction to the special issue. *Progress in Physical Geography* 35(5): 571-574



The CICES was organized after the basic design of the MEA (as provisioning, regulating, and cultural services) with the important added feature of identifying the final products of ecosystems as constituting their economic value. Final ecosystem goods and services have been proposed as a foundation for defining, classifying, and measuring the components of nature, directly enjoyed, consumed or used to yield human well-being, a concept attributed to Boyd and Banzhaf (Nahlic et al., 2012). The rationale for defining and classifying ecosystem services as final outputs was summarized in four main reasons: 1) they avoid much of the ambiguity inherent in other ecosystem services definitions; 2) they minimize or avoid double-counting; 3) they are a bridge between natural and social sciences; and 4) they are beneficiary-specific easily understood by people (Landers and Nahlic, 2013). CICES sought to align ecosystem's final products with the United Nation's System of National Accounts, which are internationally accepted guidelines for compiling national accounts, as well as the International Standard Industrial Classification of All Economic Activities, and other international standards for products.

The U.S EPA has fostered the development of two closely similar accounting frameworks that focus on final ecosystem goods and services (Landers and Nahlic, 2012; US EPA, 2015). The EPA's National Ecosystem Services Classification System (NESCS), and the similar "FEGS" (Final Ecosystem Goods and Services) mirror the concepts and methods used for classifying economic goods and services as implemented by the National Economic Accounts (NEA). The NEA is the main system of accounts used to measure national market-based economic activity in the U.S. The NEA follows, in some measure, the United Nation's System of National Accounts.

The authors of the NESCS assert that the CICES framework is weakened by following the MEA organization, which they argue does not adequately distinguish between categories that characterize (1) what is provided by natural systems, (2) how these natural systems and outputs are used by humans and (3) what is produced by human systems (US EPA, 2015). The NESCS use of the preference based methods for incorporation of ecosystem services into national accounting schemes addresses the question of how to include information on ecosystem services in economic analysis. What services are included is a separate and equally challenging question.

Extending beyond the categories of benefits recognized in systems of national economic accounts to include non-use values is an essential dimension of ecosystem service value accounting. In so doing, analysis moves away from assigned values toward evaluation of held values. Held values are subjective, and introduce increased uncertainty into the valuation of ecosystem services. To look at the full economic value of ecosystems, the concept of total economic value (TEV) is a widely-used framework (MEA, 2005). The TEV is the sum of present and future values from all the service flows that natural capital generates, appropriately discounted. The framework combines two categories of value into TEV, use values and non-use values (OECD, 2006).

Benefits corresponding to direct and indirect uses of ecosystem services, (the "output value") can be derived from information of market transactions directly associated with the ecosystem service. When market information does not exist, information can be derived from market transactions indirectly associated with the ecosystem services. In the absence of any kind of

market monetary valuation, estimation techniques such as revealed or stated preferences can be employed (TEEB, 2010a; OECD, 2006).

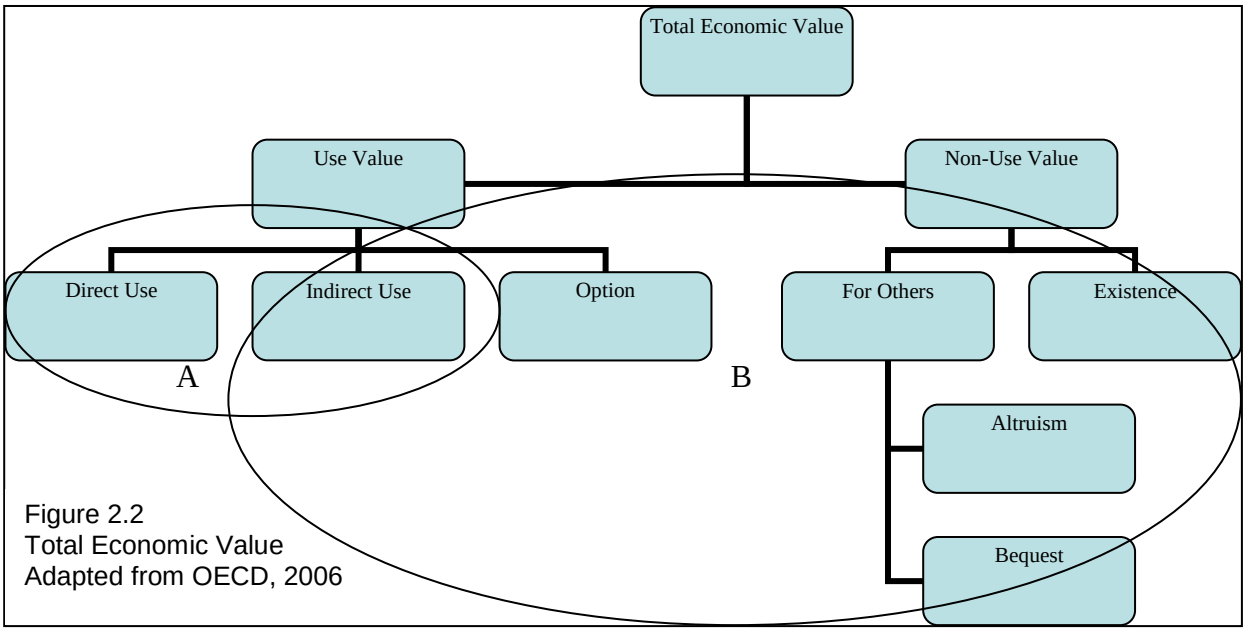


Figure 2.2
Total Economic Value
Adapted from OECD, 2006

An important sustainability concept is captured by the TEV option value. The option value for an ecosystem service extends the time-frame considered for its use. Value is placed on the potential for future uses of a service, reflecting the *option* to preserve and sustain the ecosystem for future use. The potential for discovering biologically-based pharmaceuticals in biodiverse ecosystems is an example. Another example is the possibility of future personal eco-travel. Resilience is another type of option value, which is an ecosystem's ability to maintain its stock and flow of services. This is equivalent to an insurance policy that the desired service will continue to flow. The more robust or resilient the ecosystem, the greater certainty the service will continue. Option value is likely to be far less in monetary terms than actual use values, and subject to far greater uncertainty.

Non-use values, as implied by the term, do not entail the consumption of a good or service. The opposite is true, since a non-use value typically seeks to preserve the good or service. Bequest value is the result of people desiring that future generations have the benefit of an ecosystem service/s. Existence value is the non-use value that people place on simply knowing that something exists, even if they will never see it or use it. These values can be measured by *'willingness-to-pay'* or *'stated preference'* methods. As with option value, non-use values are also generally smaller in monetary terms than use values, and subject to greater uncertainty. Non-use values are discussed further, in Section 2.2, Ecosystem Services as a social indicator of value.

Figure 2.2 is sub-divided into categories "A" and "B." The A grouping roughly correlates with valuation studies long performed by resource economists who have studied the contribution of natural resource use and exploitation to economies and national accounts. Conventional resource economic analysis was established as an economic sub-discipline by valuing the "commodity" dimension of ecosystem services, and has more recently developed valuation tools for measuring

their indirect use (e.g. contingent valuation). The "nature" dimension of ecosystem services lies partly in both groupings A & B. Some indirect uses, such as cultural use, and types of regulatory services, such as climatic regulation, are manifestations of "nature."

Table 2.2 Total Economic Values (adapted from TEEB, 2010a)

Value type	**Value sub-type**	**Definition**
Use values	Direct use	Derived from consumptive or non-consumptive direct human use of ecosystem services (extractive or non-extractive)
	Indirect use	Derived from the regulation services provided by species and ecosystems (e.g. flood control or climatic regulation)
	Option	Relates to the importance that people give to the future availability of ecosystem services for personal benefit.
Non-Use Values	Bequest	Value attached by individuals to the fact that future generations will also have access to the benefits from ecosystems (intergenerational equity).
	Altruist	Value attached by individuals to the fact that other people of the present generation have access to the benefits from ecosystems.
	Existence	Value related to the satisfaction that individuals derive from the mere knowledge that species and ecosystems continue to exist.

Grouping B is more difficult to observe and measure value. These service values, such as "existence", are subjective and much more uncertain and difficult to quantify. Some indirect uses, such as regulatory services, are of highly uncertain value and difficult to measure with precision. Thus, the value of their existence is difficult to factor into some types of decisions that require greater certainty. An example would be risk assessment, with high thresholds of certainty required by tradition and in some instances legal statute. Other types of decisions, however, may allow for the inclusion of more uncertain values, such as when conducting comparative analyses.

Much of the current focus on ecosystem services is discovery of the value of lessor recognized and more difficult to quantify services – that none-the-less are consequential for human welfare. Because ecosystems may serve multiple and concurrent functions, and thus provide a "stack" of services, it is recognized that greater study and inventory of services in the category of indirect services is necessary to more fully value the complete range of services provided by ecosystems.

Even should the valuation of services in the B grouping be "perfected," they must still be recognized in an accounting system, or a decision-making framework, if they are to be relevant. Such recognition is the unrealized goal of ecosystem services valuation. But valuation of those services is only useful for decision making if the decision-making framework can integrate them into the decision process. A sustainability framework is proposed for providing such integration in a decision-making framework. Sustainability offers an advantage as a decision framework to incorporate ecosystem services because the conceptual construction of sustainability around social, economic and environmental considerations parallels the value cascade of ecosystem services from ecological production to social benefit and economic value. The significance of

this similarity is explored in sections throughout this dissertation, including in Section 6, Conclusions. The social and economic attributes of ecosystem services are introduced in this Chapter, and greater attention to the ecological science dimension is provided in Chapter 4.

Economists have recognized the difficulties associated with establishing value to society through aggregation of individual values, as is done with TEV. However, because TEV includes altruistic, bequest, and existence non-use values – all of which extend beyond individual use values; an argument can be made that the TEV framework better incorporates shared and social values than do conventional cost-benefit models. It remains a valid question whether shared and social values are adequately included in the TEV framework (Kenter et al., 2015). For this reason, social indicators, other than strictly economic, are discussed in Section 2.2.

The decision context and data collection capacity are determinants of how completely the economic valuation of ecosystem services can be characterized for a given purpose. One of the driving motivations behind the valuation of ecosystem services has been to enable their better representation in decision-making where utilitarian and cost-effective factors have dominated. The ability to value them economically can advance this goal. Fully capturing value to society, however, requires additional considerations that are addressed in following section.

2.2. Ecosystem services as a social indicator of value

Any economic indicator is inextricably linked to social outcomes because any economy is intrinsic to its society. The TEV of any national economy, for example, would capture information on the nation's resource base and the value of ecosystem services to its society. Consequently, it is appropriate to include all economic indicators of ecosystem services as a sub-set of social indicators. Because conventional measures of economic value aggregate individual valuations to estimate or derive underlying social preferences and values, some attributes of social welfare may not be readily apparent. Kenter et al. make the argument that:

> "…such an approach may not capture collective meanings and significance ascribed to natural environments, potentially missing important, shared dimensions of value. Choices about the environment are fundamentally ethical and social, because the preferences we hold as individuals are influenced by socialization within a particular society" (Kenter et al., 2015).

Kenter et al. highlight how ecosystem services as social indicators differ from their use as economic indicators. Kenter et al. observe the preferences we hold as individuals are influenced by socialization imparted from normative social values, which will likely account for some degree of socially imparted value that an economic indicator could capture. One could also reason that in a heterogeneous society where multiple and conflicting values co-exist, that aggregate valuation of individual preference is the most accurate estimate of "shared dimensions of value." However, with aggregation the differences in shared values held by various parts of society may not be identified, which can mask important differences in ecosystem needs or preferences.

A distinguishing feature of ecosystem service social indicators is recognition that they are in large part defined by society, or segments of society. They are not only quantifiable outputs, but also a reflection of socially realized values. Ernston (2013) offered the example that it is only recently that the absorption of carbon dioxide by vegetation was considered an ecosystem service. This realization has in turn mobilized new forms of land-use governance in many countries. Due to the consequences of fossil-fueled modern industrial society the absorption of CO_2 (or its reduction) is now being translated into policy arenas as an ecosystem service with a market-based monetary value.

Kenter et al. observed that "shared dimensions of value" may be missed when economic valuation occurs because they are aggregated *individual* valuations – as opposed to "*shared*." This researcher identified three dimensions of shared social values that stand out separately from economic valuation. The first two, cultural and legal, are discussed together, and the third, distributional, is discussed separately. The cultural dimension was identified in the Sec. 2 discussion of Table 2.2: Tiers in the TEEB framework for valuing ecosystem services. Recall the description for Tier 1, "Recognizing Value":

> Where the spiritual or cultural values of nature are strong, as with sacred places in some cultures, natural areas are protected, without the need to place a monetary value on the 'services' provided. Protected areas such as national parks were established in response to a sense of shared cultural or social value being placed on treasured landscapes, charismatic species and natural wonders.

After allowances for the most basic necessities of life, the underpinning of ecosystem services is fundamentally cultural. Key to understanding the creation of benefits from ecosystem services is recognizing the necessary investment of physical resources, energy, labor, and money to mobilize most of them. Mobilization is mediated by cultural, economic and legal factors, and human agency essentially determines what are most of the services provided, and to whom (Spangenberg et al., 2014). Müller and Burkhard (2012) emphasized in their definition of ecosystem service the contributions to human well- being of ecosystem structures and functions – *in combination with other inputs*.

Spangenberg et al. (2014) described how value orientations are an "input" of sorts by comparing traditional and current services generated from the same ecosystem in four countries undergoing socio-economic transitions (Kenya, Mongolia, the Philippines and Vietnam). Spangenberg et al. demonstrated that changing habits, preferences and modes of regulation result in different services being demanded and provided at different times and places from the same type of ecosystems. Traditions, belief systems, markets, or institutions of state planning help define which benefits from ecosystem services are sought or are considered important.

Kenter et al. observes that environmental valuation based on the measurement of aggregated individuals has limits, and that a more social approach to valuation has the potential to provide a more convincing and legitimate evidence base (Kenter et al., 2015). Understanding social dynamics shaping demand for ecosystem services will permit improved planning. Conversely, understanding necessary environmental conditions associated with ecosystem services permits

the use of ecosystem services as indicators of demand for certain levels of ecological function or quality.

Another dimension of shared social value is the institutionalization of value established in law. An example is the U.S. Endangered Species Act[12] (ESA). The ESA protects species and their habitat from hunting or development once they are identified through a governmental regulatory process as endangered. Another example is the protection of watersheds in the Catskills mountain region of New York State to preserve the service of high quality drinking water for use by New York City that is provided by the watersheds. This was legally formalized in a 1997 memorandum of agreement between New York City and a Coalition of Watershed Towns (Hanlon, 2017).

The action of protecting ecosystem services by either cultural norms or legal requirements is a qualitative indicator of the underlying shared social values. The ESA is a social recognition of the importance of protecting biodiversity and the habitat that supports it, and does not originate with an economic argument. However, shared social values may include beliefs arising from economic reasoning. The protection of the New York watershed also reflected the shared social value of the protecting a *shared public service* - the drinking water supply, but also arose from economic reasoning. It was resolved as preferable to construction of a drinking water filtration plant because it was, in balance, perceived as the most cost-effective. Had the prevailing social value been to maximize investment to generate private wealth rather than optimize a shared public service, a filtration plant might have been the preferred option.

These two dimensions of shared social values, cultural and legal, establish the normative, social zeitgeist[13] that creates the personal, social and institutional context for decision-making, and thus, establishes a framework for what data are incorporated into decisions, and how they are considered, or what weight they are accorded by institutions (Habermas, 1986-87). The dominant framework for decision-making in nations governed by rule of law is cost-benefit analysis. In cost-benefit analyses, policy choices are evaluated by summing up benefit and cost monetary equivalents of a proposal/project to determine a ratio of cost to benefit (Adler, 2016). There are established methods for identifying both costs and benefits depending upon the policy arena, but they are subject to variation with changing values (individual or institutional) or social norms. This means that if information in cost-benefit analyses remained constant, the outcome could still shift temporally and spatially based upon the values of the assessor, the institution, or the society.

This is illustrated by the collection of ecosystem services valuation data for inclusion in cost-benefit analyses to inform environmental management decisions. As this dissertation research found, reported in Section 4.2 of this thesis, receptivity to information is an important decision-making condition, and is a factor in whether or not data to better quantify the monetary equivalents associated with the conservation of natural resources and environmental benefits can shift the outcome of cost-benefit more favorably toward conservation (Martin, 2014).

[12] U.S. Code of Federal Register, Title 50, Chapter IV, Subchapter A, Part 402. https://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title50/50cfr402_main_02.tpl Accessed 5/30/17.

[13] Zeitgeist (spirit of the age or spirit of the time) is the dominant set of ideals and beliefs that motivate the actions of the members of a society in a particular period in time. https://en.wikipedia.org/wiki/Zeitgeist Accessed 5/26/17.

Receptivity may be conditioned by many different factors, including prior knowledge, familiarity, and social norms.

The third dimension of shared societal value is social justice. Within cost-benefit analysis it has been discussed as a distributional consideration, and pertains to the introduction of distributional weights in the analysis, and the multiplying of monetary equivalents by weighting factors that are inversely proportional to individuals' incomes (Adler, 2016). As such, it is like the cultural and legal dimensions discussed in previous paragraphs because it *values* an accounting for income disparities in analysis. Social justice is different, however, in its potential for use in quantitative spatial analysis of the distributional fairness of ecosystem services across time.

Decisions on ecosystem services provisioning in urban areas are not systematic or consistent, often neglecting economically, socially or racially disadvantaged groups (Marshall & Gonzalez-Meler, 2016). Urban ecosystem services, including recreational, are provided by green space and infrastructure. However, the provision or protection of ecosystem services can increase cost-of-living expenses, property values and hedonic prices which can cause displacement of disadvantaged populations and deepening the environmental justice divide. Placing green space and infrastructure and provision of other ecosystem services into a justice framework that incorporates sociocultural and ecological tradeoffs can create a spatially explicit use of ecosystem services to address social inequities and health disparities, creating a solution driven science for socio-ecological decision-making (Marshall & Gonzalez-Meler, 2016).

Ernston (2013) assembled a framework to analyze both the generation and distribution of ecosystem services. The first component recognized the mobilization of services through human agency discussed by Spangenberg et al. Methods for analyzing the social production of ecosystem services are identified that characterize ecosystem service flows based on an interplay of changes to social network conditions and ecosystem structure and function. A central part of the analysis is the distribution of ecosystem services and the user's ability to derive benefits. A second analytical layer is examining the process of "finding the right trade off" among different ecosystem services. Ernston observed that this "is often simplified into a consensual process, or a rational choice game between actors with fixed interests (so called stakeholders)"; and that it leads to a strictly functionalist approach to understanding ecosystem service distribution. He stated that there are processual and relational dynamics that construct knowledge as a product of social class and cultural processes, explaining how different stakeholders can bias management-decisions towards certain ecosystem services. Closely related to that, Ernston noted, that if ecosystem management maintains the generation of ecosystem services absent from consideration of social justice, then unjust and oppressive social structures (i.e. unfair distribution of ecosystem services) can occur unevenly among members of a population. This, concluded Ernston, means that provision of ecosystem services "is not just good or bad, but that it can be good for some and bad for others" (Ernston, 2013).

This subsection on societal indicators highlighted three dimensions of valuation that may not be fully captured in an economic valuation. Because of this, the examination of social indicators of ecosystem services should be incorporated as an important dimension in any analysis. A well-developed TEV can incorporate these social indicators into a comprehensive socio-economic analysis. Inclusion of the three dimensions of shared social values discussed in this section into a

TEV is recommended for the potential richness of the analysis when questions of the value of services are discussed in the context of social norms and distributional fairness.

Because ecosystem services are measurable indicators of economic and social value, and as is discussed in Chapter 4, also a robust indicator of ecosystem health, they can be used as an integrated indicator to evaluate the social, economic and environmental outcomes of management decisions. Integrated indicators are useful to simplify analysis in systems with multiple objectives, such as is the case with sustainability (Krajnc & Glavic, 2005). Many suites of sustainability indicators have been developed for different applications ranging from cities to particular industries like cement manufacturing (Bell & Morse, 2008). Most are not integrated, but are instead indices including indicators particular to economic, environmental and social objectives. The consequence for decision-making is to determine the significance of one indicator's decline and another's improvement when considering options. When, in considering sustainability objectives, an ecological indicator is allowed to decline to enable the improvement of an economic indicator, it has been called "weak sustainability." Such tradeoffs are common and may generate conflict among competing interests, but are regarded as an intrinsic feature of indicator indices (Bell & Morse, 2008). Integrated indicators such as ecosystem services can be used to mitigate the weakness inherent to indicator indices. In Chapter two some description for how ecosystem services can function as an integrated indicator for key dimensions of sustainability is provided. Chapter three discussed the implication of this for decision-making; and also examined how sustainability science can offer a framework for decision-making.

3. A Literature Review of Decision Science and Sustainability Science

3.1. Sustainability – a context

Using ecosystem services as an indicator for environmental, social and economic activity (or welfare) is useful because it integrates the status of these related areas of function. Their interrelatedness is highlighted, and the ways in which they are interrelated is made more visible. Integration is desirable because the connections between these, sometimes competing dimensions are illuminated, and understanding of cause and effect between them can be better described and understood. The parallel with how sustainability is similarly comprised of environmental, social and economic objectives recommended a closer examination of how these two concepts of sustainability and ecosystem services could be complementary and reinforcing for decision-making purposes.

The published article in Section 3.2, *Incorporating values into sustainability decision-making*, explored the utility of sustainability as an analytical framework for decision making. It functions as the core component in this dissertation's literature review, in which this thesis author examined the relationships between decision-making, values, and the use of both quantitative and qualitative information. These considerations are central to the examination of the hypothesis that ecosystem service valuation provides improved information for decision-making. This article provided insight by comparing sustainability as a decision-making framework with that of public versus private interests, which is a dominant and widely used decision-making

framework for cost-benefit analysis. The comparison illuminates the difference in how different decision-making frameworks can be more or less conducive to different types of information.

This author also examined the role of values in the analysis of information for decision-making. Sustainability was found to embody environmental protection and other values that are consistent with the objective of valuing ecosystem services so that they can be better represented in decision-making. Both sustainability and ecosystem services tools, in some measure, are designed to help to protect the Earth's environment, to sustain human habitation, and to protect biodiversity more generally. Because the objective to sustain human habitation and life is a value-based goal, the importance of understanding how values play a role in decision-making is central to understanding how and when ecosystem services valuation is used.

This sustainability framework advances environmental resource and ecosystem management as a primary factor for decision-making. It is predicated on the belief that ecosystems are the primary source for all resulting social and economic conditions, as is described in Figure 2.1, the Cascade Model. This idea was explored in rich detail by Herman Daly and John Cobb Jr. in their book, For the Common Good (1994). Daly and Cobb underscored that all social, and thus, economic prospects follow from ecological conditions that give rise to opportunities. They challenged conventional economic thinking that extends the idea of substitutability for all ecological services, referring to it as suffering from the fallacy of misplaced concreteness.

3.2. (Article) Incorporating values into sustainability decision-making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Incorporating values into sustainability decision-making

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a r t i c l e i n f o

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a b s t r a c t

This paper explores rigorous methods to transparently incorporate values in sustainability decision- making. Empirical, normative and other decision-making methods are discussed using a conceptual architecture borrowed from the Aristotelian ideas of Episteme, Techne and Phronesis. The application and limits to positivist reasoning for decision-making is explored through discussions of wicked and tame problems (where the introduction of values is discussed), the analytic-deliberative framework (that characterizes most assessment methods), and post normal science. An example examining air quality regulation and enforcement is used to explore concepts. Recognizing the continuum of quantitative to qualitative decision-making

calculus, and how to apply it constructively to decision-making is an area of needed inquiry for scientists, policy-makers, consultants and corporate leaders concerned about helping to effect the transition to more sustainable societal patterns. This necessitates researchers and decision makers acknowledge that sustainability preferences are driven by values. This author concludes that decision-making methods that provide a transparent means to value outcomes and to integrate disparate information and perceptions (and values) have been demonstrated to be the most useful in settings with a variety of stakeholders that value different outcomes. Such conditions are typical in natural resource and sustainability problems where trade-offs are often necessary.

1 *Introduction*

This paper is a theoretical and methodological exploration of the incorporation of values in sustainability decision-making. In general, the incorporation of value-based judgment occurs on a continuum from analytical and objective to biased and subjective. Science has an interesting history of grappling with where to draw the line on what value-judgments will be validated and what will be dismissed as unsubstantiated. Sustainability, in contrast to fluid dynamics, for example, is subject to greater subjectivity by the researcher, from problem formulation and the selection of data, to interpretation of results. Sustainability and sustainable development follow from policy and judgments very much informed by values. Sustainability decisions are contextual, value laden, and often focused on social action. In the quest for relevance and persuasive power, researchers seek to design studies and to explain results and recommendations with as great a rigor as possible. Understanding the utility and productive use of values in the context of the science of decision making and sustainability science can aid the practice of sustainability decision-making through the deliberate, judicious and transparent use of informed value-based judgment.

This paper is organized as a selective review of decision science and sustainability science literature, highlighting features of both that are relevant to the use of value judgment in sustainability decision-making. By weaving together elucidation of key concepts and the use of an example, systematic methods are described for anchoring judgment based on values into sustainability decision-making with rigor and transparency.

The science of decision making and sustainability science each have rich literatures, *decision science* in particular having mushroomed with applications throughout business, research and the social sciences. *Sustainability science* has also grown tremendously in recent years as governments and other institutions have worked to incorporate sustainability objectives into their decision-making. This paper is focused on how to incorporate the normative, values dimension of sustainability into decision-making for sustainable outcomes. It explores the Aristotelian concept of phronesis, the incorporation of values into judgments. The author acknowledges a normative framework that advances environmental resource and ecosystem management as primary to sustainability decision- making, predicated on the belief that ecosystems are the primary source for all resulting social and economic conditions. This idea was explored in the book, For the Common Good, by Daly and Cobb (1994).

This author examined decision-making method, which is distinguished from decision support or "problem analysis" (Kepner and Tregoe, 1965). Good decision-making begins with the proper framing of the problem and selection of decision support tools to inform the analysis (NRC, 2009). This is typically a recursive and deliberative process between framing the problem, considering decision support studies or methods to inform the analysis, and criteria by which the decision is made. In contrast, decision support is less a process, and more a discrete tool, model, or data set. Consider the difference in use of environmental indicators and environmental accounting.

The System of Integrated Environmental and Economic Accounting (SEEA) was introduced in 2003 to standardize environmental indicators and accounting methods for national accounts. It is available as the Handbook of National Accounting: Integrated Environmental and Economic Accounting: An Operational Manual.[14] Ziegler and Ott (2011) observed that the SEEA covers a wide range of conceptual and empirical issues relevant to sustainability; and the use of indicators can be useful to measure weak and strong sustainability. Indicators provide useful measurement of data, and are thus valuable as decision support tools. A decision-making method is then used to place the data measurements (or other information) into a context, such as an accounting frame- work, to inform a decision. Ideally, such a framework provides transparency on what criteria were used to make the decision. The SEEA provides both a library of decision support indicators, as well as an accounting framework to evaluate the data in the situation under study. A decision-making method is still required to use the information productively to inform a decision.

Both decision and sustainability science share an investigation of the proper role for (or balance of) a positivist, scientific process versus purposeful inclusion of subjective values into decision-making. Considered on a spectrum, the information considered can range from fully reproducible physical science to a time and place-specific opinion survey. The means to incorporate values into the decision-making process while preserving rigor constitutes the primary dimension of this review. It was not intended that this review should provide a survey of the full range of theories or methods employed in either decision or sustainability science. It provides grounding in both fields, with a particular focus on how information can be used to advance sustainability in environmental decision-making and resource management.

1.1. An introduction to decision science

Seminal works in decision science are considered to include von Neumann and Morgenstern's Theory of Games and Economic Behavior (1944), Savage's The Foundations of Statistics (1954), and Luce and Raiffa's Games and Decisions (1957). Other important works include De Groot's Optimal Statistical Decisions (1970) and

[14] http://unstats.un.org/unsd/pubs/gesgrid.asp?id¼235 Accessed 3/7/2014.

Berger's Statistical decision theory and Bayesian Analysis (1985). Decision Sciences: An Integrative Perspective by Kleindorfer et al. (1993), offers a comprehensive survey of the numerous disciplines contributing to the formation of a decision science (e.g. economics, political science, sociology). They observed that the science is focused on descriptive and prescriptive attributes of decision-making that is distinguishing between understanding how humans typically make decisions, in contrast to developing and refining rational models of choice (e.g. utility theory). The authors noted that these two areas of research are integrated, largely through the descriptive studies informing prescriptive decision-making methods.

The focus in this inquiry is less on understanding how people make decisions, and accordingly, more on the theory and methods available to make decisions (prescriptive decision-making methods). Rational Choice Theory has been the most prominent and influential approach for shaping the social sciences, which evolved from the naturalist-positivist tradition (Hausman, 2013). The fundamental theory holds that patterns of behavior develop within society that reflect individual choice as they maximize benefits and minimize costs (Hausman, 2013). The theory has been widely translated into predictive models, most significantly and successfully in economics to describe markets.

An Introduction to Decision Theory by Peterson (2009) is notable for the author's attention to theory, and for his philosophical grounding which is not widely found emphasized in other texts that discuss methods. Peterson observed that decision theory is commonly understood to be comprised of three largely separable topics: individual decision-making where the theory of maximizing expected utility is the dominant paradigm, game theory with its characteristic concern with concepts such as equilibrium strategies, and social-choice theory, which is largely the theme focused upon in this literature review.

A social choice decision-making method of used for addressing environmental problems that may have multiple (and sometimes competing) variables for optimization is multi attribute utility theory (MAUT). A useful survey of this approach was written by Figueira et al. (2005) in Multiple Criteria Decision Analysis: State of the Art Surveys. Because authors of this book explored various dimensions of MAUT, the reader receives a broad understanding of issues such as decision-maker's strength of preference, judging riskiness, and additive and multiplicative forms of MAUT. Hossein Arsham, in his web-based matrix of decision science companion sites,[15] described how quantitative models can incorporate values by positing them as quantifiable problems (e.g. sustainable fishery = recruitment > or = to harvest (+ mortality). The values must be reflected in construction of the model itself. Arsham's discussions on decision science are organized on-line, searchable, and include an inventory of quantitative decision- making methods with notes on their applicability.

1.2. An introduction to sustainability science

[15] http://home.ubalt.edu/ntsbarsh/business-stat/opre504.htm Accessed on 1.25.2015.

Kates et al. (2001) and twenty-two colleagues published a policy forum piece in Science that outlined sustainability science in broad strokes as: "A new field … that seeks to understand the fundamental character of interactions between nature and society and to encourage those interactions along more sustainable trajectories." Seven core questions were proposed by Kates et al. to guide the study in sustainability science with an emphasis on understanding the systems complexities associated with sustainability. Sustainability science was presented as studying and representing the interactions, behaviors and emergent properties of natural and social systems, and providing decision-makers with improved information on the effects of various forms of behaviors or interventions (Swart et al., 2004). Of the seven questions, two are key for this inquiry – "what are the principle tradeoffs between human well-being and the natural environment," and "can there be meaningful limits that would provide "warning" for human- environment systems?" The other questions are second order pertaining to matters of measurement, model development, guidance, trends and evaluation. These two questions are based upon values used to characterize human wellbeing, and how it is best served.

The Proceedings of the National Academy of Sciences (PNAS, the Academy's weekly news publication[16]) editorial board announced the creation of a Sustainability Sciences section in 2007 and it continues to maintain a current literature website.[17] In that same year, Harvard's Initiative on Science and Technology for Sustainability[18] ceased operation and support for a sustainability science website,[19] and transferred it to the American Association for the Advancement of Science (AAAS).[20] This hub provided a refereed source for key literature through 2011, when it ceased to update its sources. This foment of scholarship was struggling to create a scientific research paradigm. Bettencourt and Kaur (2011) charted the evolution of the paradigm by performing bibliographic analyses of papers written between 1974 and 2010. They compiled an extensive database of approximately 20,000 papers authored by about 37,000 authors. Bettencourt and Kaur noted that by using network analysis of co-authorship, sustainability science unified around the year 2000, with most scholars and places connected with links of authorship. They assert that the scholarship created a new field, judged by the emergence of extensive scientific collaboration.

Kates (2011), in a subsequent analysis of the field's growth and status, observed that the choice of search terms used by Bettencourt and Kaur to build their publication database "is probably not equivalent to sustainability science." None-the-less, based on Bettencourt and Kaur's paper, he observed that the number of articles began to grow rapidly in the 90s and had continued to double every 8 years since then. In Kates (2011) the author characterized himself as a

[16] http://www.pnas.org Accessed 7/27/2014.
[17] http://sustainability.pnas.org/ Accessed 2/28/2014.
[18] The ISTS It was initiated in 2001 to help channel perspectives to the 2002 World Summit on Sustainable Development (WSSD) and hosted a series of followeup activities during the five years after WSSD. The ISTS was based in the Harvard Kennedy School's Sustainability Science Program. The Program continues to sup- ports initiatives in policy-relevant research, teaching, and outreach.
[19] http://sustainabilityscience.org/document.html Accessed 2/28/2014.
[20] http://www.aaas.org/page/about-center-science-technology-and-sustainability Accessed 7/27/2014.

sustainability science "insider" and indeed he was a principal driver along with William C. Clarke, in building the Harvard Initiative on Science and Technology for Sustainability. Kates and Clarke were also editors for the PNAS Sustainability Sciences section. In his 2011 paper, published in PNAS, Kates concluded that sustainability science is a "different kind of science, primarily use inspired … with significant fundamental and applied knowledge components, and commitment to moving such knowledge into societal action." Ziegler and Ott (2011) concurred that sustainability science does not fit easily within established criteria of the quality of science. They noted that four features of sustainability science – normativity, inclusion of nonscientists, urgency, and cooperation of natural and social scientists result in the explication and articulation of values and principles. They observe that sustainability science appears to "rest on shaky ground" when examined using "customary disciplinary approaches" because of the inclusion of normative consideration of values and principles.

A thorough overview was published by Kates as: Readings in Sustainability Science and Technology (2010). This reader is comprised of three parts. Part 1 is an overview of the dual goals of sustainable development – the promotion of human development and well-being while protecting the earth's life support systems. It concludes with discussion of the interactions of human society and Earth's life support systems. Part 2 covered the emerging science and technology of sustainability. Part 3 discussed the innovative solutions and challenges of moving sustainability science into action. The reader is provided a guided tour through the sustainability literature with links to 93 articles or book chapters. The readings on the science and technology of sustainability focus on its utility for managing human-environment systems, and the goal of integrated, value-driven understanding. The "science of identifying and analyzing values and attitudes" is particularly relevant to the focus of this author's review. Readings on the linking of knowledge systems and action to address three critical needs: poverty, climate change, and peace and security round out Kate's reader, providing both a solid scientific treatment and a principled orientation to the sustainability challenge.

2. Methods

A selected review of decision science and sustainability science literature was undertaken to identify key issues relevant to sustainability decision making. Elsevier identified decision science among its headings for journals in the area of social science. Forty-two journals were listed under this heading, and range in scope from number theory to special applications in transportation management.[21] The review was focused on key words, initially "sustainability" and "decision science", and introduced other terms as key concepts became illuminated, including "values", "methods", and "rational choice theory".

The rigorous and transparent incorporation of values into sustainability decision-making was prioritized based on its relevance for sustainability, and the dispute it engenders in the field of decision science. Secondary topics important for elucidating the primary theme of values in sustainability decision making were then prioritized for inclusion into the outline. A narrative describing how systematic methods for anchoring judgment in values can be incorporated into

[21] https://www.elsevier.com/social-sciences/decision-sciences/journals Accessed 2/24/14.

sustainability decision-making with rigor and transparency was created by weaving together elucidation of key concepts and the use of an example.

3. Empirical, normative and other approaches to decision- making

3.1. Positivism and scientific method

The basic premise in all decisions is that the best information available, under the circumstances, was employed to deliberate and resolve the problem or choice. There are philosophically different approaches to decision-making within which different types of information may be available or preferred. The strict positivist position is that the scientific method allows science to grow through a process of hypotheses followed by statements of testable empirical predictions and experiments that either support or refute them.[22] Karl Popper in his influential publication "Conjectures and Refutations: The Growth of Scientific Knowledge" (1963) described a process of conjectures and refutations that lies at the core of the scientific method. A proposition is only scientific if it is possible to test and disprove it. Much of decision science, and particularly that relying on quantitative analyses, fit into that positivist tradition.

In A General View of Positivism, Comte and Bridges (1865) established a hierarchy of sciences based upon the degree to which the phenomena can be exactly measured and described. Mathematics is the metric employed to determine the position of every science in the hierarchy. Thus, it is the degree to which a science can be subjected to mathematical demonstration that it's "positivity" is ranked. Today, Comte's philosophy is the foundation of our current scientific approach for understanding the relation- ships between theory, practice, and comprehension of the world. His emphasis on a quantitative, mathematical basis for decision-making is the foundation of quantitative statistical analysis, and decision science (Lodahl and Gordon, 1972). Many view this technical rationality as the highest form of knowledge, and place great faith in science and the importance of leaving decisions to experts (Miller, 1993).

3.2. Normative science

Championing normative science is Thomas Kuhn, who in his book, The Structure of Scientific Revolutions (1962) describes the social structure of science as one of scientific communities that are constituted by a shared faith in a paradigm. The brief introduction to sustainability science, in Section 1.1, most assuredly fits that description (although Kates (2011) disagreed, stating a preference for "post-paradigm"). Paradigms offer theory articulation, empirical experimentation, and measurement units; and thereby, provide a framework for deciding what scientific work is worth performing. Paradigms are structured by an ontological understanding of concepts, and a belief that the paradigm provides insight into some basic reality. In Kuhn's view, scientific claims are adopted and rejected according to criteria that stem from the paradigm itself. A normative science becomes established through scientific literature, which leads to basic axioms, concepts, and mindsets, as well as to conferences and peer-reviewed journals that make it possible to assure the quality of research done within the scientific community. Kuhn emphasized that positivist science is essentially shaped through the social processes occurring

[22] http://en.wikipedia.org/wiki/Positivism Accessed 1/28/15.

through its adherents, and thus becomes normative by virtue of being defined through a lens of values and principles (Ziegler and Ott, 2011). Sustainability science and decision science both comfortably reside within this system. Sustainability (or sustainable development) essentially defines a set of normative values for the evaluation of decision options. That evaluation can be more or less positivistic.

3.3. Quantitative vs. qualitative methods

In examining decision-making methods, it is useful to include a brief treatment of the concept of "hard and soft science". Science has been characterized as on a continuum from hard to soft, with the hardest employing a more rigorous scientific method, and supported by quantifiable data and mathematical models, accuracy and objectivity (Lemons, 1996). According to Popper (1963) hard science methods favor testable predictions that can be tested in controlled experiments. In contrast, soft sciences either do not possess that feature, or their predictions have a higher degree of uncertainty. The origins of this distinction can be traced to Auguste Comte's positivist philosophy of science. Interestingly, Comte's grand project was to apply the principles of positivism to what he viewed as the most complex of sciences, sociology (a term attributed to him in many sources); and in contrast to the physical and natural sciences, is referred to by some as a "soft science."

The social sciences have seen substantive quantitative research contributions. Economics, in particular, has evolved from a highly qualitative and philosophical "political economy" to a science largely dominated by quantitative descriptions. However, the extent to which this has succeeded in a functional set of theories to accurately describe and predict economic activity has been challenged (Daly, 1996). Development of the social sciences followed a naturalistic model in America, seeking to emulate methods used in the natural sciences to understand causality and predict outcomes (Ross, 1992). This was accentuated by the emergence of behavioralism in the mid-20th century, with its emphasis on predictive causal models to explain political behavior (Caterino and Schram, 2006). This is significant to this author's discussion because of the fault line between decision methods that incorporate non-quantified or subjective information, and those that do not.

In their introduction to Making Political Science Matter, Caterino and Schram (2006) provided a lucid description of the positivist enterprise that arose from naturalism, and what they referred to as the pluralism of post-positivism, which led to a variety of interpretive approaches to the social sciences (e.g. Critical Theory, Hermeneutics, Post-structuralism). The pluralism they wrote about referred primarily to scientific methods; but they noted that the social sciences remain "constrained by" positivist hegemony. Nonetheless, social science is still widely considered to be soft science (within the framework of the hard sciences at least); and it is reasonable to state that economics, despite its quantitative analytical rigor is several steps removed from the hard sciences of physics and chemistry in its predictive capability. Quantification works reliably in deterministic systems, and has been proven to be valuable in characterizing social systems, but its methods have not been found to be capable of achieving the same reliable degree of predictive ability as demonstrated in the physical (i.e. "hard") sciences (e.g. physics, chemistry).

Return to Reason by Toulmin (2001) described the enchantment of western thought with "universal rationality". Universal rationality was held as the gold standard for objective knowledge of truth. Schram and Caterino (2006) discussed Toulmin's description of universal rationality by underscoring that there was an idea that a distinctive scientific method existed that all sciences should share, and that all other forms of knowledge were inferior to the degree that they failed to conform to the dictates of the scientific method. Social scientists sought to emulate the precision and mathematical rigor of the physical scientists – "Physics envy morphed into science envy" Schram and Caterino (2006). Toulmin's main point was that epistemological theory in the social sciences was decontextualized from experience and observations, and was abstracted in increasingly mathematical terms such that its utility and fit for purpose were often challenged. He asserted that different sorts of knowledge should emphasize different ways of knowing. He held that between absolutism and relativism lay "reasonableness" as a methodology for understanding and using information. Importantly, Toulmin's prescription was for a social theory based upon practice.

3.4. Episteme, techne and phronesis

The distinctions between hard and soft science were first identified in the literature by Aristotle, not as such, but in terms of knowledge types rather than a hierarchy of quantitative rigor. In the Nicomachean Ethics, Aristotle described three approaches to knowledge and named them episteme, techne and phronesis. Episteme most closely approximated facts derived scientifically. Aristotle likened episteme to what we describe as empirical science, arguing that it was based on observations and was useful to explain why things are as they appear. It can be loosely associated with theory insofar as the concept was tied to the notion that episteme existed with or without our conscious attention to it. Techne, in contrast, was characterized as a productive state, associated with the art of craftsmanship or technology; the practice of an art being the study of how to bring something into being. This can be interpreted to mean the introduction a more subjective understanding of knowledge through practice or contextual under- standing (Dunne, 1997). In Making Social Science Matter (2001) Bent Flyvbjerg explained that whereas episteme concerns theoretical "know why," techne denotes technical "know how." Whereas know why is unvarying, use of the knowledge, or know how, can vary by culture, introducing a normative feature into knowledge.

Aristotle observed that we might grasp the nature of phronesis if we consider the sort of people we call prudent. A prudent person is able to deliberate correctly about what action is good and advantageous … but does not deliberate about things that are invariable (episteme). They may deliberate about how to do something (techne), but whether to do it becomes a decision about action. Ultimately, the decision maker must decide if the outcome is good – and who/what benefits; and this is based upon value judgment. The distinguishing quality of phronesis is a reasoned decision about action with regard to whether the outcome is thought to be advantageous (Aristotle considered that this quality belongs to those who understand the management of households or states). Flyvbjerg (2001) characterized phronesis as emphasizing practical knowledge and practical ethics in a reasoned deliberation about values with reference to praxis. For this reason, the concept of phronesis is of particular interest and consequential for this inquiry.

The physical sciences have been highly successful in establishing scientific laws, and in so doing created a scientific standard embodied in the scientific method. Social scientists have tried to mimic them with varying success, as expressed in Comte's notion of scientific hierarchy and the deprecating concept of soft sciences. Because phronesis explicitly introduces values into judgment it is highly subjective. In a scientific culture that values objectivity as the virtual end in itself, subjective science is heavily discounted as subverting episteme with highly normative prescriptions, and losing sight of the prize – immutable scientific laws. As Ziegler and Ott (2011) observe, sustainability science, thus, does not fit easily within the established criteria for quality science. Put simply, our scientific culture has a bias against the incorporation of values in sustainability science.

On occasion the dispute over the value of data collected using qualitative methods, much less methods informed by a value proposition breaks the surface. The most famous example of this in recent times was the Socol hoax[23] (Berube, 2011), which was a major battle in what was referred to as the science wars (Brown, 2001). The "wars" were consequential because they contributed to shaping our beliefs in what information is valid for decision-making. The wars also helped to explicate and refine our understanding of what information is appropriate for what types of decisions.

One of the most radical and important outcomes from the science wars was the publication of Bent Flyvbjerg's Making Social Science Matter: Why Social Inquiry Fails and How It Can Succeed (2001). Flyvbjerg was critical of social science's pursuit of episteme (in contrast to Comte, who expected sociology to follow the quantitative methods of the physical sciences). Similar to Toulmin (2001), he asserted that sociology's pursuit of episteme is not its strongest means to advance, and that phronesis is the proper model for social science scholarship. Flyvbjerg argued that to be relevant, social science must inform praxis and that this should be undertaken with a focus on values. This is important because of the relevance of values to sustainability decision-making, which is discussed in Section 4.3.

It is useful to recall that sustainability (and thus sustainability science) is widely acknowledged as incorporating three principle areas of inquiry, and seeking to integrate them into praxis for decision-making: ecology, economics and social welfare (Millennium Ecosystem Assessment, 2005). In each of these areas of inquiry the objectivity of the science may be challenged, and both economics and social welfare are strongly normative, each with competing paradigms predicated on different philosophical understanding (e.g. "welfare" vs. "laissez-faire" economics). Ecology, rooted in the natural sciences, is still none-the-less widely viewed as normative due to the conservation bias in prescriptions drawn from the study of structure and function (de Laplante et al., 2011).

The principal objective for phronetic social science is to formulate problems and to conduct analyses that incorporate a range of methods that are both informed and motivated by values in society and aimed at social action e for which decision-making is implicit. Among the core questions identified for sustainability science by Kates (2011) are:

[23] http://en.wikipedia.org/wiki/Sokal_affair Accessed on 1/29/15.

- "How can society most effectively guide or manage human environment systems toward a sustainability transition?"
- "What are the principal tradeoffs between human well-being and the natural environment?"

These areas of inquiry are problem driven, value laden, and focused on social action that require suitable decision-making methods capable of incorporating the decision support information being generated. Phronetic decision-making methods are the most compelling, as is clearly implied by these sustainability science core questions.

4. Decision making methods and approaches

4.1. Wicked and tame problems

An important contribution to understanding the proper application of positivist reasoning for decision-making or other more subjective (or value directed) strategies was provided in the literature on wicked problems. Rittel and Webber (1973) coined the term to describe a particular sort of problem that they described with ten characteristics, the first being the most consequential: "There is no definitive formulation of a wicked problem." An important dimension of this is recognition that multiple stake- holders may bring different perspectives on the nature of the problem informed by different values. The authors contrast wicked problems with those considered "tame." Tame problems, such as mathematics or optimization problems lend themselves well to techniques such as those widely practiced in quantitative approaches to decision science.

Wicked problems are typical of the sort of problems associated with sustainability decision-making. Take for example Kate's formulation: "What are the principal tradeoffs between human well-being and the natural environment?" Many indicators have been identified to provide a scientific bases for human well-being, but their selection entails social policy and are likely to be contested, because in a pluralistic society there is no incontestable public good, and no objective definition of equity. Moreover, societies vary through time and space, and so at the very least a normative approach to such a problem, grounded within a social context, would be necessary. Understanding that problems of this nature, wicked problems, may require non-quantitative methods is helpful as a criterion for considering preferred decision-making methods and thus the type of decision-making likely to occur. Recognizing the continuum of hard to soft, quantitative to qualitative decision-making calculus, and how to apply it constructively to decision-making is an area of needed inquiry for sustainability scientists.

4.2. A risk assessment case study of decision-making

Risk management, built upon risk assessment is a common type of decision-making. An air pollution risk management case study is presented to illustrate how a problem can be misunderstood as tame, leading to a problematic outcome; but successfully resolved once its wicked qualities are properly understood. As is clarified in subsequent paragraphs, even the tame problems can be difficult, beginning with setting an ambient air pollution standard for particulate matter.

This author uses a U.S. example of criteria air pollutant regulation for particulate matter (PM) pollution by the U.S. Environmental Protection Agency (EPA). The law, process, current science and risk characterization for the regulation of PM are to be found in two EPA publications:

1. Integrated Science Assessment for Particulate Matter (U.S. EPA, 2009)
2. Quantitative Health Risk Assessment for Particulate Matter (U.S. EPA, 2010a)

In this context, a decision to list criteria air pollutants for regulation is made by the EPA Administrator when they may reasonably be anticipated to endanger public health and welfare. EPA's listing and regulation of criteria air pollutants is required by the U.S. Clean Air Act, and the pollutants are collectively referred to as the National Ambient Air Quality Standards (NAAQS). Their status is updated every five years (U.S. EPA, 2009). Particulate matter is among the six NAAQS. The EPA prepares the Integrated Science Assessment for Particulate Matter assembling all relevant information, including health effects, ambient air concentrations, exposure data, exposure pathways and mode of action. Then these data are organized into a Quantitative Human Health Risk Assessment. The risk assessment provides estimates of premature mortality and/or selected morbidity associated with levels of PM (both 10 ug/m3 and 2.5 ug/m3), consideration of susceptible populations; and provides insights into the distribution of risks and patterns of risk reductions and the variability and uncertainties in those risk estimates (U.S. EPA, 2010a).

The risk assessment strongly relies on quantitative data to make a determination of what levels of PM are acceptable to protect public health, which will in turn drive the regulation of PM sources (U.S. EPA, 2009). The process is straight forward, because it relies on health science data, and provides hard, quantified information to support the EPA Administrator's decision. None-the-less the data must be interpreted in context and scientists may disagree with the final determination, as EPA's Clean Air Scientific Advisory Committee (established under statute[24]) has on occasion (U.S. EPA, 2010a). Regardless, a scientifically based decision is argued and then made using a method prescribed by law. Currently, the annual primary standard (averaged over three years) for PM2.5 is 12 ug/m3 (U.S. EPA, 2014a). A decision of this kind that is defined by law, is explicitly based upon best available science, and which relies entirely on empirical data derived through strict adherence to the scientific method (with only a minimum of normative context) – is on a continuum of wicked to tame decisions, a very tame problem.

The means for compelling compliance with NAAQS is beyond the scope of this review (but may be explored on the EPA web- site[25]). EPA provides a Menu of Control Measures to assist states and metropolitan areas in meeting compliance goals; and how optimal control measures are selected is the next step in this process. A metropolitan area seeking to comply with the NAAQS

[24] The Clean Air Scientific Advisory Committee (CASAC) was established under Section 109(d) (2) of the Clean Air Act (CAA) (42 U.S.C. 7409) as an independent scientific advisory committee. CASAC provides advice, information and recommendations on the scientific and technical aspects of air quality criteria and NAAQS under Sections 108 and 109 of the CAA. The CASAC is a Federal advisory committee chartered under the Federal Advisory Committee Act (FACA).

[25] http://www.epa.gov/oar/urbanair/sipstatus/overview.html Accessed March 7, 2014.

PM2.5 standard may consult the EPA's Menu of Control Measures to assess options for a decision for how to manage PM2.5 in their jurisdiction/ s (U.S. EPA, 2014b). From this and other sources a jurisdiction pre- pares a State Implementation Plan that either demonstrates compliance or shows steps designed to achieve compliance with the NAAQS standards.

Presume for discussion purposes, a jurisdiction of the U.S. that is not in compliance with the PM2.5 standard, is the home to industries emitting PM2.5 from electricity production, ferrous metal production, cement production and vehicular transportation. To achieve compliance the jurisdiction must prevent the release of X tons of PM2.5 annually. This decision is an optimization problem with economic parameters. The decision must select control measures that will limit emissions to the set level. Optimization results from the set of control measures that succeeds in meeting the set level at the lowest – or "optimal" price. This is also a tame problem. The Menu of Control Measures and other sources provide data on the costs of pollution control equipment, and its effectiveness. The formula to optimize PM2.5 reductions is to meet the standard at minimum cost, and to maximize reductions in those industries that provide the greatest cost-effectiveness. This is a tame problem because the value to be protected, or optimized, is established by law in the form of an ambient air standard for a specified pollutant; and the means to achieve compliance with that standard is a menu of options for which prices are known. With all factors known and the solution established by law this is a tame, deterministic problem.

Decisions of this kind have simple decision-making rules, and a best answer. They are entirely fit for standard quantitative risk assessment methods. A good overview and easy read on the use of risk assessment for decision-making is the book authored by Charles Yo: the Primer on Risk Analysis: Decision Making Under Uncertainty (2011a). This book has a solid treatment of risk assessment as a tool for decision-makers. It is especially valuable because of its focus on uncertainty – a fundamental tenet of risk assessment, but a pretty standard part of decision-making in general. Professor Yo also published a more rigorous treatment of risk assessment in the book, Principles of Risk Analysis: Decision Making Under Uncertainty (2011b).

Our air problem can be made more complex if other variables or criteria are introduced, such as industrial profitability, subsidies, potential loss/gain of jobs, or vulnerable populations. Then the model for the problem would become multivariate. However, it would not change the suitability of quantification for identifying the best answer. The use of multi-criteria decision analysis (MCDA) is a structured approach to such problems that has been adopted widely. In Multi-Criteria Decision Analysis: Environmental Applications and Case Studies, Linkov and Moberg (2012) provided a very understandable treatment of the subject with applied examples of the methods employed. The book contains important references useful to comprehend this quantitative approach to decision- making and includes step-by-step examples of how this method can be used.

Risk management problems, illustrated by our PM2.5 example are typically "by the book" calculations, but they can turn wicked. Green and Berkes (2011, 2013) described a community's experience with carbon black PM2.5 pollution. Initially the issue was investigated by the state environmental agency as a straight-forward risk assessment. The data within the established analytical context were insufficient to resolve the problem to the community's satisfaction.

Essentially, the community held a different view of the issue than the state agency's statutory culture. Unsatisfied with the state's response, the community pursued legal means to change the decision context in order to resolve their complaint. Civil courts routinely deal with competing values leading to a choice of decision outcomes. While legal reasoning is typically constrained by law and precedent, in the cases where different values drive competing interests the problem is one of the wicked variety.

In Ponka City, Oklahoma citizens lodged 726 complaints concerning a fine black dust between 1993 and 2011. Largely attributed to a carbon black plant, the community – including the local government, sought an appropriate control action from the state Department of Environmental Quality (DEQ). The DEQ investigated, seeking evidence of fugitive PM emissions crossing the property line from the suspected facility. In the absence of such evidence, nearly all the cases ended inconclusively. Unsatisfied with the DEQ's response, various plaintiffs brought four lawsuits between 2005 and 2009, which alleged PM pollution from the plant was in violation of permits and resulted in settlements of over $20M. Reportedly, the PM “dust” in Ponca was subsequently reduced (Green and Berkes, 2011, 2013).

Residents pointed to the sizable settlements as having driven the PM abatement. The residents maintained that paltry state fines of $25,437, and required “environmental improvements” of $127,631 levied by DEQ since 1995 had no effect. Following the successful legal intervention by Ponka City the OK DEQ changed its policy on fugitive dust “from having to see it cross the property line,” as DEQ spokeswoman McElhaney put it, “to if there is clear evidence of fugitive dust crossing the property line, such as dust on cars.” In this example reliance on data and quantitative methods was insufficient to achieve a decision agreed to by all stakeholders, with the result being legal action by the aggrieved parties (Green and Berkes, 2011, 2013). This is an example of a wicked problem where stakeholders held differing perceptions of the issue. A decision amidst circumstances where there is not an agreed upon problem definition make effective use of quantitative methods difficult simply because parties to the decision disagree on the relevance of the information.

4.3. Using qualitative methods for decision-making

In such instances as the Ponka City example, non-quantitative decision-making methods can offer both insights and strategies for resolution that quantitative methods cannot (Rittel and Webber 1973). Disagreement on the nature of the problem is not an uncommon occurrence in risk assessments characterized by scientific “expert” assessors conducting assessments using objective analysis methods in communities with strong but often unstated value preferences. Bryan Norton in his 2005 book titled Sustainability: A Philosophy of Adaptive Ecosystem Management, discussed the consequences of decision-making predicated on value-neutral problem formulation and analysis, and contrasted that with the advantages of careful incorporation of values into the decision-making process. Norton noted that the risk assessment and risk management (RA/ RM) model developed by the U.S. Environmental Protection Agency (US EPA) for environmental decision-making (beginning in the 1980s) arose from the positivist tradition that best answers should be derived scientifically and objectively. He characterized early EPA risk assessors as guided by science, independent of values or policy predilections, and they were purposely segregated from the decision-makers to ensure unbiased, objective science.

The author described the process of law and policy that evolved alongside RA/ RM as effectively detached from ecological science, as it was effectively focused on single chemical pollutants targeting single human receptors. He argued that the "serial" approach to first exploring the science in isolation from a value context, followed by piece-meal interpretation through environmental laws, fragmented by differing media, obscured system level ecological functions. Ecological functions are critical dimensions of sustainability (Millennium Ecosystem Assessment, 2005), and thus, the problem identified by Norton offers insight to sustainability decision-making.

In *The role of analytical science in natural resource decision-making*, Miller (1993) made the same assertions as Norton, citing "a continuing debate about the proper role of analytical (positivist) science in natural resource decision-making." Miller recognized that certain kinds of problems, to which he referred to as wicked, or "trans-science," problems, might not be amenable to the standard scientific method analytical processes. He argued that mistaken application of analytical methods to wicked problems might serve to "hinder policy development." He advocated a more "holistic" approach to the problem by balancing empirical information with professional judgment, intuition and a broader problem context. To illustrate the idea of a broader problem context, Miller posed pollution as conventionally viewed to be a waste management problem. Within a broader context, however, the pollution could be addressed as a production process problem, and rather than waste management, the solution could be waste prevention. This insight also formed the basis for Miller's argument for systems thinking as an important element in the holistic approach to sustainability.

In *Environmental Modelling, Software and Decision Support: State of the art and New Perspectives*, edited by Jakeman et al. (2008), the editors appear to have internalized the argument for holism. They asserted that integrated assessment is a holistic method within which to examine issues and to inform decisions. Integrated Assessment was described as pulling on expertise from multiple disciplines to understand complex systems of interest and identifying options for decision-makers. Features included a transparent, iterative, and adaptive process open to stakeholders. The method is designed to inform decisions about complex societal problems that arise from the interactions between humans and the environment. Integrated assessment is about understanding the system of interest and assessing options for decision-making about what to do, where, when and with whom (Jakeman and Letcher, 2003). Jakeman et al. (2008) observed that the sustain-ability of one system may compromise that of others, and that there will always be tradeoffs and policies across different sectors that need to be integrated. They proposed sustainability as the context within which to frame problems for integrated assessment.

Norton (2005) observed that the movement away from dogmatic scientific objectivism toward integration of context into analysis, a position also advanced in Jakeman et al. (2008), and Winterfeldt and Edwards (1986), represent an important advance. Norton asserted that Winterfeldt and Edwards were instrumental in building a connection between the descriptive empirical work of behavioralists with the "formal and theoretical" work of decision scientists. Similarly, Jakeman et al. (2008) actively sought to integrate value based positions of stakeholders with modeling rigor. Norton underscored that the National Research Council's (NRC) 2005 report, *Decision-making for the Environment: Social and Behavioral Science Research Priorities*, provided the direction for effective environmental decision-making. The

NRC panel observed that Risk characterization was the outcome of an analytic-deliberative process. Its success depends critically on systematic analysis that is appropriate to the problem, responds to the needs of the interested and affected parties, and addresses uncertainties of importance to the decision-maker. Analysis and deliberation are complementary approaches to gaining knowledge about the world, forming understandings on the basis of knowledge, and reaching agreement among people. Analysis uses rigorous, replicable methods, evaluated under the agreed upon protocols of an authoritative discipline such as the natural, social, or decision sciences, as well as mathematics, and logic to provide factual answers. Deliberation is a process for communication and collective consideration of issues and answers. Participants discuss, exchange views, and reflect upon information in the effort to persuade one another (NRC, 2005).

In *Risk management frameworks for human health and environmental risks* Jardine et al. (2003) provided a comprehensive analytical review of the risk assessment, risk communication, and risk management approaches currently being undertaken by various North American and international agencies. “The information acquired for review was used to identify the differences, commonalities, strengths, and weaknesses among the various approaches, and to identify elements that should be included in an effective, current, and comprehensive approach applicable to environmental, human health and occupational health risks.” Among inventories of best practices is a list of ten principles to guide risk management decision-making. It is significant that the authors stated, without reservation, that “the principles are based on fundamental ethical principles and values.” Further, they observed that the application of the principles “requires flexibility and practical judgment.” One of the principles (identified as the Golden Rule) is to “Impose no more risk than you would tolerate yourself.” These statements are notable for the close similarity to the concept of phronesis whereby, decisions are made based on judgments informed by values and an ethical orientation to the outcome.

Deliberative tools to complement analysis are many. Mental maps are described as useful in understanding participants' cognitive value structure (Linkov, 2008). Scenario development is also a well-established strategy for exploring shared and different understanding of prospective outcome options from a decision. Scenario analysis, including new participatory and problem-oriented approaches provides is a tool for integrating knowledge, and internalizing human choice into sustainability science (Swart et al., 2004). These methods provide sustainability decision-makers a means to examine conceivable outcomes for social systems as they interact with ecosystems under conditions of uncertainty and complexity.

Decision support tools, risk assessment, environmental impact assessments and the full complement of data collection and analysis in support of decision-making are appropriately tied to the decision-making process itself. Selection of the analytical tools, just as definition of the problem, will bracket the information available to the decision-maker for the options presented. In revisiting recommendations for environmental and human health risk assessment, the NRC (2005) proposed that risk managers and risk assessors should work together closely to initiate the assessment to better enable the assessor to provide the manager with information targeted to the decisions to be made. This is considered, by some, to be a departure from earlier recommendations that the assessment should be carefully segregated from risk managers who might seek to steer the assessment in support of a preferred outcome (Norton, 2005). Increasingly, authors of recent literature on this topic acknowledge that decisions cannot be

divorced from the formulation of the problem and the choice of analytical tools, and also recognition of the importance of stakeholder values.

The Journal of Integrated Environmental Assessment and Management[26] has functioned to integrate domain-specific knowledge in ecological risk assessment to support decision-making with multi-criteria analysis methods for trade-offs among sociopolitical, environmental, ecological, and economic factors. The ultimate purpose of modeling is to inform the process of making good decisions. Barton et al. (2012) asserted that models should promote social learning, that is learning that helps managers and decision-makers pull together stakeholders to support decisions that, without the benefit of models, might seem unacceptable. Journal authors call for models that allow environmental and resource managers to consider social values in decision-making and how to promote social learning by requiring stakeholders to articulate their values (Barton et al., 2012). In Bayesian networks in environmental and resource management, Barton et al. provided an overview of a special series on probabilistic modeling, and discussed advances in the last decade in the use of Bayesian networks as applied to environmental and resource management. Bayesian networks are models that graphically and probabilistically represent relationships among variables (Barton et al., 2012). As a highly mathematical model that has been harnessed to explore and explain social variables with value foundations, Bayesian networks represent state-of-the-art in the integration of rigorous scientific methods with expressed value-based objectives.

For those who would explicitly seek to incorporate phronesis into their decisions, and to use the process to drive sustainable outcomes there is action research. Action research proponents make no claims to objectivity, and differ in their methods from other theoretical approaches primarily because the institution and or people studied have some degree of control over the design and methodology of the research (Kathryn and Anderson, 2005). In their guide to the action research Herr and Anderson highlighted the active quality of the research by noting that through engagement with the studied population(s) a shared exploration of both thesis and method occurs in connection with mutually agreed upon objectives. Action research is responsive to assertions by scholars such as Habermas that knowledge and human interests are inseparable, and who emphasized the social nature of all experience and action (Habermas, 1971). The action researcher seeks to forge closer bonds between knowledge generation and knowledge application (read: "decisions"), bypassing the traditional academic separation between research and application, discounting neutrality and objectivity in formulation of the research thesis and methods. "Action research is therefore, an inherently value-laden activity, usually practiced by scholar-practitioners who care deeply about making a positive change in the world." (Reason and Bradbury, 2001). This is also consistent with the strategies for phronetic social science espoused by Fryvbjerg. Proponents of action research characterize their methods as appropriate to the situations and circumstances they study, and argue that positivistic methods are poorly suited to their work. Practitioners of action research have sought to establish recognized methods of scholarship and quality measures to create a core of standardized scholarship (Reason and Bradbury, 2001).

[26] The journal of the Society of Environmental Toxicology and Chemistry (SETAC) http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1551-3793 Accessed on 3/12/14.

The value of information (VoI) is a decision analytic method for quantifying the potential benefit of additional information in the face of uncertainty (Keisler et al., 2014). A decision-maker might consider use of VoI if available information does not provide a persuasive direction, and there is a question whether additional information – that comes with a cost, can be expected to be worth the effort of obtaining it. VOI analyses can provide useful insights in risk management and other similarly deliberative decisions. VoI is not widely used because of the complexity in modeling and solving VOI problems, with most applications currently being made in environmental health risk management (Yakota and Thompson, 2004). The technique is highly quantitative and can be resource intensive (Hoomans et al., 2012). The complexity of solving VOI problems with continuous probability distributions as inputs has emerged as the main barrier to greater use of VOI (Yakota and Thompson, 2004). The comprehensive review of methods for modeling and solving VOI problems for applications related to environmental health by Yakota et al. provided the first synthesis of VOI methodological advances for environmental health. Their insights provided decision scientists with guidance on how to structure and to solve VOI problems focused on environmental health decisions.

In Systematizing the Use of Value of Information Analysis in Prioritizing Systematic Reviews, the authors at the U.S. Agency for Healthcare Research and Quality (Hoomans et al., 2012) reported on newer approaches to VOI that are less burdensome. One, the minimal modeling approach to VOI is useful when data on comprehensive outcome measures, such as quality-adjusted life-years or net benefit, are already available from existing research. VOI can then be estimated without constructing a complex model.

Decision oversight is important to mention, although it is largely beyond the scope of this paper. In the book Scientific knowledge, controversy, and public decision-making, Martin and Richards (1995) explored decisions made (and unmade) in public controversy analysis. Decisions between choices concerning a sustainable outcome can result in public disagreements among scientific and technical experts. Martin and Richards describe four distinctive approaches to controversy analysis, labeled as: 1. Positivist, 2. Constructivist, 3. Group politics, and 4. Social structural. The essence of the positivist approach is that the social scientist accepts the orthodox scientific view and proceeds to analyze the issue from that standpoint. In contrast, the constructivists challenge the positivist's approach by seeking to explain adherence to all scientific beliefs on both sides of the controversy, whether they're perceived to be rational or irrational, or successful or failed. The constructivists' approach has opened up the content of disputed scientific knowledge to sociological analysis. The group politics approach concentrates on the activities of various groups, such as governmental bodies, corporations, and citizens' organizations, and is essentially the study of the social controversy, with only passing attention to the scientific issues. Arie Rip argued that controversies provide societies with an informal means of technology assessment that is often superior to any of the institutionalized methods of assessing the risks and benefits of new technologies (Rip, 1987). These methods might be of use to the sustainability decision-maker embroiled real-time in a protracted public controversy or seeking to draw insights for optimal decision outcomes from other similar circumstances.

One book stands out for addressing concerns over what role is appropriate for normative science and values in decision-making. The book is titled: Structured Decision-making: A Practical Guide to Environmental Management Choices by Gregory et al. (2012). The authors observed

that decision science as applied to environmental decision-making is moving beyond the debate of the positivist-naturalist scientific method vs. normative value-informed social science. The authors outlined the "Structured Decision Making" approach to developing environmental management decisions. It is a guide to a process for helping stakeholders and decision-makers think through tough multidimensional choices characterized by uncertainty, diversity in opinions and values, and the need for tradeoffs. Thus, it is largely transferable to sustainability decisions, which have been similarly characterized (Kates, 2011). Structured decision-making is designed to be rigorous, defensible, transparent and inclusive. It combines analytical methods drawn from decision sciences and applied ecology with deliberative methods from cognitive psychology and facilitation. Case studies are used to illustrate how structured decision-making was applied to a wide range of situations, ranging from those where there was only a small amount of data, to those where there were large quantities of information.

5. Discussion

Efficient and effective decision-making begins with a clear and unambiguous statement of the problem requiring resolution (Kleindorfer et al., 1993). Articulating the correct problem is challenging because what is typically identified as the problem will often be an element of a larger system of which the problem is only a characteristic, condition, symptom or element. Sustainability expressly addresses this through a planning and assessment process that scopes the linkages between issues and relevance to the initial problem statement in an effort to establish logical boundaries on the problem to both include relevant elements but also to keep it tractable. The final problem definition and scoping includes preliminary options for the analysis, stakeholder involvement, and identification of opportunities for collaboration (NRC, 2011). Decision-making methods are only as good as the characterization of the problem to which they are applied.

Jakeman et al. (2008) proposed that data on indicators of sustainability are valid for supporting good decision-making. If the problem for which a decision is required is grounded in the systems context of sustainability, the analysis in support of the decision is appropriately drawn from the tool box of assessment tools, and the decision method appropriate for the analytical findings, then the decision-makers are as well-equipped as possible to make their decisions.

Decision support tools discussed in this inquiry included a limited set of well-known approaches including Structured Decision-making, Multi-Criteria Decision Analysis, Risk Assessment, Bayesian Networks and Action Research. There are many other methods this author has not touched such as material flow analysis, life cycle analysis, benefit-cost analysis or environmental footprint. These tools are considered important sustainability decision support tools, and many are discussed in the context of informing sustainability in EPA's *Sustainability Analytics: Assessment Tools & Approaches* (U.S. EPA, 2013). Aristotle would have termed these tools "techne." Instances where decision-makers rely on the analysis provided by decision support tools – without any further reliance on a framework or other decision-making method simply demonstrate that some decisions can be relatively easily made. Sustainability decisions as discussed previously tend toward greater complexity and thus a decision framework or method can be helpful for integrating results from multiple decision support tools.

Investigations of the tools used for sustainability decision-making were conducted on supply chain management. A sizable literature has been published over the last 15 years on the topic of green or sustainable forward supply chain management. Decision making on supply chain typically balances risks against desirable factors (Seuring, 2013). Seuring and Müller (2008) conducted a literature review on sustainable supply chain management that examined 191 papers published from 1994 to 2007. It characterized initiating factors for decision making as either supplier management for risks and performance, or supply chain management for sustainable products. Seuring (2013) summarizes research on quantitative models and determined that on the environmental side, life-cycle assessment based approaches and impact criteria dominate. Equilibrium models, multi-criteria decision making and analytical hierarchy are three dominant modeling approaches. He reported the social side of sustainability is generally not taken into account. Brandenburg et al. (2014) report that a content analysis of 134 carefully identified papers on quantitative models that address supply chain sustainability showed most favored multiple criteria decision-making methods such as the analytical hierarchy process, the analytical network process, and life cycle analysis.

The supply chain research highlights that quantitative models easily lend themselves to the incorporation of data reflecting sustainable values. The conclusion that environmental sustainability appeared more often in the analysis than did social welfare is indicative of the degree to which different values can be reflected in choice of data. This demonstrates that phronetic reasoning is in evidence not only in the final decision-making phase of problem solving, but also throughout the design and analysis of the problem. An important interpretation and assignment of phronetic reasoning was presented by Funtowicz and Ravetz (1991) in *A New Scientific Methodology for Global Environmental Issues*. They described post-normal science (PNS), as having the characteristics of uncertain facts; disputed values; high stakes and urgent decisions. They argued that PNS was needed to guide society-scaled decisions when uncertainty and disagreement created a road- block (or grid-lock) for traditional science, and suggested a process to advance decisions under such circumstances. Stakeholders are construed to be the "extended peer community." The discussion process among the stakeholders introduces "extended facts," including local knowledge (teche). Funtowicz and Ravetz argued that this extended discussion process is necessary for improving the quality of applied science. The features of PNS are consistent with other methods discussed previously.

A political case for PNS has also been made that is germane to a thorough understanding of the decision-making dominion of sustainability. According to Hulme (2007), the limits of normal science to inform decisions are reached once scientific "knowledge" interacts with other ways people understand and make decisions, such as politics, ethics and spirituality. Hulme stated that "scientific knowledge is always provisional knowledge, and that it can be modified through its interaction with society." To appreciate the value of this insight one must consider that a "normal" reading of science presumes science will first find truth, then it will persuade the social nexus of power, and then finally policy consistent with the science will be developed and implemented. Hulme observed that most scientists function on this level of objective process, as if the battle of science, once won, assures the war of values will be won. However, when science turns "post-normal" disputes "focus as often on the process of sciences – who gets funded, who evaluates quality, who has the ear of policy makers – as on the facts of science" (Hulme, 2007). This is probably an accurate description of most efforts to use science to inform and advance a

socioeconomic agenda such as sustainability. Thus, an understanding of post-normal science decision-making is valuable to those who seek to understand and influence sustainability decision-making.

Emblematic of the difficulty in resolving sustainability decisions, and the requirement for judgment (phronesis), is the classic debate between weak and strong sustainability paths. Eric Neumayer in *Weak Versus Strong Sustainability: Exploring the Limits of Two Opposing Paradigms* (2013) opined that the central debate on sustainable development is the question of whether natural capital can be substituted by other forms of capital – termed "weak sustainability." Proponents of strong sustainability regard natural capital as non-substitutable. Neumayer wrote: "It will be argued here that both paradigms are non-falsifiable under scientific standards. Therefore, there can be no unambiguous support for either weak sustainability or strong sustainability." Neumayer invoked Popper's seminal contribution to the philosophy of science (1963): a proposition is only scientific if it is possible [to test] to disprove. How- ever, he also described weak and strong sustainability as paradigms – that is, according to Kuhn (1962) a normative science where claims are adopted and rejected according to criteria that stem from the paradigm itself. If, as Neumayer asserted, weak and strong sustainability are "paradigms" they cannot be refuted through research arising out of their own normative science. As Ziegler and Ott (2011) observed: "Paradigms are not falsifiable according to Kuhn's rich account of the history of science and arguably also for conceptual reasons (for example, the holism of paradigms makes it unclear what would have to be rejected if an experiment is to be falsified)." Neumayer stated at the end of his discussion: "the contest between Weak and Strong cannot be settled by theoretical inquiry. Nor can it be settled by empirical inquiry."

Such decisions depend heavily on the reasoned judgment of the decision-maker, as well as on the circumstances in which the decision must be made. This is the distinctive freedom of sustainability science and decision-making, as well as the greatest challenge/responsibility to applying decision-making methods. Because the value of what is to be sustained is weighed on the subjective scale of the decision-maker/s, positivist decision-making methods cannot fully inform the decision because they eschew values, as such.

6. Conclusions

Sustainability decisions are contextual, value laden, and focused on social actions. The evaluation of a decision must also provide a means to value outcomes. Decision-making methods that provide a transparent means to integrate disparate information and perceptions (and values), and outcomes have been demonstrated to be the most useful in settings with a variety of stakeholders that value different outcomes. Such conditions are typical in natural resource and sustainability problems where trade-offs are often necessitated. The act of decision-making, in the terminology of Aristotle, is "techne," and it is very much a craft executed with subjective judgment by any practitioner. Consistent with development of a craft is recognition that the practitioner is guided by internalized values – normative and paradigmatic, mathematical or otherwise. The concept of phronesis is appropriate to describe this, and is also consistent with sustainability decision-making because it carries the essential element of value-based judgment that is key to resolving the tradeoffs that are often needed when considering complex systems.

With the identification of values transparently included in decision making, it follows that the values served by outcomes will be similarly transparent.

4. Using Ecosystem Services in Decision-Making

4.1. NEP ecosystem services community of practice

This chapter described a three-year process by this thesis author to understand how ecosystem services information was understood and used by the management of 28 national estuary programs (NEP) in the United States. The published article presented in Section 4.2, *Use of ecosystem services information by the U.S. National Estuary Programs*, summarized the results of the findings of the action research[27] between this researcher and the managers of several NEPs, who together, planned several conference workshops, conducted a year-long community of practice[28] (CoP) study, and dialogued on appropriate survey questions for the NEP managers. The article reported the results of two surveys conducted with the NEP sample population, and the conclusions made based upon the findings of that research.

The action research in support of this dissertation was initiated in the spring of 2008, when this thesis researcher, in his capacity as an employee of the U.S. EPA, made a presentation to a bi-annual meeting of the Association of National Estuary Programs, providing an overview of the EPA's research on ecosystem services. This thesis researcher initiated conversations with NEP managers present at the spring 2008 meeting. As a result of his presentation an agreement between the ANEP and this researcher to form, among self-selecting NEP managers, a CoP to advance the use of ecosystem service information among the NEPs. Elements of the CoP included ecosystem service presentations at future ANEP meetings, calls among CoP members to share information and perspectives (described in Table 1 of Section 4.2), and the development of a questionnaire to the ANEP membership. It was agreed that the purpose of the questionnaire would be to establish a baseline of information on the current awareness of, and use of

[27] Action Research is characterized by Reason and Bradbury in "Handbook of Action Research" as "research with, rather than on practitioners… in effect action research bypasses the traditional, constructed separation between research and application." pg. xxv.

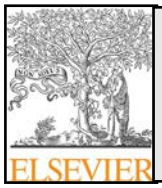
[28] A Community of Practice (commonly abbreviated as CoP) is increasingly recognized as both an informal and a formal means for shared learning and information communication. The benefits of CoPs lie in providing a collaborative environment that connects people to other people, information and knowledge. CoPs can encourage the development and sharing of new ideas and strategies; support faster problem-solving; and provide access to expertise. A February 1991 article in **Organization Science** (Vol.2, No. 1, pp. 40-57) by John Seely Brown and Paul Duguid (*Organizational Learning and Communities of Practice: Toward a Unified View of Working, Learning, and Innovation*) describes a study of Xerox repair representatives who self organized a CoP to share insights to complex repairs that were not adequately addressed in company manuals and course training. Brown and Duguid called this type of informal work-related social grouping a "community of practice." CoPs have subsequently been recognized as a viable strategy for inculcating new information or strategies into groups sharing a purpose or function. Generally, the purposeful establishment of a CoP succeeds best when the area of interest is fairly narrowly defined and focused. This ensures that people's time is spent in a way directly responsive to their perceived need. There is a description of the theoretical underpinnings of CoPs on Wikipedia: http://en.wikipedia.org/wiki/Community_of_practice.

ecosystem service valuation by NEP early adopters in their decision-making processes about program planning and operations; and to provide the ANEP project team a source for potential themes for the CoP discussion that would help the NEP to achieve its goals.

The ANEP action research and this researcher's literature review (Section 3.2) were concurrent and iterative. The decision to focus the published literature review on sustainability science and decision science resulted from this researcher's observations that within the NEP CoP, there was an indication – not measured, that participants who more broadly viewed their program's objectives to actively include economic and social objectives, as well as environmental outcomes, were supportive or curious about the use of ecosystem services' information as an aid to decision-making. The notable correlation between ecosystem services and sustainability sharing the elements of environmental protection, economic equity and social justice led to the literature review to focus on sustainability science and decision science to inform the investigation of the roles ecosystem services information can have in decision-making.

The ANEP action research and CoP ended in 2011 with a second survey to all ANEP managers. The article, Use of ecosystem services information by the U.S. National Estuary Programs in Section 4.2 discussed this researcher's observations of how the ANEP members' views on ecosystem services changed between the 2008 and 2011 surveys, and provided conclusions in response to the research questions posited in Section 1.2.

4.2. (Article) Use of ecosystem services information by the U.S. National Estuary Programs



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The use of ecosystem services information by the U.S. national estuary programs

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a r t i c l e i n f o
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a b s t r a c t
This research explored how the concept of ecosystem services has been characterized and used to aid decision-making, and to promote the success of environmental protection strategies in the management of estuaries. The research was conducted between 2008 and 2012, and is based upon reports and survey information received from the study population of U.S. Environmental Protection Agency (EPA) National Estuary Programs (NEPs). The research examined the

perceived benefits from articulating the value of ecosystem services in various NEP functions. The study population was comprised of 28 geographically defined programs on all coasts of the United States, created under authority of the Clean Water Act, expressly to protect estuaries. Estuary management programs have used ecosystem service valuation successfully, both quantitatively and qualitatively, to set environmental protection and restoration objectives, and to communicate to stakeholders. The most widespread use of ecosystem service valuation information was to frame issues and to ground discussions in values that are important to stakeholders. NEP managers who had some direct experience with the use of ecosystem service valuation were nearly twice as likely to assert "ecosystem services information is useful" as those who were merely alert to the concept.

1. Introduction

1.1. Overview

This research explored how the concept of ecosystem services (ES) has been characterized and used to inform decision-making, and to promote the success of estuary protection strategies in select estuaries of the United States. This includes informing program planning priorities, communication with stakeholders, and evaluation of trade-offs between ecological preservation and economic development (i.e. cost-benefit analysis).

Ecosystem service valuation (ESV) research is conducted with the belief that knowledge about the value (economic or otherwise) of ecosystem services will help to characterize the benefits to society from the protection of ecologic systems, particularly when compared with the monetized benefits from economic development (Costanza et al., 1997; de Groot et al., 2012). This belief is predicated on rational choice theory,[29] and the presumption that additional information about the value of ecosystem services will improve the representation of environmental protection outcomes in discussions of the merit of economic development of natural resources (Wegner and Pascua, 2011, Irwin and Ranganathan, 2007).

The National Research Council publication "Valuing Ecosystem Services: Toward Better Environmental Decision-Making" (NRC, 2004) observes:

> …the value of ecosystems derives from two points of view. The first is that the values of ecosystems and their services are non- anthropocentric and that nonhuman species have moral interests or rights unto themselves. The other, which includes the eco- nomic approach to valuation, is that all values are anthropo- centric. However, the committee recognizes that all forms of value may ultimately contribute to decisions regarding ecosystem use, preservation, or restoration. Although economic valuation does not capture all sources or types of value (e.g., intrinsic values on which the notion of rights is founded), it is much broader than usually presumed. It recognizes that economic value can stem from the use of an environmental resource (use values), including both commercial and

[29] For discussion see Rational Choice Theory: advocacy and critique edited by James Coleman and Thomas Fararo (1992) #7 in Key Issues in Sociological Theory, Sage, London.

noncommercial uses, or from its existence even in the absence of use (nonuse value).

In this paper the term ecosystem services is understood to mean the direct and indirect contributions of ecosystem structures and functions—in combination with other inputs—to human well- being (Müller and Burkhard, 2012). Ecosystem service valuation is defined broadly to include both economically derived values as well as qualitative characterization of "value," meaning simply that the service is recognized as valuable even if not denominated economically. The questions in this research are presented in the context that all values considered for ecosystem services are anthropocentric, and thus *subject* to economic quantification, although they may not be so denominated.

The purpose of this research was to survey and assess the perspectives and experiences of environmental managers on the use of ecological service valuation in the planning and management of estuary resources to learn if ecosystem services have resulted in any of the positive outcomes for environmental protection supposed by those who assert the utility of ecosystem services valuation (Needles et al., 2013; Engle, 2011; de Groot et al., 2009; Boyd and Banzhaf, 2007). Numerous authors have reported that the ES/ESV literature is rich in methods and recommendations but notably lacking in reports of how ES/ESV is used in decision making (Fisher et al., 2008a). Laurans et al. (2013) conducted a literature review to assess if and how ESV is used by decision- makers. Through a systematic process they identified the journal, *Ecological Economics* as being the most influential journal publishing on the topic of ecosystem services, based upon having published the highest number of ESV articles and receiving the highest number of citations in the researcher's database of 5028 references. They concluded that the reporting or documenting of the use of ESV in decision making is largely absent in peer-reviewed scientific literature. They typify the literature as presenting economic valuations and recommendations for use in decision-making; but with few documented examples of its use.

The main conclusion by Laurans et al. (2013) from their analysis of the ESV literature is the "paucity of papers that describe… how a specific ESV has played a role in a decision." They identified eight papers that reported on the actual use of ESV in decision making, representing 2% of the published articles in Ecological Economics where ESV is mentioned. Only three among the eight papers analyze how ESV was actually used. The three papers noted by Laurans et al. include:

1) Gowan et al. (2006) who examined the contribution of ESV in a dam removal on the Elwha River in Washington state. Gowan et al. (2006) concluded that ESV had only a minor role in the decision.

2) Henry (1989) who reported on the case of a harbor extension project in the Netherlands where authorities used cost-benefit assessments to evaluate alternatives, including ecosystem out- comes. The result was that none of the extension options that did not seriously harm the natural environment were economically viable.

3) Rival (2010) who explored the Ecuadorian Yasuni-ITT (Ish- pingo–Tambococha–Tiputiniinitiative) initiative, and described a rich involvement of stakeholders using ESV to

debate and challenge the calculations made by professional economists to actively engage in discourse about the country's economic future.

Suhardiman et al. (2013) described paying for ecosystem services (PES) as an innovative approach for improving natural resource management. Considering the large number of publications examining PES, it appears in the literature as an important example of how ESV can affect policy and program outcomes. However, Liu et al. (2010) point out that with respect to technical guidance: "Indeed, one would imagine that ESV, the process of assessing the benefits of environmental services, must have been applied widely to guide PES." "In practice, however, ESV results have rarely been applied in setting payment amounts" (p. 68). This analysis was preceded by a similar observation from Landell-Mills and Porras (2002) who surveyed almost 200 PES mechanisms. Pirard and Billé (2010) concluded similarly.

Pittock et al. (2012) note the accomplishment of Australian institutions in considering multiple land values, highlighting the Victorian Environment Assessment Council that evaluates public land values using an "approach similar to that which we would now call an ecosystem services evaluation" to make recommendations on future land uses. However, Pittock et al. (2012) note that while the term ecosystem services is widely used, it's use is mostly superficial, typically referring to only a few services. Their research concluded that the full suite of services and benefits have not been systematically included in decision making and management. Liu et al. (2010) also report on the use of ESV for natural resource valuation purposes, noting its use well established in Natural Resource Damage Estimates and in cost-benefit assessments for water and forest resource-use planning.

The focus on high visibility, economically important services is not unlike how *resources* in the U.S. have been traditionally valued and considered in land management decisions.[30] Molnar and Kubiszewski (2012) confirm this assertion in their paper "*Managing natural wealth*: *Research and implementation of ecosystem services in the United States and Canada*." Primary among their examples are the PES associated with no net loss of wetland under the Clean Water Act[31] and the Conservation Reserve Program managed by the U.S. Department of Agriculture.[32] Both programs implement conservation initiatives that predate widespread publication on the topic of ES, and harken to the time when objectives such as the protection of water quality stood for what are increasingly referred to as ES. They report that many of their examples use services that can be traded in a market and that are focused on ecosystems and services that are easier to measure and have more obvious beneficiaries.

1.2. Study population

[30] See for example the "Recreational and Resource Economic Values for the Peconic Estuary System" at: https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryID=85730;
and the "Indian River Lagoon Economic Assessment and Analysis Update" at:
http://floridaswater.com/itsyourlagoon/pdfs/IRL_Economic_Assessment_2007.pdf (accessed 30.4.14).
[31] Sec. 404 of the Federal Water Pollution Control Act (33 U.S.C. 1251 et seq.) See:
http://www.epw.senate.gov/water.pdf (accessed 30.4.14).
[32] See http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp (accessed 30.4.14).

The research was conducted in association with the Association of National Estuary Programs (ANEP).[33] ANEP is a non-profit organization that works with the 28 individual programs in the National Estuary Program (NEP). ANEP works to coordinate a national agenda, and to promote mutual support and communication among the NEPs. The study population was comprised of the 28 U.S. NEPs associated with ANEP. The study population is heterogeneous, but is clearly demarcated by subscription to the nation-wide NEP program associated with the U.S. Environmental Protection Agency (EPA).[34] The EPA established the NEP to protect and restore the water quality and ecological integrity of estuaries of national significance pursuant to the 'Estuaries and Clean Waters Act' of 2000 under Section 320 of the 1987 Clean Water Act Amendments. Individual NEPs were created to foster development of a community partnership for the protection of an area's specific estuary and watershed. Each NEP is required to develop and implement a Comprehensive Conservation and Management Plan[35] (CCMP) that identifies targeted actions to protect and conserve water quality, habitat, and living resources in its estuarine watershed.

The individual NEPs are managed through local decision- making processes that rely heavily on stakeholder involvement, interaction and consensus. NEPs are guided by Management Conferences constituted of stakeholders—including citizens, various governmental agencies, non-profits, and private sector entities. A collaborative decision-making process is used to identify CCMP objectives and implement the actions. NEPs involve external experts in policy discussions and nurture strong interpersonal ties among stakeholders. The methodical collaboration between stakeholders has led to greater confidence in the procedural fairness of local policy in NEPs when compared with other estuary protection programs (Schneider et al., 2003).

1.3. *Research questions*

The research questions used to frame this study were the following:

(1) Does information on ecosystem service valuation provide value to decision-makers and does it advance progress in achieving environmental protection objectives?

(2) Does ESV represent a successful technique to communicate the importance of ecological health and ecological systems' integrity to society or stakeholders?

(3) Does communication of ESV improve environmental decision outcomes in decisions that balance ecological protection against economic development?

2. Methods and materials

2.1. *Methods*

[33] Details on ANEP are available on-line: http://www.nationalestuaries.org/ (accessed on 30.9.13.).
[34] http://water.epa.gov/type/oceb/nep/index.cfm (accessed on 30.9.13).
[35] Links to the CCMPs are found here: http://water.epa.gov/type/oceb/nep/ (accessed on 30.9.13).

This research was conducted using a survey method couched within an action research[36] framework (Reason and Bradbury, 2001). The action research framework featured a qualitative approach to the surveys, conference presentations to survey recipients on the subject of ecosystem services and their valuation, and a semi-structured "community of practice" (discussed in Section 2.2) also targeted to the survey recipients.

The research methods employed in this study included a baseline evaluation of the study population and two surveys. Questionnaires used in the surveys, and an aggregation of responses are provided in [Appendix A]. The surveys loosely follow the phenomenological method. Generally, a "survey" used in the social sciences describes a quantitative study, the primarily aim of which is to describe numerical distributions of variables in a population (Groves et al., 2004). Groves et al. (2004) state: "The survey is a systematic method for gathering information from (a sample of) entities for the purpose of constructing quantitative descriptors of the attributes of the larger population of which the entities are members."

Although statistical attributes are collected and described in results (Section 3, Tables 2 and 3), the surveys were primarily designed to learn about the range of ways that ES information is used by NEP managers. In contrast to a statistical emphasis, the surveys employed a qualitative method to investigate the variation in responses by the survey population. The objective in using a qualitative method is to determine the diversity of some topic of interest within a given population (Jansen, 2010). This method does not focus on the number of people with the same characteristic (value of variable), rather it establishes the meaningful variation within that population on the matter of interest. In many qualitative surveys, the relevant topics are identified through interpretation of raw data from the survey. However, the surveys employed in this research were pre-structured based on a specific area of inquiry (how ES & ESV are *used*) and prior dialog with NEP managers. This resulted in a set of predefined characteristics describing how ES were or could be used in the population of NEP managers that was used to prepare the survey questionnaires. The phenomenological approach allowed collection of in-depth data through open-ended questions. This research method facilitates insight and understanding, and captures the points of view of the participants without categorically predetermining those points of view. Easterby-Smith et al. (1991) portray the phenomenological paradigm as representing the world as socially constructed and subjective, in contrast to the naturalist/positivist-quantitative paradigm that asserts the world is external and objective. Other features noted by Easterby-Smith et al. (1991) include the following:

- Observer is part of what is observed;
- science is driven by human interests;
- focus on meanings, try to understand what is happening; and,
- look at the totality of each situation and develop ideas from data through induction.

[36] Action Research is characterized by Reason and Bradbury in "Handbook of Action Research" as "research with, rather than on practitioners… in effect action research bypasses the traditional, constructed separation between research and application." pg. xxv.

Easterby-Smith et al. (1991) note that preferred phenomenological methods include using multiple methods to establish different views of small sample population investigated in depth or over time. This research meets the criteria with a small, fixed sample population that is engaged for a period of three years and surveyed twice.

An initial study of NEP Comprehensive Conservation and Management Plans (CCMP) was undertaken in 2008 to establish a baseline of how widely ecosystem service concepts were already incorporated into the NEP's planning documents. The CCMP for each of the 28 NEPs was reviewed for references to ecosystem services, or terms that roughly equate with those concepts.

Following upon the baseline study, this researcher was able, through work with several NEP managers and EPA colleagues, to develop introductory presentations on the topic of ES and ESV, which were presented to members of the ANEP at two meetings in 2008. This began an interaction between this researcher and the ANEP best characterized as "action research." The action research was purposeful interaction with members of the population that this researcher sought to study (Herr and Anderson, 2005). In addition to the initial ES/ESV presentations an ES community of practice was convened to foster discussion among NEP managers on current research and applications in estuaries. Finally, again in conjunction with NEP managers and EPA colleagues, a final ESV presentation was made in 2010 at an ANEP meeting.

The purpose of the three-year interaction was to both understand how ES/ESV was understood and used by the members of ANEP, as well as to create conditions within ANEP where the concept and utility of ESV could be explored and advanced. This formed the context for the surveys that were conducted. The first survey followed upon ES presentations at two ANEP meetings in 2008. The second survey followed a third ANEP meeting ES session in 2010, and ANEP sponsored CoP discussions of ES and ESV. Further information on these presentations is provided in Section 2.3 and Table 1.

Table 4.1 Topics of presentation to, and discussions with the ANEP

Table 1
Topics of presentations to, and discussions with the ANEP.

Topic	Date	Presenter
Overview of the EPA/ORD Research on Ecosystem Services	Spring 2008 mtg.	EPA
Ecosystem Services: A key element of the New York City watershed filtration avoidance determination—Going from concept to on the ground ecosystem service valuation	Fall 2008 mtg.	Guest
Watershed Scale Application of ESV (comparing Narragansett, Puget Sound, Indian River and Peconic) in the NEP action plans	Fall 2008 mtg.	L. Martin
Highlights of 'Partnership for Delaware Bay's' work using ESV, in the context of ecological management, to prioritize marsh-grass conservation and restoration. An assessment and monitoring program developed to characterize the extent, condition, function, and ecosystem services	Fall 2008 mtg.	NEP
The Ecosystem Services Research Plan for the Tampa Bay Estuary Services Research Plan for the Tampa Bay Estuary: How can this NEP-based application of ESV be applied in your estuary/watershed program?	Fall 2008 mtg.	NEP
Highlights of Narragansett Bay's Biological Condition Gradient (BCG) incorporation of ES into characterization of different levels of the BCG	2010 CoP	NEP
Discussion of 'Partnership for Delaware Bay's' potential use of a natural capital framework, including ESV, to guide regional restoration and climate adaptation in the Delaware Estuary watershed	2010 CoP	NEP
ESV research in the Gulf of Mexico on estuarine sea grass value	2010 mtg.	EPA

2.2. *ANEP community of practice (CoP) and the first ANEP survey*

Following the November 2008 NEP meeting, this researcher arranged with the ANEP Board to allow members of the ANEP to self-select and advance the discussion of ES within the ANEP. The ANEP membership was informed of the opportunity to participate in a community of practice[37] (CoP) focused on ES. The CoP was created to focus and deepen the discussion of ES and ESV among ANEP members. Staff/management from eight NEPs initially self-selected to participate, with two joining later. A questionnaire was prepared by this researcher and validated by EPA colleagues and members of the ANEP board. On behalf of ANEP the questionnaire was then distributed to the eight initial participants in the CoP in early 2009. Results from the questionnaire were used as the baseline for awareness of ES and ESV concepts among the ANEP participants in the CoP; and were used to guide preparation of agendas for two facilitated discussions among the members of the CoP in 2010. Most of the ANEP CoP participants were early adopters of ESV concepts. Although all NEPs work with the EPA Office of Water to formulate and implement programs, the Tampa Bay and the Albemarle/Pamlico NEPs were also working with the EPA Office of Research and Development's (ORD) ecosystem services research program to research, pilot, and demonstrate ES applications. The participants in the CoP included the following representatives:

Albemarle/Pamlico Estuary Program; Barataria–Terrebonne Estuary Program; Casco Bay Estuary Partnership; Coastal Bend Bays and Estuaries; Delaware Estuary Program; Indian River Lagoon National Estuary Program; Long Island Sound Study; Narragansett Bay Estuary Program; Peconic Estuary Program; and Tampa Bay Estuary Program.

2.3. *ANEP meeting and CoP Topics*

Analysis and conclusions from this researcher's interactions with the ANEP members through ANEP meetings and the CoP are not reported in this article; however, a list of the topics addressed during the three ES sessions presented at ANEP annual meetings and within the CoP is considered important background, and as a practical matter important for understanding results from the surveys that were conducted. ANEP CoP participants were nearly all senior managers at their respective NEPs, except for the senior scientist from one NEP. Following the CoP conversations, a final presentation on applications for assessment of coastal ESV was made to the ANEP at their December 2010 annual meeting. Topics addressed at the three ANEP meeting sessions and at the two CoP conversations (calls) are described in Table 1.

2.4. *The second ANEP survey.*

A second questionnaire was developed for the ANEP membership in 2011. The questionnaire was conducted in an interview format over the phone to eight of the ten members of the ANEP CoP. One of the Estuary Programs, which was in transition during this time, did not elect to participate. Another CoP participant elected to instead complete a similar on-line web survey that was provided to the executive directors of the ANEP member organizations who had not participated in the CoP. Seven of the eight respondents to the first survey agreed to the second

[37] Communities of Practice are self-organized groups of practitioners commu- nicating together on a subject of mutual interest to advance their understanding and skill, see: http://en.wikipedia.org/wiki/Community_of_practice.

phone-based survey. One other CoP member who joined following the first survey also agreed to the phone based survey. The NEP directors, whose organizations were not participants in the CoP, were contacted by email on three separate occasions over a period of four weeks in August and September 2011, and were requested to respond to the web survey. Of the 19 NEPs invited to respond to the web survey, 12 participated (plus one NEP from the CoP cohort) for a participation rate of 68 percent. The participation rate for the overall final survey, including the eight phone inter-views resulted in a 75 percent response rate (21 of the 28 NEPs).

3 *Results*

3.1 *Highlights*

The CCMP for each of the 28 NEPs was reviewed for references to ecosystem services, or terms that roughly equate with those concepts. Ecosystem services were not found to be directly referenced, but were identified as resources or assets—principally fisheries and recreation.

Highlights from the first and second surveys are presented in Tables 2 and 3 which provides tabular findings from the two surveys. The richness of replies from NEP respondents and summary of key points[38] with examples and quotes is provided in Appendix A.

3.2 *The first ANEP survey (2009)*

Table 2 (Table 4.2) summarizes responses from the initial eight members[39] of the NEP CoP.

[38] The bullets do not necessarily correlate with the number of responses to any given question. In some instances not all respondents offered substantive responses for each question.

[39] The CoP initially had eight NEP participants, all of whom answered the first questionnaire. Two NEPs joined the CoP subsequent to the issuance of the first questionnaire.

Table 4.2 Summary responses to the 1st ANEP Ecosystem Services Survey in 2009

Table 2
Summary responses to the 1st ANEP Ecosystem Services Survey in 2009.

Survey question	YES	NO	Maybe	Summary remarks
(1) Have you knowledge of the approach (or doctrine) of ecosystem services being used in decision making?	7	1	0	A Conference on ES[a] (ACES) in December 2008 in Naples, was widely acknowledged in advancing understanding of ES among the NEPs. NEP management and staff also frequently cite published literature and the EPA–ES Research Program. Other sources noted include Bill Mates, NJDEP Natural Capital Valuation Project with the Gund Institute, the work by Dr. Danielle Kreeger at the Partnership for the Delaware Estuary (one of the NEPs & CoP participant).
(2) Does the concept of "ecosystem service" offer any advantage in framing social and economic initiatives to meet environmental objectives for stakeholders?	7	1	0	Responses highlighted the importance of framing "environmental issues" in ways that are relevant to the general public and stakeholders. An NEP noted that people need to know that ES protect them from harm, form the foundation of the economy, keep the planet in balance, and help to maintain people's quality of life. One response asserted that framing issues in terms of ES has the power to engage the public to drive the success of environmental initiatives. Also noted was the importance of communicating effectively with officials. ES helps to integrate socio-economic principles into the communication of program objectives and present issues in a meaningful way to local officials and decision makers (i.e. protect resources, or there will be the loss of revenue and business generated by tourism and the summer population). Sensitivity to messaging was noted. ES can be viewed as the environmental dimension of some issue, and those who focus efforts on socio-economic issues may not feel it represents their concerns. ES can be hard to define or for people to understand. If they can be expressed in a way that people see a personal benefit, they can be useful. Finally, it was also observed that: "The limiting factor to environmental initiatives is usually not lack of public appreciation of the values of the services. The challenge is how to incorporate that value, to monetize it in some fashion in the decision making process… how to give credit to expanding these services… We need to go beyond identifying the service to identifying those who will pay for the service."
(3) Do you think a measurable characterization of what ecosystem services need to be sustained (e.g. crab fishery or flood protection) can serve as an effective means to communicate environmental protection objectives to decision-makers?	7.5	0.5	0	Some responses to this question were skeptical. Most NEPs who replied positively indicated services such as recreation and provisioning were relatively easy to value and use. One NEP used dollar amounts in their CCMP to show the value of specific ecosystem components such as agriculture, commercial fisheries, and tourism. Another tried to use the estimated value of enhanced recreational opportunities to characterize benefits associated with habitat restoration. One NEP successfully used statistics on the recreational monetary value of the estuarine system as grounds to generate support of policy makers for an innovative funding source to support protection initiatives. A 2% real estate transfer tax on all real estate transactions occurring within the Estuary watershed is put in a dedicated fund used for land protection and acquisition activities. One response noted that a Florida TMDL (Total Maximum Daily Load) was developed that employed the use of ES associated with sea grasses as the basis for targets in an estuary.
(4) Have you ever used ecosystem services as you define them to make a decision?	4	4	0	NEPs indicated that ES were mostly employed to support planning and project prioritization. Several NEPs indicated that ES have not been quantified to the extent needed to consider them in decision-making to date. Until ES values are better quantified, they were described as difficult to use.
(5) Can you imagine circumstances that would cause you to explicitly consider ecosystem services in a decision you might make (e.g. legal obligations, personal values, economic concerns, organizational goals, significance)?	8	0	0	Participants in the community of practice were uniformly able to conceive of circumstances where use of ESV would add value to decision-making. Among situations identified was ES arguments supporting decisions leading to better managed ecosystems and more funding and partnership opportunities because the decisions made are science based. ES information was also considered useful to prioritize projects, partner with, and/or help fund. Putting a dollar value to most valuable resources; beaches, shellfish, multitude of aquatic-based recreational activities etc… was considered an effective way of gaining support for legislation & the adoption of local land protection ordinances. There was uncertainty expressed if ES could function in meeting legal obligations (e.g. CWA attainment of WQS), though as part of an argument for a TMDL ES might have a role.
(6) Does the use of measures of ecosystem service condition correlate in any way with a project's success?	6	1	1	Responses ranged from simple doubt in the concept, though narrow conceptualization equivalent to fishery dockside market value; to thoughtful consideration of how the concept could be employed. One NEP perceived that ecosystem-based management would observe improvement in ecological services resulting from the implementation of particular actions and changes as a positive correlation and the project deemed successful. Habitat restoration and large-scale research projects

Table 4.3 Summary responses to the 2nd ANEP Ecosystem Services Survey in 2011(Table 3 below)

Table 2 (*continued*)

Survey question	YES	NO	Maybe	Summary remarks
				may be expensive and require many entities and forms of support. Being able to correlate project costs with potential creation or preservation of revenue or habitat value was identified as important. Also noted was the correlation of the ES an ecosystem component project should be producing with measured results can be used to assess the success of that project.
(7) Which means to characterize ecosystem services is potentially most constructive:	Quantitative monetary value-3	Narrative qualitative value-0	Both 5	The focus on monetary value creates a high bar for perceived value by some NEPs. A majority viewed both monetary value and narrative qualitative value as providing utility, in some cases depending upon who it is to be informed. It was noted that everyone understands the concept of a dollar. However a downside noted for monetization was with compensatory mitigation where the dollar amounts might not be entirely relevant. It was also noted that it depend on the service, with some easily monetized, while others not. It was noted that InVEST recognizes the market values of some services and applies scores to others. In some cases, giving a resource a monetary value can be a very effective means of establishing the importance of that particular resource or for comparing and prioritizing alternatives. A qualitative value may be needed to describe the biophysical components that cannot be valued in dollars but still provide valued services to the public who need qualitative information to help make informed decisions on the impacts of proposed actions… "a picture is worth a thousand words."

[a] The conference abstracts and presentations are archived at: http://www.conference.ifas.ufl.edu/ACES/

Table 3
Summary responses to the 2nd ANEP Ecosystem Services Survey in 2011.

Survey question			CoP phone	Web	Total
(1)Were you aware that ANEP partnered on a project to explore the utility of ecosystem services valuation for NEP estuary programs?		Yes	7	8	15
		Faintly	1	4	5
		No	0	1	1
(2) Have you used the concept of "ecosystem service" in decision making or framing information for stakeholders on the tradeoffs between social, economic and environmental objectives?		yes	8	8	16
		no	0	5	5
(3) Can you imagine circumstances that would cause you to explicitly consider ecosystem services in a decision you might make (e.g. legal obligations, personal values, economic concerns, organizational goals, significance)? If yes, what? Otherwise enter "no."		yes	8	9	17
		maybe	0	4	4
		no	0	0	0
(4) Have you used other sources to understand and explore how ecosystem services information could be relevant to your NEP? If yes, please identify the source/s. Otherwise, enter "no."		yes	7	7	14
		no	1	6	7
(5) Which of these answers best fits with your basic impression of ecosystem services information?[a]	**Responses**		**CoP phone**	**Web**	**Total**
	The information is useful and we've used it productively		5	3	8
	It is not much different from an economic resource value assessment.		.5	4	4.5
	It is a good concept but the science is too immature for current ease of use.		.5	3	3.5
	The value of the information it provides does not warrant the effort to obtain it.		.5	0	.5
	The concept is good and valuable, but resources do not allow our development of it at this time.		1.5	3	4.5
(6) Decisions regarding economic development in previously natural areas are informed by analytical and deliberative processes like cost-benefit analysis and risk assessment. Do you think that the introduction of information on the value of ecosystems services to these processes would substantively alter the outcome of the decisions? If yes, why? If no, why not?		yes	8	6	14
		maybe	0	2	2
		no	0	4	4
		don't know	0	1	1

[a] Some responses were described as "in-between" two of the five categories provided. In these instances the votes were split between the two selected options.

3.3 *The second ANEP survey (2011)*

Table 3 summarizes responses from eight of the ten members of the NEP CoP and an additional 13 NEP directors. The responses collected from the second survey were taken by phone interview with eight CoP participants, and by email survey using "Survey Monkey" for the other 13 NEPs.

4. *Discussion*

The sample size for the two surveys was small and targeted a small population, which is not unusual for a qualitative study. The surveys were spaced two years apart and targeted senior managers at NEPs. Seven of the eight respondents to the second telephone survey had replied to the first survey. In the first survey the respondents self-selected by volunteering to participate in the ESV CoP. The second survey sought to solicit responses from all 28 of the NEPs. Although the response rate was acceptable, 25 percent of the NEPs did not respond. In the traditional quantitative survey, "nonresponse" is usually considered a source of bias in a survey, aptly called nonresponse bias. Nonresponse bias arises from the fact that there are usually differences between the target pool of respondents and the sample that actually responds to a survey. In this research, nonresponse bias is construed as representing a lack of interest in the subject of ES or ESV. Because ES sessions were presented at half of the ANEP meetings over a period of 3 years it is presumed that NEP managers would have had opportunity to become informed on the subject of ES. Multiple emails were directed to NEP managers on behalf of ANEP requesting their participation in the second survey (in 2011), and it is presumed that coming on behalf of their own organization, they might have been predisposed to participate. A lack of interest should reasonably be considered to reflect the non-respondent as seeing little value in ES or ESV. This is discussed further in Section 4.4.

The NEPs function to identify, plan and execute targeted actions to protect and conserve water quality, habitat, and the living resources in their estuaries and watersheds. While all NEPs conduct this work and the associated stakeholder planning and project prioritization, the NEPs have somewhat varying focus. For example, some focus more on water quality as pertaining to recreation, while others more with a focus on living resources. The variation in budgets also affect the range of activities a NEP can take on, with some better suited to the conduct of research in their estuary, and substantive projects such habitat restoration, while others are somewhat more limited in the projects they are able to fund and execute. All the NEPs engage in communication and education with their communities.

4.1. *Discussion pertaining to Section 1.3 (question #1)*

"Does information on ecosystem service valuation provide value to decision-makers and does it advance progress in achieving environmental protection objectives?" The responses to the survey questions show that ESV provides utility to decision-makers in the consideration of environmental protection objectives. In both the surveys half the responses from NEPs that became associated with the CoP indicated that they had used ES concepts in decision making. The responses that characterized information on ecosystem services as valuable for decision making largely focused on its use for planning and project prioritization, and were fairly consistent from the first survey to the second. One NEP reported that they prioritized restoration activities and projects around general concepts of which activities return the greatest ecosystem services per investment. Another NEP initiated a project to develop an ecosystem based management plan that involves conducting a needs assessment based on ecosystem services. The purpose of the plan was for prioritizing funding opportunities and meeting ecosystem restoration goals. Other responses included: "…expansion of our current suite of indicators especially as we

advance our Climate Ready Estuaries initiative and our wetlands monitoring and assessment work." "In our recent [planning] report ESV constituted about 25% of the weight in our decision making." "We've used the concept in discussions about habitat protection and managing storm surge in the context of wetland losses. A qualitative use of ESV contributed to good results in this discussion." "…adapted it in new planning process for the ecosystem management plan. It offers a means to highlight benefits from ecological protection that are not otherwise readily valued by conventional cost benefit economics." Examples of program areas where ESV was employed include a classification scheme for an estuary wide monitoring program, and for creation of a biological condition gradient framework.

A small set of responses to questions inquiring if and how ES information can be useful in decision making (Table 2 (4), Table 3 (2) and (3)) focused on legal constraints. One response was that quantitative ESV "is necessary if it is to be used to inform and address permit applications. Specific applications such as considering the value of an acre of wetland vs. the services associated with dredging would be valuable." Another response was "that most water quality decisions are based on Clean Water Act requirements." Another response echoed the above concern: "It is not clear how it [ES] would function in meeting legal obligations (e.g. CWA attainment of Water Quality Standards. It is possible that part of an argument for a TMDL may be that the resulting improvements would allow for more swimming, fishing, and public access." This research was not structured in such a way as to investigate the differences expressed by respondents to these questions; where one response asserted that well quantified ES would be useful "to inform and address permit applications," and others asserted that "It is not clear how it [ES] would function in meeting legal obligations" (e.g. permits). One response stated a necessary condition: "ES can't be considered in those decisions unless explicitly included in statute, regulation, or policy."

A response from Florida in fact illustrated how TMDL could be harnessed to WQS. The respondent reported the use of ecological services associated with sea grasses (or lack thereof) as the basis for assigning benefits to proposed CCMP implementation actions and in assessing the overall ecologic health of their estuary. They noted that sustaining and enhancing the ecological services provided by sea grasses was adopted by the Florida Department of Environmental Protection as the basis for TMDL targets in their estuary. Modeling the watershed's nutrient loadings and their impacts on water quality/sea grasses and communicating these impacts to decision makers is helping to meet the Program's goals to "attain and maintain water and sediment of sufficient quality in order to support a healthy, macrophyte-based estuarine lagoon ecosystem, and which supports endangered species, fisheries and wildlife, and to achieve heightened public awareness and coordinated interagency management of the lagoon ecosystem that results in the accomplishment of the aforementioned goals." It should be noted that "sea grass" is an assessment endpoint rather than an ecosystem service, but represents the NEP's measurement criterion for multiple services associated with sea grass species' success.

4.2. Discussion pertaining to Section 1.3 (question #2)

"Does ESV represent a successful technique to communicate the importance of ecological health and ecological systems' integrity to society or stakeholders?" Survey responses were strongly

supportive for this function of ESV information. Responses in (5) of Table 3 reinforced the perception that maintaining ES was largely viewed as congruent with ecological protection generally and would be readily recognized by the general public. Respondents expressed a high degree of comfort using qualitative as well as quantitative ESV information to frame issues and ground discussions in values that were relevant to stakeholders. A qualitative use of ESV was credited with good results in discussions about habitat protection and managing storm surge in the context of wetland losses. One respondent cautioned that care should be taken with ESV information because it can be nuanced and technical. They noted that it requires a time investment to educate stakeholders if the concept is to be useful. Importantly, one respondent observed that using ESV helps to broaden stakeholder's perspective beyond immediate advantages perceived from economic development.

In response to survey question (3) of Table 2, the development of a Florida TMDL that employed the use of ESV associated with sea grasses as the basis for TMDL targets was noted. This use of ESV in an estuary demonstrated the strength of ESV as a means to communicate ES benefits within a regulatory framework. While sea grass health as an assessment endpoint does not communicate meaningful outcomes to non-scientists, the direct and quantifiable association with fisheries (provisioning & recreation services) and support for wildlife and endangered species (recreation & cultural services) communicates information meaningful to the public. This respondent also noted that the way marine dissolved oxygen criteria are written to ensure fish survival also demonstrates how indicators associated with the provisioning services of eco-systems are integrated into existing regulatory processes.

4.3. Discussion pertaining to Section 1.3 (question #3)

"Does communication of ESV improve environmental decision outcomes in decisions which balance ecological protection against economic development?" This research offers no evidence that ESV information was being deployed to "level the playing field" in cost-benefit assessments that lead to decisions on development vs. protection. Two responses to the surveys suggested that use of ESV was or could be useful. One response noted that "in discussions of economic development proposals, ESV helped to identify hidden costs on water quality and consequences for recreational services." In another, the respondent observed: "For an NEP, goals [setting] would be a primary use of ES. For some of our local government partners, ES values would be very useful for land use decisions."

This research is inconclusive with regard to research question (3) of Section 1.3. As noted above in the second response, NEPs do not appear to generally arbitrate decisions over land-use where a cost- benefit analysis might compare ESV to the economic advantages of commercial or private development. NEPs would be expected to champion protection using any information available, including ESV, but are not vested with authority to make such decisions. The research did not demonstrate that NEP programs performed project specific cost-benefit advocacy using ESV. As organizations with broad stake- holder participation (including economic development interests) in their programs, such direct interventions in economic development initiatives could prove divisive within the NEP, and thus, interventions of this nature—with or without ESV does not appear to be a strategy that NEPs employ. The research does suggest, however, that ES concepts

and ESV may have informed discussions within NEPs leading to land-use decisions by other authorities.

4.4. *General discussion of results*

Estuary managers reported that ESV is useful for various purposes whether characterized quantitatively or qualitatively. While both are considered useful, the limit to qualitative information—which was generally characterized as a description of the services provided by ecosystems, is implicit in responses to the surveys. Managers that found the qualitative information useful expressed the desire for better quantification of value. ES information currently used by the NEPs is primarily qualitative, and its main use is to help characterize the utility of ecosystems beyond most commonly quantified services (i.e. provisioning and recreational) to decision-makers and stakeholders in terms that they can directly value, like flood protection and support of economic sectors that are dependent on water quality.

Survey question (4) of Table 2 investigated NEPs use of ES "to make a decision." In addition to helping provide impetus for action, qualitative information has also been used to help determine what actions to take—where restoration and other resources will likely provide the greatest utility. The most widespread use of ESV was to "frame issues and to ground the discussions in values that are important to audiences." This was possibly held to be an important use of ES information in support of decision making in part because it was affordable—requiring little time, expertise or budget to implement.

Quantitative ESV information was perceived as better demonstrating value, and providing greater persuasive power when used to validate protection and restoration projects. Responses to survey questions (4) of Table 2 and (2) of Table 3 indicate that when ESV is used quantitatively, it is largely in association with highly valued and economically established recreational or provisioning services (i.e. fisheries).

Several responses to survey questions (3) of Table 2, and (3) and (5) of Table 3 brought into focus that the difference between an economic assessment and an ESV assessment was not immediately evident to all environmental program managers. Many of the NEPs had already conducted environmental resource economic assessments. In these instances, the information obtained was presented as quantitative ESV information. Plainly, it did capture substantial services that were highly valued in the estuary region. That the economic assessments did not capture the entire spectrum of services provided by ecosystems was not remarked upon.

Complete quantitative ESV information—understood by some respondents to include as a subset that which would be generated by an environmental resource economic assessment, was widely viewed as too expensive to obtain. Some respondents expressed that the value of the information did not justify its expense, but others stated that resource limitations prevented its collection—suggesting that were resources made available, the collection of such information might be pursued.

It may also be that resource managers do not find the persuasive power of less obvious services, such as nutrient cycling, to justify the expense of quantifying them. Allocation of funds to

quantify more easily valued ecosystem services such as provisioning is a logical approach to ESV because it is likely to yield information that is most easily obtained, communicated and understood. Although stacking services such as storm surge protection might actually add to a higher value, the uncertainty associated with such a service could lead to its being discounted. This, and other difficult to integrate factors such as insurable losses, may make investment in quantifying such ESV less attractive.

This may explain why quantified ESV was typically confined to services captured by environmental resource economic assessments. Not surprisingly, this is also in evidence when examining global scale studies—even those that purport to highlight the contributions of ESV. The natural capital assets measured in the Inclusive Wealth Report (UNU-IHDP and UNEP, 2012) included five categories: (1) forests, represented by timber and non-timber forest benefits; (2) fisheries; (3) fossil fuels; (4) minerals; and (5) agricultural land. These are primarily provisioning services that are most easily valued using existing environmental resource economic data. This information is important; however, it does not represent new information that would lead to improved decision making as is sought through the introduction of more thorough and complete ESV. While it is properly thought of as valid ESV information in every respect, it does not fully represent a complete inventory of ESV. Typically, economic assessments fail to identify and value the difficult to quantify, but possibly substantial and important ecosystem services.

This is also consistent with published findings discussed in Section 1.1. Representative was Molnar and Kubiszewski's (2012) findings that highlighted examples of ESV use by PES associated with no net loss of wetland under the Clean Water Act and the Conservation Reserve Program managed by the U.S. Department of Agriculture. Both programs implement conservation initiatives predating widespread publication on the topic of ES, and harken to the time when objectives such as the protection of water quality stood for what are increasingly referred to as ES. While there is agreement that protecting water quality also protects ES, and thus PES accurately describes these activities, it begs the question: If these activities pre-existed ES nomenclature, how does describing them in terms of ESV serve to substantiate the use of this information—it is a distinction without a difference. This question was very much explicit in the response of one NEP manager to several questions in the 2010 ANEP Survey. "… Just about everything NEPs do, and, thus, most decisions we make, are built around the protection or restoration of one or more ecosystem services. Perhaps there's some nuance to the term I am not getting. Do you mean economic value of ecosystem services?" Rather than the issue of "economic value of ecosystem services" this research suggests that the substantive issue distinguishing an assessment of ecosystem services from conventional natural resource economic assessments is the extent to which the full suite of services associated with an ecosystem are identified and valued (economically or otherwise).

Responses to question (5) of Table 3, "Which of these answers best fits with your basic impression of ecosystem services information?" offers substantive insights into how ESV is

perceived by environmental protection managers. The results[40] reinforced the perception that ANEP members who had self-selected for the CoP, had more of an appreciation for the utility of ES information than did the other ANEP members who did not participate in the CoP, but had agreed to respond to the web-based survey. In responding, both phone and web-survey participants could only select a single answer. Thirty-eight percent (38%) of the managers selected the response: "ES information is useful" and they had used it productively. The CoP members favored this response almost 2:1 over non- CoP members. Seventeen percent (17%) of the managers selected "ESV is a good concept but the science is too immature for current ease of use." Non- CoP responders were almost 4 times more likely to select this option than CoP members. Twenty-one percent (21%) of managers chose "ESV concept is good and valuable, but that resources did not allow their development of it at that time" as best representing their experience. Non- CoP responders were almost twice as likely to select this option as CoP members. This option, added with the two preceding options, shows that nearly 70% of the population surveyed had a favorable view of ES information or ESV more specifically.

It is worth noting however, that 25% of the NEP population did not elect to participate in the survey after repeated invitations. It is reasonable to surmise that the NEPs that did not participate probably perceive the least utility from ES and ESV. When these NEPs are added into the survey as not viewing ES/ESV favorably, then the number of NEPs with a favorable view toward ES/ESV drops from nearly 70% to only 57%.

Twenty-one percent (21%) of managers believed ESV is not much different from economic resource value assessment. Non- CoP responders were five times as likely to select this option as CoP members. As discussed above, this result suggests that greater familiarity with ESV, as was evidenced by participants in the CoP, led to a greater appreciation of how ESV represented a larger universe of services than is captured by environmental resource economic assessments. This uncertainty between economic valuation and ESV was also expressed in response to survey question (3) of Table 2. The uncertainty of the difference between ESV and economic resource value could be due to the overlap of "resources" with ES, and the quantification techniques used to establish value for both. Stated more simply, economic resource value is a subset of ESV – capturing those services for which value is most easily established by revealed and stated preference studies.

None of the managers opted to solely express that the value of ESV information was not worth the effort to obtain it; though one split this option with the option stating ES was valuable, but resources did not permit their use of it at that time. This author interprets the response as ambivalence by this manager over the cost-effectiveness of ESV information for purposes of their operations.

Challenges to the use of ES/V information were identified in several responses to different questions. Some are typical and expected, such as "good, local data to derive valuations are often lacking," and, of course, the resources to pay for it are not available. Nuanced obstacles were

[40] Percent responses do not total to 100% due to rounding error.

also identified, such as "there is not wide recognition or a lot of exact quantification that services exist and benefits flow." The published literature is increasingly responsive to this need as evidenced by the special edition of Ecological Complexity: Ecosystem Services —Bridging Ecology, Economy and Social Sciences (2010).[41] Other noted obstacles included: "The tradeoffs between ecosystem service use and restoration are not well defined;" and "The returns on investment of ecosystem recovery have not been quantified."

One respondent observed "We need to go beyond identifying the service to identifying those who will pay for the service." They explained: the "limiting factor to environmental initiatives is usually not lack of public appreciation of the values of the services. The challenge is how to incorporate that value, to monetize it in some fashion in the decision-making process; for example, in exploring the ecosystem value of bivalve or seaweed harvest for nutrient remediation." They further noted: "The challenge is how to give credit to expanding these services in lieu of less valuable, more expensive but potentially regulated nutrient control actions."

5. *Conclusion*

In Nature's Services (Daily, 1997), Gretchen Daily posited that tradeoffs between amenities, products and services, including ecosystem services, are being made daily, with little appreciation of the environmental implications. A great deal is known about ecological structure and function, and the processes that provide "free environmental services" to human populations. At issue is how effectively this information is communicated, and if it is sufficiently consequential to the public and decision makers in decision making processes. The principle impetus for ESV is to assert the value of those services so that the value of what might be lost in a "tradeoff," is fully appreciated by stakeholders and decision makers. There is a perception that the information about this value is not conveyed well or persuasively to decision-makers in current forms (U.S. EPA, 2010b). The primary argument behind the concept of developing and using ESV information is that it will improve on the effective delivery of ecological information to inform the environmental implications of decisions (Farber et al., 2002).

This research offers qualified support for this thesis. The research findings demonstrate that estuary management programs have used ESV successfully, both quantitatively and qualitatively, to set environmental protection and restoration objectives and to communicate to stakeholders. The three questions asked in this study, presented in Section 1.3, explored different dimensions of how ESV might be employed in NEPs to inform decisions.

- (1) in Section 1.3 asked if information on ESV provides any value to decision-makers and promotes achievement of environmental protection objectives? The results of this research demonstrated that it does.

[41] http://www.sciencedirect.com/science/journal/1476945X/7/3

• (2) in Section 1.3 asked if ESV represents a successful technique to communicate the importance of ecological health and ecological systems' integrity to society or stakeholders. The study results provided evidence that this is a function for which ESV is well suited.

• (3) in Section 1.3 asked if communication of ESV improves environmental decision outcomes in decisions that balance ecological protection against economic development. This question was intended to more directly explore the extent to which ESV has been employed to favor improved ecological outcomes when cost-benefit analyses are used to weigh environmental protection against economic development. For this purpose, the research results found little evidence that ESV has been used to directly influence the outcome of these types of decisions. The absence of demonstrated use of ESV for this purpose by NEPs is construed as inconclusive of its suitability or effectiveness in other circumstances.

This research supports a conclusion that an introductory awareness of how ES can be used to communicate with stake- holders, and aid in prioritization of operations or investment, appears to lead to a stronger appreciation in natural or environmental resource managers for the prospective use of ESV. With this appreciation, there also appears to be a greater willingness to collect and use ESV information. This suggests that the most constructive means to advance the adoption of ESV for environmental management is to introduce no/low-cost qualitative ES applications, such as terminology to characterize the many ecosystem services that are typically overlooked when characterizing environmental value, or to frame issues and discussions about values that are important to audiences. These low-cost initiatives will familiarize environmental resource managers, stakeholders, and decision makers with ESV concepts, and open the prospect for investing in and adopting other ESV concepts.

Consistent with the previous conclusion, there is utility in highlighting the value of environmental resource economic assessments as a limited set of quantitative ESV information. Economic assessments do capture substantial services that are highly valued in an estuary. It is important to recognize that although environ- mental resource economic assessments provide important ESV information; it is none-the-less critical to also inventory what is not included. It is with this added dimension that ES is differentiated from environmental resource economic assessments. It would be through this awareness that decision makers will understand the limits of traditional economic assessment in contrast to a fully developed ESV report. Additionally, building awareness of the wider constellation of ES beyond those captured with an economic assessment can demonstrate to stakeholders the utility of the ESV concept and pave the way to wider adoption.

Disclaimer and Acknowledgements[42]

[42] This work is not a product of the United States Government or the United States Environmental Protection Agency, and the author is not doing this work in any governmental capacity. The views expressed are those of the author only and do not necessarily represent those of the United States or the US EPA. The author wishes to acknowledge the help of Irene Purdy, Suzanne Marcy and the Jeff Poteat (currently or formerly) of EPA, and ANEP associates Holly Greening, Richard Ribb, and Danielle Kreeger, who collaborated in developing presentations on

4.3. Expert elicitation on the ecosystem services survey research

The use of expert elicitation is considered to be a valuable addition to other approaches for gathering evidence in support of decision-making. Expert elicitation efforts are typically designed to address uncertainty and to fill data gaps, using subjective probability distributions obtained through careful survey and interview design, with experts representing a defined range of knowledge and perspectives (Morgan, 2014). In 1954, Savage established the foundation for taking this statistical approach to expert opinion; he coined the phrase "probabilities of orderly opinions," in which he described the probability cluster of opinions on a given subject by rational individuals (Savage, 1954). From this origin, expert elicitation has evolved to become a systematic process for "formalizing and quantifying expert judgments for an uncertainty quantity as the probability of different events, relationships, or parameters." There are also informal and non-probabilistic expert elicitation methods for obtaining expert judgment (U.S. EPA, 2011). It can be false to claim that everything is quantifiable, and in some situations more inclusive, qualitative approaches are required (Stirling, 2010).

In all instances of elicitation, experts are called upon to provide opinions to help answer difficult questions. As employed in this research, the experts were involved to provide independent and objective perspectives on the design of the ANEP survey, and to reflect upon the conclusions drawn from the survey responses. Thus, the elicitation design used was non-probabilistic and used the subjective judgement of the experts to challenge, confirm and inform this researcher's survey design and interpretation of the results. The qualitative approach was consistent with action research methods. It was an external check on the research design and methods of the research action partners.

Eleven experts were approached to participate, six agreed, and ultimately responses were received from four. Their subject matter expertise was established through their presentations at a professional conference of "Social Science for Coastal Decision-Making", titled the Social Coast Forum, which was convened in February 2012. The experts met a basic criterion for having presented at the conference on a subject that incorporated use of ecosystem services' information. This established that the expert had conducted social science research, was focused on a coastal issue, and had a familiarity with the concept of ecosystem services.

In general, responses from the four experts expressed agreement with the research methods and conclusions. This was qualified by several statements observing that the summary information provided limited their ability to reply with detail or certainty. A summary of the expert's responses to the six questions posed in the elicitation is provided in Table 4.1. The background information provided to the experts and their complete responses are provided in appendix B.

ecosystem services at the ANEP meetings, and/or reviewed the draft ANEP surveys. The author also expresses gratitude to the anonymous reviewers of this article who offered substantive recommendations for its improvement.

Table 4.4 Summary of expert elicitation	
Question	Summary of responses
1. Please enter your name. Your remarks will not be directly attributed to you at any time in any media. If the name line is left blank, you will not be identified to the other five participants in this elicitation - nor will I be able to identify you.	ZC, TS, CF, & MR.
2. What is your assessment of the research population and response rate for this study, in the context of the conclusions drawn?	The experts agreed that use of NEP programs as the sample population was appropriate given the research questions. A larger panel of experts would have been better, but the response rate was defensible.
3. Do you think that the information collected in this study can be extrapolated to other organizations involved in the use of environmental information for environmental program management? Why or why not?	Generalizability of findings will be difficult due to homogenous respondents, however, using a similar panel from a different "program" (e.g. NOAAs National Estuarine Research Reserve System) could produce rich complementary data. If you mean this somewhat more qualitatively, this information could probably be extrapolated, but should be heavily qualified by describing the organizational and social position of NEPs compared with other organizations.
4. Do you disagree with any of the assertions made regarding NEPs in the research description, or the conclusions I've drawn from their survey responses? If so, please describe your concern/s.	The experts disagreed with very little. Finding #4 was considered interesting and garnered the most positive responses. An additional explanation for not using ES data in conventional cost-benefit analyses was offered: lack of capacity (which may include lack of understanding, time, or money). One expert suggested that the assertions made regarding hesitation in using quantitative analysis of ES information could be enriched by highlighting the perceived immaturity of the concept. A social network analysis of the dynamics between NEPS was recommended to help understand the drivers of tipping toward adoption or inertia.
5. Conclusion # 5 addresses the utility of ES data for valuing ecosystem services in cost-benefit assessments. This researcher does not believe that because cost benefit decisions were not identified as a use for ES data it should lead to a conclusion that the information is mismatched or unavailable. Rather, this researcher does not think that the NEPs choose to use the information in this manner. This research shows that ES data is used in a comparable manner for scenario planning. Therefore, this researcher asserts that the ES data could be used to inform cost benefit assessments. Based upon the information presented and what you may know of NEPs, does this conclusion seem to be reasonable or not? If yes, why? If not, why not?	Three of the four experts replied that drawing the foregoing conclusion was reasonable. The fourth expert explained that the information provided was insufficient for him to make any conclusion. Two experts thought that the information collected was important for advancing the use of ecosystem service valuation for basing resource decisions.
6. Does the information presented by this researcher suggest to you any other conclusions or questions that should be further examined? Or, do you have any comments on the scope or content of this elicitation? If yes, please elaborate.	Two experts expressed enthusiasm for the research. One of them expressed interest in the argument that if ecosystem services valuation is useful in situations such as decision- validation and priority/investment setting, it could reasonably be applied on the "demand-side" of decision-making that is currently occupied by natural resource economics. One stated that time limitations constrained their active engagement in the elicitation. The fourth recommended more information on the perceived immaturity of the ecosystem services concept, and current practices in ecosystem services use in scenario planning as helpful.

5. Analysis and discussion

5.1. Introduction

In this Chapter, Jürgen Habermas' Theory of Communicative Action and the theories of Ecological Modernization, and Institutional Change are introduced and used to analyze the conclusions presented in Chapters 3 and 4. Additional concepts are also introduced to expand upon issues concerning how values influence decision-making, and sustainability. The Theory of Communicative Action was chosen as the primary theoretical lens for this research because it provides insight to the sociological implications for the primary distinction in how ecosystem services information was used by the NEPs – either qualitatively for framing issues, or quantitatively as data inputs for decision-support methods. Habermas' theory offers a compelling explanation for how the interplay between individuals, society and institutions lead to the evolution of our thinking, social norms and reasoning; an issue addressed in the conclusions. Ecological modernism is an important adjunct theory for its emphasis on social and institutional change in response to pollution and other forms of environmental stress. Institutional Change Theory was included for its restatement of principles advanced by both communicative action and ecological modernism, as applied to structures in modern day society.

5.2. Habermas' Theory of Communicative Action[43]

The Theory of Communicative Action (TCA) presents an explanation of social change and evolution, and offers an explanation for how ideas contribute to the qualitative changes in subjective, normative and objective belief systems that constitute our personal understanding, cultures and societies, and institutions (Habermas 1984, 1987). The TCA provides a means to understand how information can, through communication between individuals,[44] and through "steering media,"[45] result in changes to, or "evolution" of societal understandings and the contexts in which decisions are made. The example of businesses recognizing the social shift in demand for socially responsible and environmentally harmless products in Sec. 3.1.1 is illustrative. The TCA is important for this thesis because it illuminates how qualitative value-based beliefs are translated to quantitative rational decision-making frameworks (see also 5.4). This is relevant to the discussion on balancing interests in societal decision-making, such as economic development versus environmental conservation, which is essentially the core issue of social consequence addressed in this thesis.

The TCA theory functions on three levels that are integral to understanding how purposive rational action effect changes in the world: (TCA, Vol.1, pgs. 68-83, pg.100)

[43] Reference to Habermas' Theory of Communicative Action will be abbreviated as TCA, with the volume identified (1 or 2), and a page number. e.g. (TCA, Vol. 1, pg. 1); but referenced as (Habermas, 1984, 1987)
[44] Individuals in community may be proximal, sharing interests as in academia, or virtual.
[45] In its most simple form communicative action is a rational discussion (or "argument") between people (or within a group) pertaining to "validity claims" about some subject leading to coordinated actions. On the scale of institutions or the economy, communicative action functions through steering media such as wealth and power, which, in effect, substitute for language as the mechanism for coordinating action. (TCA Vol.1 pg. 342)

1. The *subjective* ego, the subjective world is the totality of the experiences of which the individual has privileged access;

2. The *normative* context of community, religion, and other "groups" that provide the immediate uncritical understanding of the world through received social reference conditions, and is largely mediated through intersubjective exchanges – this is the social world and the totality of all legitimately regulated interpersonal relations (referred to as "lifeworld"); and

3. The *objective* constructed institutions of economy and government that are mediated through communicative actions generally channeled through steering media rather than intersubjective exchanges. The objective world is the totality of all entities about which true statements are possible.

The methodically rational conduct of life combines the three rationality structures so that they are mutually stabilizing (TCA Vol.1, pg.173). The communicative model of action advances language as a medium of communication whereby speakers and hearers, from the context of their pre-interpreted lifeworld, refer simultaneously to things in the objective, social, and subjective worlds in order, to negotiate common definitions of a situation (TCA Vol.1, pg.95). Communicative action functions to resolve decisions in each of these levels, and directs change between levels, e.g. when societal demand for "green products" results in recalibration of institutional planning to reduce environmental impacts from merchandise.

Habermas used the term "lifeworld"[46] to describe the normative context that connotes "culturally established standards of value." (TCA, Vol.1, pg. 20) Further, he wrote of lifeworld as "Achieving, sustaining, and renewing consensus … that rests on the intersubjective recognition of criticizable validity claims." A communicatively achieved agreement must be based in the end on reasons (TCA Vol.1, pg.17). In this way, Habermas described how people reaffirm and evolve the understanding of values and the world. Habermas also stated that lifeworld provides society and culture with normative "grounding" of understood validity statements, the acceptability of actions, and evaluative statements establishing value preferences (TCA Vol.1, Pg. 39). Habermas observed that lifeworld "…must be equipped with a more comprehensive concept of validity that is not restricted to validity in the sense of truth, but must also contend with questions like what is good or what one ought to do." (TCA Vol.1, Pg. 30-31). Habermas thus described how lifeworld defines, propagates, and integrates value preferences into the objectified rationality of institutional decision-making.

In modern cultures, the rationalization of lifeworld has led to instrumental reason and cognitive rationality, which gave rise to objective institutions of law and the economy, splitting off from lifeworld to establish independent sub-systems. This differentiation of subsystems, principally economy and administrative government, enabled greater social complexity. However, it also resulted in a weakening of the means, by which values are established and sustained, such as through traditions and religion (TCA, Vol.1, pgs. 68-83).

[46] A term coined by Edmund Husserl (1936), and understood to be an assemblage of overlapping and competing normative framings.

Tension between lifeworld and instrumental rationality

Habermas stated that modern western societies promote a distorted understanding of rationality that is fixed on cognitive instrumental rationality, to the diminishment of normative and subjective judgement. He incorporated R.C. Baum's theory of media (*On Societal Media Dynamics*) to explicate the loss of freedom through monetarization conceived by Karl Marx, and loss of freedom through bureaucratization by Max Weber (TCA Vol.1, pg.66).

The transfer of coordination from language mediated communicative action to that of steering media was believed to decouple interactions from the lifeworld context (TCA Vol.2, pgs.173-183). It was also described as a "technisizing of lifeworld" whereby integrative functions previously fulfilled normatively by lifeworld are shifted to objective institutions of government and the economy that direct action through positive and negative sanctions. This circumstance is associated with modern maladies of alienation and disempowerment (TCA Vol.2, pg. 281). Habermas employed Baum's assertion that only money has been sufficiently anchored institutionally whereby, it can function both as a store and as a measure of value. He noted that this form of steering media was developed to a much greater degree than others, and a consequence is that there is an inclination to define problems in terms of the medium, which can best be managed (i.e. money). One result is that many problems remain intractable, in part because of the use of money to measure outcomes that money alone cannot serve or direct (TCA Vol.2, pg. 293). Thus, economic feasibility may function well as a metric of instrumental rationality, but be entirely disconnected from any prevailing values associated with lifeworld and the public's experience of principles, ethics or morality.

5.3. Theory of Ecological Modernization

The significance and use of ecosystem service information is consistent with Rational Choice Theory[47] and with the Theory of Ecological Modernization, insofar as ecological modernization is predicated on the rationalism of industrial society theory, as was argued by Spaargaren (1997). Spaargaren argued that the main problems in modern society follow from the instrumental rationality of industrialism "colonizing" lifeworld (also asserted by Habermas). Spaargaren, argued that this colonization extends to the biosphere. He stated that these problems, described as structural design faults of the industrial system, can be overcome by ecological modernization, which is an "eco-social restructuring of the technosphere." Spaargaren synthesized ecological modernization concepts from leading theorists including Joseph Huber, Martin Jänicke, Udo Simonis and Arthur Mol, and concluded that two projects are central to ecologically driven modernization:

1. re-structuring of processes of production and consumption towards ecological goals; and
2. placing an economic value on nature.

Ecosystem services valuation is, for some, the placing of an economic value on nature. While the science supporting ecosystem services valuation has advanced (Seppelt, et al., 2011), its contribution to decision-making remains less obvious (Martin, 2014). Ecosystem services

[47] For discussion see Rational Choice Theory: Advocacy and Critique edited by James Coleman and Thomas Fararo (1992) #7 in Key Issues in Sociological Theory, Sage, London.

valuation as an input to decision-making and ecological modernization, have both been subject to criticism as serving instrumental rationalization. The criticism was leveled by those who believe that the instrumental rationalization of modern institutions is itself the basic problem and that environmental consequences are only a symptom. Thus, efforts to ameliorate the environmental consequences still leave the basic problem unresolved.

Fisher and Freudenberg (2001) summarized critiques of ecological modernization and discussed how some challenge the theory as only mitigating the environmental negatives of industrialism, while ignoring the socioeconomic consequences such as environmental injustice and the excesses of capital accumulation. They asserted that ecological modernism conforms to the logic of instrumental rationality, and is not directly linked to the values underlying social democratic thought. This criticism is relevant to the application of ecosystem services valuation information in decision-making for the distinction made between qualitative-normative decisions and values, and decisions arising through instrumental rationality. This criticism, as it is leveled against ecosystem services valuation, was discussed in Sec. 3.2.

Habermas distinguished between the outcome of discursive communication leading to value-based understanding that occurs in lifeworld, and the instrumental rationality occurring in the institutionalized parts of society. Skollerhorn (2000) also made this distinction. He characterized it as two different ways of coordinating action and decision-making, corresponding to privatization vs politization of the economy. Privatization represents the way of capital accumulation – instrumental, means-ends rational and value-free technology. In the realm of instrumental rationality only the purely material consequences in monetary terms of a decision are in focus. Politization is the democratic way of knowledge based on interactive and egalitarian debate leading to shared understanding. Skollerhorn stated: "Social learning reached in this way is directed towards immaterial values, i.e. what are temporarily true states of affairs and what is the normatively right thing to do." The resulting ideas are generated through "social knowledge and legitimate norms connected to values" (Skollerhorn, 2000).

The two paths to coordinating actions identified by Skollerhorn parallel two types of decision-making contexts, each with their own attendant processes. They need not be mutually exclusive, but in any decision, one context will be dominant. When the issue and decision context are well aligned, then there is no ambiguity whether the decision-making processes or methods fit; for example, public policy on legal death penalty decided normatively through communicative action. Because the decision is clearly public it is unlikely that there will need to be a balancing of public vs. private interests. Where a balancing of public and private interests is required, however, there may be a blending of the decision contexts, or the context processes may not align well with the information from both public and private inputs.

An example of this is a corporate sustainability plan that incorporates value-based arguments, and may include public participation, but must ultimately be cost-effective to serve the company's stockholders. In this example, the decision context is mixed between a value-based context and the quantitative "bottom-line" context more typical of business operation. The relative importance of factors informing the decision context and decision criteria themselves may not be agreed upon by all parties. The decision support methods used in the dominant

decision context may not easily accommodate all information. Table 5.1 presents contrasting factors that characterize the public and private interest decision contexts.

Table 5.1. Contrasting factors in public and private interest decision contexts

	Lifeworld - Communicative Action -Public Interest	**Institutional** - Instrumental Rationality - Private Interest
Type of arguments	Value based	Objective
Participation	Democratically derived	Private
Motivation	Socially motivated	Strategic motivation
Time horizon	Longer	Shorter
Objective	Understand what is right to do	Capital accumulation
Decision support	Sincere, rational debate	Quantitative data analysis
Scale	Large, societal or subpopulation	Set by the private interest

5.4. Institutional Change Theory

Institutional Change Theory holds that values are carried by two different types of social behavior, ceremonial and instrumental. They are thought to be inherently incompatible, but intertwined through complex social and institutional relationships (Bush, 1987). Bush accorded great significance to the "ceremonial – instrumental dichotomy." This is interesting for the parallels with the Theory of Communicative Action, with lifeworld holding the normative "ceremonial" value structure of a culture that informs and shapes processes in society's institutions, and "institutional" activity where objective decision-making occurs. This researcher views Institutional Change Theory as largely consistent with communicative action, as a description of how communicative action occurs and drives changes in society.

Although, there are many different needs for decision-making by institutions, the most prevalent are those that include economic analyses because cost effectiveness has become such a prominent feature of modern society. This is the case when considering the monetization of ecosystem services. A key question to address is "How are benefits identified if they are not monetized?" If not monetized, benefits must be otherwise valued. Bush asserted that mainstream economics evades that intellectual responsibility, eschewing any accommodation of values, and instead adhering to the claim of objectivity. The consequence is that value-based, normative considerations are suppressed in most forms of instrumentality (Bush, 1987). The weakness of strictly quantitative decision frameworks to incorporate value-based reasoning was addressed in Chapter 3. Others have also identified similar shortcomings and made efforts to provide decision support alternatives that address the weaknesses discussed, but retain the methodological rigor (Virapongsea et al., 2016; McGinnis and Ostrom, 2014).

5.5. Ecosystem services, sustainability and theories of change

The emergence and diffusion of ecosystem services concepts and valuation can be seen as empirical instances in TCA, Ecological Modernization Theory, and Institutional Change Theory. All three theories help us to understand how ideas and concepts move through society and affect how decisions are made by people and institutions.

The theories introduced in Sections 5.2, 5.3 and 5.4 share common explanations of how changes occur in civilizations, societies, and institutions. These theories are useful for examining the primary and secondary research themes in this thesis: "Has ecosystem services information improved decision-making in National Estuary Programs?" and "What is the significance of values for decision making?" (See Section 1.3). This researcher observed that for the significant amount of research published on the value of ecosystem services, there was little published on how the information had been used to influence the outcomes of decisions. This observation was also the impetus for planning and performing the survey research with the U.S. National Estuary Programs (NEPs), to explore how the information was being used by management in decision-making (Martin, 2014). The survey research showed that qualitative information on ecosystem services appeared to be more useful to the NEPs, but for purposes such as stakeholder communication rather than for decision-making. This finding, with other contextual information, was interpreted in Section 5.6 through the TCA to explore implications and to suggest a strategy to improve the use of ecosystem services information in decision-making.

In Section 5.7 sustainability and decision science concepts that were introduced in Chapter 3 were examined through the lens of the TCA. The significance of public vs private interests as the framework for societal decision-making was juxtaposed with sustainability and discussed to highlight the importance of values in shaping how decisions are made. This idea, in turn, was examined for its potential to illustrate how changing knowledge can change values (and vice versa), and can lead to institutional changes resulting in decision frameworks that more or less welcome different types of information.

Section 5.8 addressed the difficult problem of why information may not be used or be influential in certain decision-making contexts. One implication is that information may not match well with the values inherent in that decision-making framework. The criticism leveled at the Theory of Ecological Modernization, that it is overly instrumental, is compared to similar criticisms of ecosystem services. An evaluation of *'wicked problems'* and *'clumsy solutions'* was made to help inform the significance of competing values in decision-making. Because wicked problems are typically understood differently by different stakeholders as a result of different value orientations, the literature describing them is helpful in understanding how even when data, such as ecosystem services valuation, are provided in a decision context, they may not be persuasive. Or, they may simply not be regarded as useful by some stakeholders whose values dictate that their significance should be discounted.

5.6. Uses for ecosystem services information in decision-making

In Chapter 4 the results of two surveys were described. They were conducted with NEPs to explore how the concept of ecosystem services was used to inform decision-making. The NEPs identified how ecosystem services were used to inform program planning priorities, communication with stakeholders, and evaluation of trade-offs between ecological preservation and economic development. Habermas' Theory of Communicative Action augmented by theories of Ecological Modernism and Institutional Change, were used to interpret the survey results and to develop conclusions, especially, with regard to the spread of knowledge and values, and the dynamic for balancing societal interests. The balancing of private and public interests was juxtaposed with sustainability to examine aspects of societal decision-making.

The responses to survey questions addressing research question (1) "Does information on ecosystem services valuation provide value to decision-makers and does it advance progress in achieving environmental protection objectives?" indicated that when used, ecosystem services valuation provides some utility to decision-makers in the consideration of environmental protection objectives. The responses favorably characterizing ecosystem services information as valuable for decision making largely focused on its use for planning and project prioritization, and were consistent from the first survey to the second.

Responses to the survey, which addressed research question (2) "Does ecosystem services valuation represent a successful technique to communicate the importance of ecological health and ecological systems' integrity to society or stakeholders?" were strongly supportive for this function of ecosystem services valuation information. The responses reinforced the perception that maintaining ecosystem services was largely viewed as congruent with environmental protection and would be recognized by the public. Respondents expressed a high degree of comfort using qualitative as well as quantitative ecosystem services valuation information to frame issues and ground discussions in values that were relevant to stakeholders.

Responses to the survey research question (3) "Does communication of ecosystem services valuation improve environmental decision outcomes in decisions which balance ecological protection against economic development?" provided no evidence that ecosystem services valuation information was used to better support environmental protection positions in management decisions.

Most NEP managers reported that ecosystem services valuation was useful whether characterized quantitatively or qualitatively. However, ecosystem services information currently used by the NEPs is primarily qualitative. Its main use is to help characterize the utility of ecosystems to decision-makers and stakeholders beyond most commonly quantified services (i.e. provisioning and recreational), with values they understand, like flood protection and support of economic sectors that are dependent on water quality. The most widespread use of ecosystem services information was to frame issues and to ground the discussions in values that are important to audiences. This was held to be an important use of ecosystem services information in support of decision-making, in part, because it was an affordable application – requiring little time, expertise or budget to implement.

Responses to the survey questions suggested that when ecosystem service valuation was used quantitatively, it was largely in association with highly valued and economically established recreational or provisioning services (i.e. fisheries). This was also noted by Marre et al. (2016). Quantitative ecosystem services valuation information was perceived as demonstrating greater persuasive power when used to validate protection and restoration projects. However, quantitative information on the full range of ecosystem service values was generally viewed as too expensive to obtain. Allocation of funds to quantify more easily valued ecosystem services such as recreation and provisioning was viewed as a logical approach to ecosystem services valuation because it was likely to yield information that was most easily obtained, communicated, and used in conventional utilitarian forms of cost-benefit.

The National Estuary Program member's responses to the survey question, "Which of these answers best fits with your basic impression of ecosystem services information?" suggested that NEP managers who had explored the utility of ecosystem service (ES+) had more of an appreciation for the value of ecosystem service information than did the other NEP managers who had not been exposed to ecosystem services information (ES-).

Thirty-eight percent (38%) of the managers selected the response: "ecosystem service information is useful" and they had used it productively. The ES+ members favored this response almost 2:1 over ES- members. Seventeen percent of the managers selected, "ecosystem service valuation is a good concept but the science is too immature for current ease of use." ES- responders were almost four times more likely to select this option than ES+ members. Twenty-one percent (21%) of the managers chose "The ecosystem services valuation concept is good and valuable, but that resources did not allow development of it at that time," as best representing their experience. ES- Responders were almost twice as likely to select this option as ES+ members. Survey results suggest that familiarity with ecosystem services, even if only qualitative, resulted in survey respondents being more supportive of costs associated with collecting data for decision-making.

In the context of decision-making, the use of ecosystem services to inform management choices between conservation (typically perceived as public interest) vs development (typically perceived as private interest) is a logical strategy, which can support a full quantification of natural resources so that they can be accurately evaluated in an institutional decision-making framework (e.g. cost-benefit analysis) along with other similarly monetized outcomes. However, this researcher's findings documented that this did not routinely occur within NEPs. Others also reported that the scholarship on ecosystem services has not been translated directly to evidence of its use in decision-making (Marre, et al., 2016; Laurens et al., 2013). Despite significant and sustained scholarship on the valuation of ecosystem services for more than a decade, there were few published accounts of ecosystem services valuation having been used to inform decisions on whether to exploit or to conserve nature. (Martin, 2014).

Experiences in the EU reinforce this observation. The research project, "Motivational strength of ecosystem services and alternative ways to express the value of biodiversity" (BIOMOT),[48] was funded to explore what would work to motivate action to conserve biodiversity. In the EU, disappointment in the results of the introduction of ecosystem services for objective analysis in rational decision-making associated with conservation of biodiversity led to a questioning of why use of ecosystem services valuation within the decision framework of instrumental rationality was not more influential. The European Commission's Seventh Framework for research and innovation supported an inquiry to examine why, despite claims that biodiversity has total economic values running into the trillions of euros worldwide and hundreds of millions even for 'minor' ecosystem services on local scales, biodiversity in Europe is still declining. Europeans and their leaders do not appear to respond to the information (see BIOMOT Proposal[49]).

[48] http:www.biomot.eu
[49] http://www.biomot.eu/docs/biomot_general_long_version.pdf

Among the initial papers prepared for BIOMOT, one advanced a normative political theory of "deliberative democracy," which stated, that 'democratic decision-making should consist not in the utilitarian aggregation of preferences, but in public debate on the public good. Participatory and deliberative techniques begin with openness to the transformation or change of preferences through exposure to the arguments of fellow deliberators.

> "This constitutes a conception of rational decision-making that is an alternative to the market-based, instrumental rationality of economic approaches, namely, a forum-based, procedural rationality, whereby a rational decision is the outcome of fair procedures and deliberation which meets the norms of rational discussion." (Knights et al., 2013).

Interpreted through the TCA, this researcher was persuaded that the difficulty with using ecosystem services information by the NEPs, and in conventional decision-making, results from a value bias that exists within instrumental decision-making frameworks such as cost-benefit analysis that are typical of institutions. This can explain why, even when ecosystem services valuation is brought to bear in a decision, such as was documented by BIOMOT, it may be undervalued or discounted because it does not represent *cash revenue*, but instead, *calculated benefits* derived from sustainable ecosystem services.

This researcher's findings and the literature review results demonstrated that ecosystem services information has both normative meaning and can be quantified. The NEP survey findings described in Section 3.4 supported an interpretation that qualitative familiarity with ecosystem services concepts increases the likelihood that managers will be more willing to employ ecosystems services quantitatively. Within a sustainability decision-making framework, the correspondence between qualitative and quantitative use of ecosystem services can be facilitated, thus fostering an integrated and linked association between the normative, qualitative and social value of local ecology, and the means to quantify the utility of ecosystem services benefits.

5.7. Public versus private interest compared to sustainability as decision-making frameworks

The balancing of private and public interests is a binary concept that has been central in western philosophy, and served as a key entry point into many kinds of social and political analyses (Weintraub, 1997). This includes the analyses of environment and natural resources, where the concept holds explanatory power for the proportional exploitation or conservation of resources (Heimlich et al., 1998). The balancing of interests implicitly recognizes competing values between social and private objectives, and is adjudicated through law and decision-support tools such as risk assessment and cost-benefit analysis (NRC, 2012). Authors of various philosophies have sought to clarify how these competing values are perceived and received. The 'power' of the "invisible hand," as a metaphor, is significant (Smith, 1759), and the ensuing two centuries of thought regarding the size of the hand and ability to advance the interest of society remains an active and contentious debate.

The weighing of private vs. public interests continues to be a significant arbiter of decision-making for institutions charged with promoting or protecting the public interest, as well as for

corporate social responsibility (Campbell, 2007). The values represented in the public/private dichotomy have been explored in multiple ways, as there are numerous definitions of public and private interest. Jeff Weintraub (1997) described the relationship between public and private interests as replicating the "two classic answers to the problem of social order posed by utilitarian liberalism" (e.g. neoliberal economics). He asserted that, on the one hand there is the camp advancing the invisible hand of the marketplace that champions the harmonization of social and "selfish interests"; and on the other, there are those who believe that an agency is necessary to maintain order through a "structure of rewards and punishments within which individuals pursue their rational interests."[50] That this contest remains relevant is not disputed, but rather the question is asked whether this remains the best framework to support societal decision-making.

Exploitation of resources by the 'invisible hand,' has resulted in cumulative effects upon ecosystems leading to reduced function and fecundity, and in severe circumstances, collapse (Meadows, 1972, 2004; MEA, 2005). The environmental movement of the 20th century was galvanized by events such as the 1952 London killer smog, the Cuyahoga River (New York, USA) catching fire in 1969, the 1984 Bhopal Union Carbide cyanide gas disaster, and Chernobyl and 3-Mile Island nuclear catastrophes.

Academic activists, such as André Gorz (1980), Murray Bookchin (1986), and Barry Commoner (1987) advanced a critique of a wealthy private sector where corporate interests exploited the commons for private gain at society's expense. This folded into a perception that *public interest*[51] in services provided to society, such as potable water, safe food, healthy air, and equal recreational opportunities must be balanced against the *private interest* exploitation of natural resources resulting in compromise or destruction of these services (MEA, 2005). There has developed over time, the practice of cost benefit analysis, which was designed to harmonize public and private interests, as well as to provide some structure for decision-making. Cost benefit analysis frameworks implicitly underscore that a check is needed to ensure balance between private gain and benefit to society. The framing of this tradeoff is typically monetized, and the closer to a public benefit that can be demonstrated the more likely a private gain will be approved.

However, the distinction between ecological despoliation for private gain, and that attributable to provisioning society is blurry. There is not a uniform order of social interests favoring conservation of ecological resources, as opposed to their continued development and exploitation (Mol and Spaargaren, 2000). Increasing human appropriation of ecosystems' productivity (Vitousek et al., 1997; Sanderson et al., 2002), concomitant with increasing human population and wealth in society, challenges the notion that there is incontrovertible public interest in the preservation of natural ecosystems. If development and appropriation of ecosystems is required to serve a growing human population, this challenges the notion whether the withholding of those services demanded by the public can be considered to be in the public interest. This is

[50] The former is represented by the philosophy of John Locke and Adam Smith, and the latter by Thomas Hobbes and Jeremy Bentham (Weintraub, 1997).
[51] Random House: Public interest is, "The welfare or well-being of the general public; commonwealth."

confounding to any resolution between public and private interests in the preservation of ecosystems. It is appropriate to reconsider the question of *balancing* public and private interests. The metaphor of the 'invisible hand' is that public and private interests are in fact inextricably linked. Although the metaphor is intended to illuminate the relationship between private and public economic welfare gains, it may most accurately describe the relationship between private and public *ecological* welfare. As private interests enhance or degrade ecological systems through economic development, the services provided the public are similarly enhanced for degraded.

The declaration of Corporate Social Responsibility (CSR) is a private sector affirmation of this commonality of private and public interest (Sheehy, 2015). Sustainable business models in the private sector are a type of CSR that permit the examination of a business' value proposition, and how it may operate to advance ecological (and social) value together with economic value (Boons & Ludeke-Freund, 2013). A sustainable business model is one that is designed to align all stakeholder interests, explicitly considering the environment and society as key stakeholders (Bocken, et. al., 2014). This is an observation that social and private sector interests are not the same, but they can be aligned to advance economic, social and environmental objectives, concurrently. This is a characteristic of a sustainable outcome.

Sustainability, as illustrated through CSR, offers an alternative analytical framework to the public vs private interest comparison. A central idea of sustainability is that there must be a balancing of interests between economic, social welfare and environmental outcomes (Lozano, 2008). Theoretically, sustainability does not distinguish between public vs. private interests. The tension between public and private interests must be viewed differently in the context of the optimization challenge that exists among the three dimensions of sustainability (environmental, social, economic). Although the "public interest" is assigned by some to be a defining value of sustainability (Walker, 2001), this author does not agree. As an analytical framework, sustainability's relationship to the public interest is neither direct nor reliable.

This author found that public interest values are just as easily claimed by private interests embracing a sustainability (Globscan, 2015; UN, 2013; UNCED, 1992) or CSR agenda (Rangan, et al., 2015). However, neither public nor private interest is explicitly reflected in any of the three features of sustainability. Presuming sustainable outcomes are synonymous with the public interest is unfounded; as is presuming private interests are inimical to sustainable outcomes. Some businesses have demonstrated characteristics of sustainability. Illustrative of this is the responsiveness to consumer demand for socially responsible and environmentally harmless products and production (Albino, et al., 2009). It could be argued that this is no more than a sales niche defined by targeted consumers with a concern for the public interest;[52] but it does not negate the potential for alignment between private interests and sustainability.

[52] Similarly, with private sector interest in waste reduction, pollution prevention, toxic use reduction, sustainable agriculture, forestry and fisheries, cleaner production, sustainable production and consumption, industrial ecology, and the circular economy, have all been driven, in some measure, by public demand (i.e. U.S. Government environmental laws).

An example of where efforts to equate sustainability with public interest breaks down are the water rights in the western U.S. Water in the western U.S. is largely allocated through the doctrine of prior appropriation, which holds that whoever first allocated water to some useful end is allowed to continue to use a comparable volume of water (Johnson & DuMars, 1989). With what sector does the public interest lie among competitors for limited water; agriculture to affordably feed the public, cities to affordably provide water for their denizens, or the maintenance of ecological structure and function in riparian areas, estuaries and other natural areas? These are all public interests. That private interests also align with them underscores the analytical limitation of the public – private duality. Public vs private utility, frames the analysis with a single dimension of appraisal, and as demonstrated in this example, may not be well targeted to the analysis. The public – private dichotomy also contributes to perpetuation of a framing that pits business and industry against societal interests, when it is possible – some would say essential, for business and public interests to be aligned (Hawkin, et al., 2005).

Sustainability also introduces the consideration of balancing between outcomes and the temporal preservation of services – regardless of public or private utility (Cavender-Bares, et al., 2015). It is well established that private interests can be effective vehicles for the public interest as evidenced by private ownership of utilities and public transportation. The sustainability reframing of the example of water resource competition emphasized *uses* rather than private vs. public *interests*. The difference lies in the *type of decision that is made.* Is the decision to optimize the services of a resource/s over time, or simply to divide up a resource between public and private benefits, possibly with no consideration of longer-term maintenance of the resource? This author's perspective is that while the public interest is served by sustainable outcomes, they are not synonymous. Private and public-sector outcomes are equally able to serve sustainability objectives.

Sustainability, incorporating environmental protection as it does, is a response to the environmental stresses of industrial society, and consistent with theory of ecological modernism that Mol and Spaargaren (2000) advance. Advocates and users of 'sustainability' approaches attempt to align social movements for economic justice and social welfare with environmental protection (Langhelle, 2000). Through the lens of communicative action, sustainability represents a normative paradigm that is grounded in a constellation of lifeworld values loosely arranged around sustaining things that are valued (within a framework including social, economic and environmental dimensions). Sustainability exhibits attributes of lifeworld, as understood by Habermas. It is a value assemblage that establishes a normative frame through which phenomena can be observed and discussed, resulting in communicative action. Arising from that paradigm, sustainability *science* provides a rational framework to inform institutional decision-making, but remaining linked to the lifeworld value assemblage. Sustainability, thus, can span normative lifeworld and rational – objective institutions.

The significance of the sustainability concept spanning between lifeworld and instrumental rationalization is a reduction in the dissonance between held values and the outcomes of decisions. Habermas associated the dissonance with the use of money as a steering mechanism in decision-making grounded in frameworks shaped by instrumental rationality – divorced from society's normative values. Money is an unsurpassed unit of measure for instrumental rationality, but may be entirely insufficient to measure values in lifeworld. Sustainability is an example of

how a constellation of values and ideas can coalesce in lifeworld and dynamically grow as an influence in decision-making that is dominated by the institutional rationality of organizations. Through the lens of communicative action, sustainability acts as a carrier of values and qualitative ideas that diffuse from lifeworld into the quantitatively objectified world of institutions. The rise of sustainability plans as elements of Corporate Social Responsibility is a premier example of this process.

The concept of sustainability has taken root in the normative social constructs of modern lifeworld, as well as in analytical applications of the objective world. While the concept of sustainability is contestable (Jacobs, 1999), it is, none-the-less increasingly familiar. Organizations of all kinds, including governments, businesses and institutions have worked to incorporate sustainability objectives into their decision-making (Martin, 2015; UNCED, 1992). Sustainability is a decision-making method that can provide a transparent means to integrate disparate information, perceptions, and values. Such methods have been demonstrated to be the most useful in settings with a variety of stakeholders who value different outcomes (Gregory, et al., 2012).

The actual dynamic of decision-making is highly contextual. Kohornen (2003) asserted that there is not a one-size-fits-all sustainability framework appropriate for all kinds of decisions. The key is the approach, which links articulated values to quantifiable data, and is tailored to fit the purposes of decision-making. The TCA proposed that when subjective, normative and objective inputs (beliefs, social customs, and data, respectively) to a decision are all consistent, then the outcome is strongly reinforced. What this means for sustainability as a decision-making framework is that as sustainability becomes more meaningful as a normative concept for reflecting social values of ecological protection, social justice and economic equity, the use (or creation) of quantifiable metrics reflecting these values for use in institutional decision-making will likely increase, thereby, reflecting and reinforcing those values.

5.8 Wicked problems and clumsy solutions

This section revisits the discussion in Section 3.2 (Section #4 in the article) of matching information inputs to decision-making frameworks within the context of the "wicked problem" literature. Sustainability is then reexamined as a decision-making framework appropriate for addressing wicked problems with "clumsy solutions." When decision inputs and the decision-making context are complicated, or poorly matched, a condition that is associated with wicked problems arises, where participants may neither agree on the relevance of information, the type of argument that is considered most consequential, appropriate analytical methods, or even on the objectives (Rittel et al., 1973). Wicked problems can exist when information important to some parties, such as value assertions, are not accommodated by the decision context. Instead, a decision-making framework is needed that allows for "…a vibrant multivocality in which each voice formulates its view as persuasively as possible, sensitive to the knowledge that others are likely to disagree, and acknowledging a responsibility to listen to what the others are saying." (Verweij et al., 2006). This describes the process of communicative action, and it fosters personal, social and institutional learning.

The assertion by ecological modernists such as Spaargaren, that the value of ecosystems should be monetized or measured in some way to better represent ecological values in decision-making is an effort to simplify a wicked problem by accommodating the quantitative requirements of an instrumental rationality decision context. The thinking is that through the quantitative valuation of ecosystem services, the objective cost-benefit analysis of conservation vs exploitation can be better informed, and ecological conservation will be better represented. However, some view such a decision context as concerned with, limited to, and focusing on "only the purely material consequences, in monetary terms" (Skollerhorn, 1998). Although ecosystem services valuation can include a rich range of qualitative to quantitative values, they may be truncated if the decision-making framework used does not accommodate all the information necessary for the valuation. If the decision context does not support use of ecosystem services data, then monetizing ecosystem services may change little.

If, for example, the ecosystem services values of a saltmarsh are recreational fishing and hunting, and flood protection from the 100-year storm, the flood protection value is diminished by 80% and the future value of fishing and hunting all but lost entirely if the decision framework has built into it a 20-year economic value discount rate. This illustrates how a decision-making context may constrain whatever objective results can be derived from information provided. It substantiates the concern that ecosystem services may only serve to commodify the environment. To the extent that normative values are rejected in favor of strictly objective data analysis, a critique parallel to the critique of ecological modernism as being utilitarian is legitimate. This is the concern expressed by Gómez-Baggethun and Ruiz-Pérez (2011) over the use of ecosystem services:

> "Appraisal of valuation cannot be detached from the analysis of the sociopolitical processes through which the market expands its limits and through which economic value colonizes new domains. Monetary valuation of ecosystem services does not equate to commodification of ecosystem services, but it paves the way (discursively and sometimes technically) for commodification to happen."

Gómez-Baggethun and Ruiz-Pérez observed that the ecosystem services concept is, however, important to aid in the wider public understanding of how healthy functioning ecosystems are essential for human health and welfare. This is consistent with the results of the NEP survey research described in Section 4.2, where it was found that qualitative use of ecosystem services for communicating with the public was widely considered by respondents as useful.

Wicked problems are also said to not yield simple, elegant answers, such as can be defended by a proof or scientific explanation. Because participants in the decision will view it through different interpretive paradigms, any solution to the problem must necessarily be multifaceted and responsive to different perspectives. Clumsy solutions require a good match between questions and analytical processes so that information from all perspectives is integrated.

Clumsy solutions are generated through decision-making frameworks that are inclusive of all types of information and where "contestation is harnessed to constructive, if noisy, argumentation" (Verweij, 2006). Verweij et al. described the democratic ideal:

> Clumsiness emerges as preferable to elegance (optimizing around just one of the definitions of the problem and, in the process, silencing the other voices) once we realize that what looks like irreconcilable contradiction is, in fact, essential contestation.

Such a framework reinforces the decision-making contexts of both normative culture and institutions with a rational – and consistent understanding of the value of nature as an integrated whole, and the source of our essential commodities. Drawing on the discussion of this thesis author in Chapter 5, of why a sustainability decision-making framework is preferable to the public versus private interest paradigm, the sustainability framework is offered here as suitable for generating clumsy solutions. This recommendation rests on the structure of sustainability integrating social, economic and environmental outcomes. An example of a sustainability framework for decision making is the Social-Ecologic Systems Framework.

The Social-Ecologic Systems Framework

The Social-Ecologic Systems (SES) framework is one of many sustainability styled frameworks for decision-making that can be examined for features that are responsive to wicked problems. The SES is based upon the development of diagnostic tools to understand the determinants of sustainability in complex social-ecological systems.[53] The framework is useful for understanding processes of use, maintenance, regeneration, and destruction of natural resources or humanly constructed infrastructures (McGinnis and Ostrom, 2014). The SES framework is a direct outgrowth of the Institutional Analysis and Development (IAD) framework, which was developed to cope with the complexity inherent in policy analysis (Ostrom, 2007). At the heart of both the IAD and SES frameworks is the "action situation," in which individuals interact to deliver outcomes. This and other features of the SES and IAD frameworks are consistent with the central thrust of communicative action, and of the model of stakeholder participation by NEPs.

The SES was originally presented as relevant to common-pool resources,[54] however, it can also examine public goods and services, such as the ecosystem services on which many markets depend for their continued operation (Ostrom, 2007). This framework was designed for balancing resource use and systems maintenance in social-ecological-technical systems. It addresses outcomes ranging from consumption of goods to complex infrastructures shared by members of widely dispersed communities (McGinnis, 2014). The SES framework fosters a transparent discussion of "what is valued" as a key element of organizing criteria for decision-making. "The identification of "what is valued" is a testable and empirical result of subjective values, and thus, it methodically engages the normative, social value constructs of participants as a dimension of the decision.

[53] It is understood that all Earth-bound societies are nested in complex social-ecological systems.
[54] A type of good consisting of a natural or human-made resource system (e.g. an irrigation system or fishing grounds), whose size or characteristics makes it costly, but not impossible, to exclude potential beneficiaries from obtaining benefits from its use. Common pool resources are subject to overuse (Ostrom, 1990).

The SES is an example of how a value based framework organized around the sustainability paradigm is well suited to using information generated by ecosystem services analysis and valuation. Because ecosystem services analysis also features the three dimensions of the sustainability paradigm it can provide integrated data linking ecological production functions with social demand for ecological services and, when appropriate, with monetary values. In this scenario, information and data to inform a decision are well matched with the decision-making framework, resulting in a decision-making process that is:

- versatile and responsive to value-based perceptions and demands;
- integrated, linking data serving social, economic and environmental metrics; and
- oriented toward comprehensive solutions, rather than piece-meal instrumental outcomes.

Each of these features is particularly important for environmental decision-making. Because environmental decision-making is value-based, leading to wicked problem formulations, a decision-making framework that accommodates different value formulations is appropriate, and arguably essential. Because environmental decision-making affects social and economic dimensions, as well as environmental, a multi-criteria decision-making tool is essential. Most useful is information that is integrated across all three dimensions such that the decision maker does not need to weigh metrics and balance outcomes – the same metric, ecosystem services, is used for all three dimensions. Because environmental decision-making should respect the holistic and integrated nature of ecosystems with embedded society and economy, it is necessary for solutions to offer comprehensive outcomes that consider affects across all dimensions – social, economic and environmental.

5.9 Fostering Phronesis

The Aristotelian concept of phronesis was introduced in Chapter 3 (article Section 3.4). In effect, Aristotle regards phronesis as a type of knowing built upon judgement, such as would be necessary in decision-making. Phronesis supports difficult and complex decision-making (e.g. wicked or sustainability) because it incorporates value-based judgment to help integrate varied and disparate information. Ultimately, good environmental decision-making requires relevant information matched to an appropriate decision-making framework – one informed by a long-term sustainable value system, combined with stakeholder involvement. This author has argued that short-term instrumental rationality has been shown to be inadequate. Applying a sustainability analytical framework, such as SES, in a decision-making context is desirable because it can work with divergent stakeholder positions in a rationally, methodical and transparent way to build consensus in areas of shared objectives, to define differences in a way that engenders values clarification and the incorporation of quantitative data.

Although sustainability does not collapse the distinction Skollerhorn made between privatized and politicized ways to coordinate decisions, it can serve to bridge them, and to reinforce qualitative-quantitative correspondences. The sustainability construct enables this through identification of a value “bundle” in the lifeworld, assembled around the idea of “what we want to sustain,” linked to quantifiable sustainability metrics (e.g. biological diversity) that are derived from sustainability values. Sustainability provides a unified framework that has complementary quantitative and qualitative decision attributes.

Sustainability is a decision-making framework that can easily accommodate the incorporation of values for instrumental decision-making; and has, in effect, become the framework for the "two projects" asserted by Spaargaren (Chapter 3.3.1) as central to ecological modernization:
1. re-structuring of processes of production and consumption towards ecological goals; and
2. placing an economic value on nature.

When considering the *environmental* dimension of sustainability, the normative understanding of what we want to sustain as well as measurable quantities are linked to the common ecological entities through ecosystem services. Ecosystem services, offers both a normative and qualitative understanding of ecosystem value, as well as quantifiable metrics used to measure outcomes.
This is consistent with Husserl's[55] and Flyvbjerg's arguments that social sciences are stymied by their positivist emulation of naturalism, and should reorient social investigation to include value propositions to support positive social outcomes. Husserl's idea was a return to the hidden foundation of objectivity, that is, the world of immediate experience and intuition from which we derive meaning and values. Flyvbjerg's goal was to perform research for realization of the "good society." Ecosystem services valuation is a method demonstrating these strategies, rooted in our immediate experience and values, and providing a positivistic understanding of how – and how much, ecosystems are key for the welfare of society (Schatzki, 2006; Flyvbjerg, 2001; Husserl, 1970,1965).

The Aristotelian concept of phronesis,[56] (Browne, 1989) the underpinning of "good judgment," is a relevant concept for discussing how values frame and inform decision-making (Martin, 2015). Phronesis is unknown in the decision science literature because it embraces the idea of subjective judgment – in contrast to the objectivity goal of modern positivist research. The concept of phronesis is applicable to sustainability as a tool for decision-making because it carries the essential element of value-based judgment that is key to value-ranking decision criteria and resolving tradeoffs that are sometimes needed when considering complex systems. As such, phronesis is a useful concept for exploring how normative ideas of what is desirable can be employed to define sustainability, and to inform decision-making, particularly on the geographically actionable level.

Phronesis is advanced through societal, participatory and deliberative processes because they provide participants with time to learn about the good or service, and to reflect upon their preferences. Phronetic reasoning is best served by an analytical decision-making process, such as sustainability, that scales to the scope and dimension of the problem and that fully incorporates information appropriate to the problem, such as the structure and function of ecosystems and the longer time horizon that characterizes ecological hemostasis. A useful method for examining information to support such deliberative processes (e.g. Social-Ecologic System) is scenario analysis. Scenario analysis can open up narrowly defined "solutions" such as those derived from utilitarian optimization exercises. Scenario exercises can expand the examination of alternative outcomes to more broadly consider the drivers and mechanisms that affect outcomes (Peterson, 2003).

[55] Husserl coined the term "lifeworld."
[56] Aristotle, The Nicomachean Ethics

Scenario analysis can be qualitative or quantitative and data driven, or a combination. Mahmoud et al. (2009) provide a review of scenario development describing construction techniques, applications in environmental studies, issues and problems. That degree of detail is beyond the scope of this dissertation. Significant for purposes here is the assertion that the "main advantage" of scenario planning is the community-based effort that crystalizes and examines "mutual goals and sharable results" (Mahmoud, 2009). Consistent with this view is the observation that "scenario-building does not focus on making predictions or forecasts, but rather on describing images of the future that challenge current assumptions and broaden perspectives" (Duinker and Greig, 2007). Duinker and Greig conclude that environmental information analysis to forecast environmental impacts "have a high potential to be really wrong." They argue that scenario analysis can provide insight to the sustainability of decisions by exploring risks and sensitivities.

The features of scenario analysis described above provide a mechanism for fostering communicative action, where stakeholders can expand one another's understanding of respective goals and values, as well as system's sensitivities and perceived risks. Engaging in a communicative action context where various outcome scenarios can be explored critically will build the necessary experience and awareness to nurture phronesis among participants and decision-makers

Fostering phronesis contributes to a defined and transparent value constellation that reinforces understanding of the problem on the subjective, societal and institutional scales. Ecosystem services valuation can provide useful information with consistent values at each of these scales. Considered together, a sustainability framework for decision-making paired with ecosystem services information can provide the necessary support conditions for exercising good judgement in decision-making.

6. Conclusions

United States Estuary Management Programs use ecosystem services valuation in decision-making

Trade-offs between amenities, products and services, including ecosystem services, are being made daily, sometimes with little appreciation of the environmental consequences. A great deal is known about ecological structure and function, and the processes that result in services to human populations. The basic question addressed in this dissertation is can information about the environment, framed in terms of ecosystem services, be used to improve the effectiveness of how this information is communicated for decision-making? There is a perception that the information about this value is not conveyed well or persuasively to decision-makers in the current forms (U.S.EPA, 2010). The principle impetus for usage of ecosystem services valuation is to assert the value of those services so that the value of what might be lost in a "tradeoff" of environmental quality for economic development is fully appreciated by stakeholders and decision-makers. Thus, the primary argument behind the concept of developing and using ecosystem services valuation information is that it will improve on the effective delivery of ecological information to inform the environmental implications of decisions (Farber et al., 2002). This researcher's familiarity with United States Estuary Management Programs (NEPs), and access to programs' management, facilitated an examination of how the use of ecosystem

services information was used by NEPs, and what evidence existed that it could improve NEPs' decision making processes to enhance environmental outcomes.

This thesis research obtained qualified support for this thesis. The research findings demonstrated that estuary management programs have used ecosystem services valuation successfully, both quantitatively and qualitatively, to set environmental protection and restoration objectives and to communicate with stakeholders. In particular, the use of ecosystem services information to characterize the environment was found to be useful in framing issues and discussing NEP programmatic priorities.

The three research questions that framed this study, presented in Chapter Section 1.2, were designed to explore different dimensions of how ecosystem services valuation might be employed in NEPs to inform decisions.

Question #1: Does information on ecosystem services valuation provide value to decision-makers and promote achievement of improved environmental protection objectives? The results of this research demonstrated that it does. Survey responses characterizing ecosystem services information as valuable for decision making highlighted its use for planning and project prioritization. Examples included prioritizing restoration activities on which activities return the greatest ecosystem services per investment, and development of an ecosystem based management plan utilizing a needs assessment based on ecosystem services. One survey response in particular summarized the positive responses to this question. "It [ecosystem services valuation] offers a means to highlight benefits from ecological protection that are not otherwise readily valued by conventional cost benefit economics." Other examples of program use of ecosystem services information included a classification scheme for an estuary wide monitoring program, and for creation of a biological condition gradient framework.

A small, but important set of responses focused on legal constraints to the productive use of ecosystem services information for complying with legal-statutory requirements. Other responses noted that quantitative ecosystem services valuation "is necessary if it is to be used to inform and address permit applications; and "that most water quality decisions are based on Clean Water Act requirements." "It is not clear how it [ecosystem services information] would function in meeting legal obligations" (e.g. CWA attainment of Water Quality Standards. "Ecosystem services can't be considered in those decisions unless explicitly included in statute, regulation, or policy." An important response linked characterization of quantitative assessment endpoints to ecosystem services, and demonstrated how the information could enrich both statutory reporting communications with stakeholders and the public.

Question #2: Are ecosystem services valuation procedures a successful technique to communicate the importance of ecological health and ecological systems' integrity to society or stakeholders? The NEP survey responses were strongly supportive for this function of ecosystem services information. The responses reinforced the perception that maintaining ecosystem services was largely viewed as congruent with ecological protection generally. The respondents expressed a high degree of comfort using qualitative as well as quantitative ecosystem services information to frame issues and ground discussions in values that were relevant to stakeholders. A qualitative use of ecosystem services information was credited with good results in discussions

about habitat protection and managing storm surge in the context of wetland losses. One respondent noted that using ecosystem services valuation helped to broaden stakeholder's perspectives beyond immediate advantages perceived from economic development.

Question #3: Does communication of results of ecosystem services valuation improve environmental outcomes in decisions that balance ecological protection against economic development? For this purpose, the research results provided little evidence that ecosystem services valuation has been used to directly influence the outcome of these types of decisions. Two respondents to the surveys suggested that use of ecosystem services valuation was or could be useful. One respondent noted that "in discussions of economic development proposals, ecosystem services valuation helped to identify hidden costs on water quality and consequences for recreational services." In another, the respondent observed: "For an NEP, goals [setting] would be a primary use of ecosystem services. For some of our local government partners, ecosystem services values would be very useful for land use decisions." The absence of demonstrated use of ecosystem services valuation for this purpose by NEPs was construed as inconclusive of its suitability or effectiveness. This researcher learned that the NEPs do not generally function to arbitrate decisions over land-use; and the research did not show NEP programs performed project specific cost-benefit advocacy using ESV. The research results suggest, however, that ecosystem services concepts and ecosystem services valuation may have informed discussions within NEPs leading to land-use decisions by other authorities.

Additional details' supporting the conclusions from the survey research and the three preliminary research questions were presented in the conclusions of Chapter Section 4.2. Elements of it are also discussed in the following conclusions.

<u>Qualitative use of ecosystem services information can lead to quantitative uses</u>

This conclusion is responsive to the supplemental research question: "Can the concept of ecosystem service have a value in decision-making regardless of whether values are assigned to the services?" The NEP survey research findings demonstrated that estuary management programs used ecosystem services information successfully to set environmental protection and restoration objectives and to communicate to stakeholders. The most advanced quantitative applications were by managers who had demonstrated familiarity with the concept qualitatively (i.e. descriptively). Once there was an appreciation for the concept there was a greater willingness to use ecosystem services information. This author interpreted the survey research findings to support the idea that awareness of a qualitative use of ecosystem services information used to communicate with stakeholders, and aid in prioritization of operations or investment, appears to lead to a stronger appreciation among managers for the potential uses of quantitative ecosystem services information.

McKenzie et. al., (2014) concluded similarly, based on their assessment of ecosystem services use in decision-making internationally, and stated: "Conceptual and strategic uses of ecological services knowledge build understanding and compromise that facilitate instrumental use." This is consistent with the Theory of Communicative Action as it pertains to the ideas that instrumental actions are more likely when they are in accord with normative understandings. The Theory of Communicative Action also offers the explanation that ecosystem services information may not

yet have sufficiently saturated lifeworld norms – beyond research science, to provide a supportive condition for its widespread quantitative use in objective decision- making. This supports the conclusion that the most constructive means to advance the adoption of ecosystem services valuation for environmental management is to introduce no/low-cost qualitative ecosystem services' applications, such as terminology to characterize the many ecosystem services that are typically overlooked when characterizing environmental value, or to frame issues and discussions about values that are important to audiences. These low-cost initiatives will familiarize environmental resource managers, stakeholders, and decision-makers with ecosystem services valuation concepts, and will build a foundation for the use of ecosystem services valuation, or other quantifiable information for decision-making. It follows that stakeholders will be more open to the prospect of further investing in and adopting other ecosystem services valuation concepts in future decision-making processes.

The valuation of natural resources is a limited application of ecosystem services valuation

The direct economic use value of natural resources such as timber, crops, and fisheries entail ecosystem services provided by the environment, and have long been measured by natural resource economists. Typically, these ecosystem services are tied to other human and capital inputs necessary for their harvest or extraction (e.g. fishing boats and canneries). Similarly, the direct economic use of the environment for recreation has routinely been tracked in local, regional and national accounts. Many ecosystem services associated with extraction and use of natural resources are valued and accounted – termed "commodity" by Ralph Waldo Emerson.

Ecosystem services researchers refer to multiple services from an ecosystem as a services *stack*. The direct use of the resources usually only constitutes a part of the stack, with many services unknown, unacknowledged, or poorly appreciated. In considering the generation of ecosystem services, it is the full constellation of services that are thought to better inform decision making when considering optimal use of lands and waters. The NEP survey research findings revealed that the expense of conducting comprehensive ecosystem services valuations to quantify the full constellation of services was perceived as an impediment to their use. However, through the informal interaction with NEP managers this researcher learned that economic resource assessments were conflated with ecosystem services, and were considered by some to be interchangeable. Building awareness of the similarity between economic resource assessments and the wider constellation of ecosystem services, beyond those captured with an economic assessment, can demonstrate to stakeholders the utility of the ecosystem services valuation concept.

Thus, there is utility in highlighting the value of economic assessments of environmental resources as a limited set of quantitative ecosystem services valuation information. Economic assessments capture substantial services that are highly valued in an estuary. However, it is important to establish that although economic assessments of environmental resources provide important ecosystem services valuation information, it is none-the-less critical to also inventory what is not included as commodity. It would be through this awareness that decision-makers will understand the limits of traditional economic assessment in contrast to a fully developed ecosystem services valuation report. Properly understood, awareness of the wider constellation

of ecosystem services beyond those captured with an economic assessment is a gateway to a more extensive inventory and valuation of the ecosystem services stack.

Another important dimension of ecosystem services not captured through economic resource assessment is the association between ecological production, economic significance and the service to society. This is a more complete characterization of the relationship between the natural world and the lifeworld of people than is captured by the instrumental utility of an economic assessment. It is also a more useful concept as a management tool for the capacity to measure how ecological quality (integrity of structure and function) can be directly relatable to outcome, or service to society. In this respect ecosystem services support a multi-dimensional assessment that can inform sustainability decisions, in contrast to an economic resource assessment that is unidimensional and supports a less robust decision-making framework.

Decision-making frameworks influence how or if information is used

This conclusion is responsive to the supplemental research question: "Can the framework for decision-making have effects on the influence of ecosystem services information in the decisions that are made?" It follows that a decision is dependent upon the information that can be processed, or is accorded significance within a decision-making framework. This condition was discussed in Chapter 3; and the public vs. private interest framework was juxtaposed with the sustainability analytical framework to support societal decision-making. Sustainability has a different value orientation than the public-private dichotomy. Although it can be argued that sustainability reinforces a public interest value proposition, they are not the same. The public vs private interest dichotomy reflects a one-dimensional tension between benefits accruing to private interests' vs protection of the public interest. The private-public interest framework is, however, a false dichotomy when considered within the larger framework of sustainability. This is because the private-public interest framework typically focuses upon a fair sharing of whatever value proposition is on the table, but fails to capture the underlying ecological or social structure that gives rise to the value proposition (e.g. population demographics or ecosystem service). The limited scope of analysis accorded by the private-public interest framework fails to capture information significant for understanding the source of the value proposition under consideration (i.e. ecosystem service) or the longer-term opportunity cost entailed.

With the decision focus on equitable sharing of present value, other issues such as intergenerational equity and long-term provision of the value may be lost. To illustrate, the private-public interest framework will inform a decision on how to share the harvest now, whereas a sustainability framework will also inform a decision on how to ensure harvests in perpetuity. Sustainability is multi-dimensional, and provides a more sophisticated decision-making framework, representing a range of socially held values that inform both public and private interest decision-making. In contrast to the antagonistic public vs private framework, sustainable ends can be easily construed as serving both public and private outcomes. Sustainability signifies a constellation of values unifying goals of ecological protection, social justice and economic equity with measurable outcomes. As such, the decision-making framework for sustainability fosters the development of data, such as ecosystem service values, that can inform decisions to optimize those outcomes.

Decision-making methods are determined by values

That values shape our decisions is not disputed, but neither do they receive much consideration in how they affect our choice of decision-making methods. Social questions of how to allocate natural resources may or may not be accommodated by various decision-making frameworks. A decision-making framework built around a utilitarian cost-benefit value system will limit information inputs to those manageable within the framework, and will yield decisions constrained by the information considered. This researcher has characterized such analyses as utilitarian, instrumental rationalism, and linked it to a history of failure to adequately protect nature from predatory exploitation for short-term and socially inequitable economic benefit. Because there are people whose interests are served by the utilitarian cost-benefit decision-making framework it remains highly influential despite its analytical weakness, or because of it; and the rather narrow value system it represents. In contrast, there are other decision-making methods that provide a transparent means to integrate disparate perceptions (i.e. *values*), and to incorporate a broader scope of relevant information. Such methods have been demonstrated to be the most useful in settings with a variety of stakeholders who seek to evaluate different outcomes, as are typical in natural resource and sustainability problems where there is the appearance of trade-offs. The sustainability framework is such a method. Decisions arising from it are also value laden, as well as contextual, and focused on social, economic and environmental outcomes. The multi-dimensional characteristic of sustainability decision-making challenges any manager to move beyond the practice of refined skills, "techne," in the terminology of Aristotle. Instead, the decision-making process is more like that of a judge seeking justice, guided by internalized values that are normative and paradigmatic. The concept of phronesis appropriately describes this process because it includes the essential element of value-based judgment that is key to finding the balance needed when considering complex systems. The advocate for ecosystem services information use in decision-making must be cognizant of whether the decision support framework adequately accommodates the information.

Ecosystem services are a tool in sustainability assessment and a metric for decision-making

Ecosystem services were examined for their utility for providing information input and as a performance metric to inform decision-making in NEPs. There was greater support by NEP managers for qualitative ecosystem services concepts that are useful for establishing normative awareness and appreciation of how the environment provides benefits to society. Because the structure of the ecosystem services concept links ecological, economic and social dimensions, it corresponds with sustainability structure and values, and is therefore particularly valuable as a tool to understand these dimensions of assessing sustainability. This qualitative use of ecosystem service information required less expertise, time or budget to realize; and is well correlated with the less formal and more interpersonal communication common to lifeworld. The qualitative communication of ecosystem services as a social and community-based rationale by NEPs was useful for framing and influencing decisions pertaining to the protection of natural resources, and for describing what environmental conditions or outcomes the public seeks to *sustain*.

The quantification and denomination of ecosystem services can bring rigor to measurement of trade-offs between ecosystem services. It can also bring exactitude and consistency to a framework for sustainability assessment. Ecosystem science can establish correlations between

productivity and stressors, and the effects on services. Ecological economics can be practiced to measure the value of services to society (not only individuals), as well as measure the reduction of stress on ecosystems. Together, ecology and economics can define the system boundaries of a location's sustainability praxis. Within this bounded framework sustainability science is then constructively targeted to address priorities for optimizing synergies among the built and natural environment, optimizing ecosystem services for increased social welfare, and designing systems in the built environment to harmonize or enhance ecological systems on which the built environment is dependent. With the incorporation of ecosystem services as a foundation for sustainability, it can be effectively used to describe quantifiable objectives and outcomes, and thus reduce uncertainty in decision-making.

Ecosystem services and sustainability bridge between values and instrumental rationality

This conclusion is responsive to the supplemental research question: "Is there relevance in the similarity of analytical dimensions between ecosystem services and sustainability (i.e. environmental, societal, economic)?" Within sustainability there is an implicit value proposition that something is to be sustained – that is, valued; and in this regard, ecosystem services can provide a vivid appreciation for critical services from our environment, such as drinking water. Ecosystem services' information provides clear rational explication of subjective benefits to stakeholders, and when quantified, provides measurable assessment endpoints for use in performance based decision-making. This capacity for linking between the normative values of lifeworld and the instrumental rationalization of institutions bridges between our normative, value-based experiential understanding of the world, and the positivist, objective decision-making of institutions. The use of ecosystem services to characterize a normative, socially shared demand for the protection of environmental outcomes, such as biodiversity, will help ground efforts in society to quantify the value of ecosystem services for use in decision-making.

A sustainability framework similarly spans the normative lifeworld and objective institutional decision-making. Through concepts such as economic equity or social justice, sustainability fosters parallel formulations – ideas rooted in values, with rigorously quantifiable metrics. Properly understood within the Theory of Communicative Action, sustainability arises as a societal manifestation that fosters interpenetration between the realms of lifeworld and objective instrumental rationality to better enable meaning and value to illuminate decisions. This function was once served more widely by institutions such as religion. Where those institutions have weakened, sustainability concepts can be used to link between subjective values and objective rationality, and to link normative values to instrumental decisions. The ecosystem services concept can be universally experienced and valued, and can provide measurable indicators of social, economic and ecological welfare. Habermas placed significance on the ability of steering media to provide "measures of account" (TCA Vol.2, pg. 293). Following from this, ecosystem services information may, in time, prove to be a steering medium because it possesses features like money; in that it is both socially valued as well as having instrumental value.

Ecosystem Services are best used as both qualitative and quantitative information

In rough terms qualitative information about ecosystem services links to subjective and normative values, while quantitative measures will focus on objective outcomes. Both are

important and they are complementary. This thesis author cautions against the introduction of ecosystem services as only a quantified amenity, divorced from the value-based linkages associated with a normative context. The use of ecosystem services valuation data, alone, disconnected from the broader system's views and values may promote a narrow optimization for "efficient outcomes," without evaluating larger system goals for the short and long-term future. In the absence of a normative, widely accepted appreciation for the qualitative value of ecosystem services, the incorporation of quantitative valuation into cost-benefit may lack the *gravita*s necessary to adequately challenge narrow financial interests, known to maximize profits through externalization of costs to the environment and to provide quick returns on investment. The normative, value-grounded context of lifeworld supports a broader system of understanding than is typical of the instrumental rationality of objective analysis. This also argues for placing ecosystem services within a sustainability framework because of the linkage to a larger system of normative values and goals, as well as for the larger systems analysis required for effective sustainability decision-making.

It is important to use ecosystem services' information (and sustainability concepts generally) qualitatively to articulate values, so that understanding of their quantified use is epistemologically grounded. With this, a coherent foundation for *phronesis* – or "good judgement" is established. A coherent sense of what is valued normatively, that can also be defended rationally, forms a logical and consistent analytical "lens," or frame, by which people are able to bring concepts into personal use, to understand, judge, and discuss information presented to them in either their community or in institutional worlds. In this way, sustainability, and all that one may impute to it, can help societies to build capacity for individual's *phronesis* – which is to say, the use of judgement in making decisions about what to believe or to do. This is not simply objective, well-informed decision-making; it includes objective data and information married to an awareness of normative conditions informed by values, for decisions that are situationally appropriate. Phronesis, as used by Aristotle, is a way of knowing based upon an individual's informed judgement. As such, it isn't a suitable term to describe anything that institutions or organizations would employ to inform decisions, because it is ultimately the individual managers who make decisions. The choice of decision-making frameworks, and the information that is included to inform decisions are very much subject to the idea of phronesis, which can be an animating force within an institution much like creativity or conservatism. Fostering phronesis begins with clarifying the values relied upon to guide decision-making.

7. Concluding remarks

7.1. Reflections on the strengths and weaknesses of the research methods

The use of action research to guide development of the overall inquiry and to shape the research questions provided insights to question formulation and the literature to inform this dissertation. Most generally, studying the action research literature reinforced a nascent predilection in this researcher to challenge the orthodoxy of objectivism as applied to social science. It broadened the inquiry into decision science to include how value choices influence decision-making; which in turn contributed to an initial exploration of the effect of a decision-making framework on the use of ecosystem services information. Action researchers acknowledge that research is situational, and rather than being solely directed toward discovering truths, should at least be

directed toward resolving problems associated with the studied population. Strategies or steps associated with problem resolution may be evaluated for broader applicability.

Habermas' Theory of Communicative Action informs the step from problem resolution to broader application. Proponents of The Theory of Communicative Action assert that social change and development occurs through the persuasive communication of reasoned assertions between and among people, who in turn influence the positions and actions of organizations and institutions, which then further propagate thinking and action. The rational appraisal of strategies and steps to solve a social problem, and the communication of that rational analysis to others who are similarly interested constitutes a practical, methodological process for social science research to be rigorous, and are both immediately and theoretically relevant.

In this dissertation the social problem explored was properly valuing the environment in choices concerning its use, so that the benefits and services from the environment were better represented in environmental management decision-making processes. The hypothesis that using ecosystem services information in decision-making can improve the environmental management outcomes was explored through surveys and in-depth dialogue with members of the sample population. The process and the results of this dissertation's study methodology were presented, and conclusions were rationally argued to have broader applicability. As a researcher, I have performed a role in working to advance social change to resolve an identified problem. The extent to which my arguments are well substantiated by my research and are persuasive to the reader, then action research has been demonstrated to be an effective research method, according to the theory I've used to interpret my findings.

A survey method employed a phenomenological approach to gathering information for analysis. This allowed collection of in-depth data through open-ended questions. Easterby-Smith et al. (1991) portray the phenomenological paradigm as representing the world as socially constructed and subjective, in contrast to the naturalist/positivist-quantitative paradigm that asserts the world is external and objective. The survey technique employed was designed to identify meaningful variation within the sample population on perceptions of the utility of ecosystem services information as inputs to decision-making. Thus, the survey was pre-structured based on prior dialog with NEP managers about how ecosystem services information was used. This resulted in a fixed set of questions inquiring how ecosystem services were or could be used by the population of NEP managers surveyed. This survey method facilitated insight and understanding without categorically predetermining points of view. This survey approach was best aligned with the action research strategy employed in designing this inquiry, with the following features identified by Easterby-Smith et al. (1991):

- science is driven by human interests;
- focus on meanings, try to understand what is happening; and,
- look at the totality of each situation and develop ideas from data through induction.

The other methods used to collect information were consistent with these features identified by Easterly-Smith et. al. The interactive presentations on the topic of ecosystem services presented to ANEP members at national meetings, and the community of practice convened to foster discussion among NEP managers on current research and applications in estuaries supported in-depth and sustained interaction with the sample population during more than three years. A result

was this researcher's extended interaction with the sample population exploring applications for the use of ecosystem services information and both the opportunities and the barriers for its use. In conjunction to the exploration of sustainability science and decision sciences, this researcher experienced a realization of what has been described here as phronesis – the capacity for joining value-based objectives with technical information to make informed judgements about how to best advance societal outcomes.

Because action research has a value-based, subjective motivation, this researcher employed another method as a check to evaluate the reasonableness of the survey tool that was developed. A qualitative expert elicitation was conducted to ascertain how independent, neutral, social scientists with an awareness of coastal ecosystem services concepts would assess the quality of the survey questions. The responses provided an external quality control on the research that reaffirmed the rationale and rigor of the survey design.

Despite the external validation check on the survey design, scientists who favor a strict quantitative and objective design methodology may remain skeptical of the action research methods used by this researcher. This is the greatest weakness of the research methods employed. If the intent is to persuade other scholars in the value of these research conclusions, but the methods are unorthodox, there will be some readers who will dismiss the conclusions because they do not acknowledge the veracity of the research methodology. The peer reviewed publications of the empirical NEP survey findings and the literature review examining the relationship of sustainability science to decision science should in some measure ameliorate these concerns for the conclusions associated with the preliminary research questions. Conclusions associated with the supplemental research questions were not subject to peer review, and thus, were not externally validated by this process.

7.2. Reflections on the answers to the research questions and about the findings

The preliminary research questions were developed in concert with members from the sample population that was surveyed. The first survey's focus leaned heavily toward understanding how ecosystem services were, or could, help inform decisions about the actual use of environmental resources – if a river should be dammed for hydropower; if a forest should be clear-cut; should a marsh be drained and converted to use as a commercial development? These were the types of questions that the seminal ecosystem services authors sought to better inform through including information about the value of services provided to society by ecosystems. These services were thought to be insufficiently captured in cost-benefit analysis and therefore development options, with more easily calculated economic benefits, were thought to drive decisions skewed against environmental protection simply because the value of the natural environment was not easily assigned.

Through action research engagement with the survey sample population it was learned that there are many kinds of environmental management decisions that can be informed by ecosystems services information, whether quantitative valuation or via other qualitative forms of information. Examples discussed included planning, priority setting, and potentially helping to inform environmental permit compliance standards. This recognition, concurrent with the decision science literature review and study of the Theory of Communicative Action gave rise to

a supplemental set of research questions that were more theoretical, and less specific to the empirical survey research with the NEP population. However, the supplemental research questions were still directly linked to the NEP population, and influenced the questions used in the second survey. Thus, the detailed answers to the second survey provided insights that were interpreted through both a theoretical lens as well as in the context of the decision science literature review. One outcome of this process was recognition that values are an important dimension of decision-making that is sometimes, and perhaps often, obscured by a normative belief that good decisions should be objective and free of subjective values. Despite this, values are a significant part of the architecture that underlies any decision-making framework. This recognition led to a more formal literature review of sustainability science because of its unabashed acknowledgement of a set of values that define its goals. The marriage of values and science in service to those values established a sub-current of study within this thesis to explore how values might influence the use of ecosystem services information for decision-making. The article in Chapter 3 was the result. It explored the intersection of sustainability science and decision science with conclusions that were fruitful for considering the findings from the NEP action research.

Several of the conclusions were developed from exploration of the supplemental research questions. These conclusions were drawn from interpretation of the action research results through the Theory of Communicative Action primarily, and to a lesser extent from the Theory of Ecological Modernization. The action research included the surveys, the community of practice, and interactions with members of the surveyed population. The conclusions were supported by a tailored literature review and a lengthy immersion into the Theory of Communicative Action. Rather than having been drawn directly from empirical results of the NEP surveys, these conclusions reflected a reasoned analysis of the interactions with NEP managers as interpreted through the lens of two theories that are consistent in their explanation of how social and individual perceptions propagate throughout society and lead to behavioral and decision-making changes throughout social institutions.

Necessarily, the conclusions were built from subjective interpretation of both interactions with the sample population as well as with the theories used for the analysis. The literature review and discussion of theory provided support for the interpretation and made the reasoning transparent. Nonetheless, the conclusions were generalized from a unique set of interactions that were interpreted through theories selected by this author, and thus from a subjective analytical framework. The conclusion is an example of the process explored in the dissertation that acknowledges wicked problem formulations, recognizes the significance of values informing the decision-making process, and asserts a rationale for taking action to advance social interests consistent with the values used to inform the process – a strategy that is supported by the literature on sustainability, and post-normal science.

This author recognizes that the conclusions that are dependent on action research interpreted through theory are unorthodox. Philosophically, the use of action research is oriented toward advancing value-based outcomes, not only discovering underlying knowledge about social (or natural) phenomena. This author sought to explain and validate this approach to doctoral scholarship, and concluded that in the final analysis, phronesis is a desirable outcome for both scholars and activists. This researcher examined one approach to building a rational and

defendable, fact-based information base on which to develop a phronesis for the active promotion of a social outcome; the integrated use of ecosystem services information into a sustainability analytical framework to make environmental management decisions.

7.3. Recommendations for future research

There are several fruitful directions for research suggested by findings in this dissertation. The most obvious is to revisit the NEPs to determine if there has been a continued exploration and adoption of ecosystem service valuation, and to examine if any new use of quantitative information could be connected to the earlier adoption of qualitative uses. This would be of greatest interest because it would represent a third drawing of information on the use of ecosystem services information over a ten-year period, creating something of a longitudinal study. Also of interest would be to conduct another literature review focusing on the use of ecosystem services in decision making to examine if there has been any increase in the publication of reports on how ecosystem service valuation is being used to inform decision-making. With the knowledge gained in this dissertation on types of ecosystem services information and different types of decisions that are informed by it, a skillfully designed review could yield insights to which kinds of ecosystem services information are optimally collected for what purposes. A more detailed examination of sustainability literature to determine if there has been any increase in the application of ecosystem services valuation for sustainability decision making would advance this inquiry in an interesting direction.

Following the "tailor-information-to-optimize-decision" line of inquiry further would be interesting with a research design to advance the understanding of how decision-making frameworks can improve the analysis of tailored and scaled data to environmental decision-making. Ecosystem services is a system of understanding environmental information that can enhance any environmental decision-making framework; but is conceivable that information can be collected, integrated and arranged to be better responsive to the needs of decision-makers. This would in part be a value-of-information question, but also needs to include how the information is analyzed and presented to the decision-maker. Sustainability, incorporating as it does three important dimensions of outcome or consequence from decisions, could be refined and modified with the inclusion of ecosystem services information to be better tailored to the needs of specific types of questions.

However, the large question that drives development of ecosystem services valuation and a large number of sustainability decision support tools is the urgent need to understand how to improve the judgement of decision-makers when considering choices that may degrade the environment. It is evident to any student of history, and Habermas would assert, that individuals' judgements are informed by their values, which are in turn formed in part by their association, be it a privileged class, academia, religion, the mob, or what have you. The effect of values on judgement is both obvious at times, and mysterious. It is also true that there is great variation in the values of individuals within whatever association one might examine. Thus, environmental protection might be well served with the design of decision-support tools if they can influence the values, and hence judgement, of a sizable percentage of "middle of the spectrum" decision-makers who can come to appreciate the gravity of the environmental management decisions under consideration.

This researcher is curious to know how typical is it for decision-makers to be predisposed to maximizing short-term gain over the long-term sustainability of social, economic and ecological systems regardless of the information provided to highlight the significance and importance of sustainability. If it is very common, then the pursuit of improving decision-making tools is not likely to improve decision-makers' judgement, or decisions. Research to better understand if the problem lies with decision-makers, rather than the tools used to inform them, would help ensure that scholarship and resources were dedicated to the most efficacious need for improvement. Simply put, it may be that decision-makers need to be improved more than decision-support tools. In theory, at least, a hypothesis is that one leads to improvements in the other.

Two areas of exploration could be fruitful. The first is psychological. Is there a correlation (or causation) between individuals who seek to, and succeed in becoming decision-makers, and a value assemblage that pre-selects for short-term economic benefits over long-term sustainability benefits? The second is sociological, and of greatest interest to this researcher. Are there substantive and measurable differences in the pre-disposition of authority (decision-makers) to favor short-term economic benefits over long-term sustainability benefits in different types of societies or governance systems? Relatedly, what social institutions can be modified or created to better value and protect ecosystem services? The payment for ecosystem services (PES) model has been explored in the private sector, but also has application in the public sector with common asset trusts, where property rights on the commons are assigned to community (public interest) trustees for protection of the asset.

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Appendix A. Responses from NEP managers to Surveys #1 and #2.

Initial NEP survey (2009)-Questions in bold

#1 Have you knowledge of the approach (or doctrine) of ecosystem services being used in decision making? What was the source/s of your knowledge?
Yes–7 No–1
A Conference on Ecosystem Services (ACES) in December 2008 in Naples, FL presented discussions on the subject in detail and was a milestone in advancing understanding of ES among the NEPs. The conference abstracts and presentations are archived at: http://www.conference.ifas.ufl.edu/ACES/ NEP management and staff also frequently cite published literature and the EPA - Ecosystem Services Research Program webinars, and the 2008 ANEP annual meeting Ecosystem Services Valuation (ESV) pre- sentations and discussions (made by this author and identified colleagues). The work of Bill Mates, NJDEP Natural Capital Valua- tion Project with the Gund Institute was also identified as substantive, as was work by Dr. Danielle Kreeger at the Partnership for the Delaware Estuary (one of the NEPs). Economic valuations of estuaries undertaken by the NEPs were often noted as particularly relevant. They "have attempted to provide the public and stake- holders information about the ecological system and its service in terms of the estuary's monetary importance" to their regions. The valuations were limited to those services that could be easily valued in dollars and therefore, did not include aspects such as the value of the estuary for flood attenuation and other services not so easily assigned a dollar value. Some NEPs "have used the approach of stressing the importance of ecosystem services when pushing for change or garnering support for a program" or "review of mitigation proposals." One participant remarked, holding ESV to a monetary definition: "Decisions incorporating costs/benefits are made all the time," but refined ES information is not available in our area to include in the decisions."
#2 Does the concept of "ecological service" offer any advantage in framing social and economic initiatives to meet environmental objectives for stakeholders?
Yes–7 No–1
While participants were generally agreeable to this proposition, this concern was raised: "Ecological services" can be viewed as just looking at the environmental side of the ecosystem, and it can turn some groups off, including those who focus efforts socioeconomically." The opposing view was also made. People do value the recreational and ecological resources. "If we do not protect these resources, there will be economic consequences, and the loss of revenue and business generated by tourism and the summer population. This very fact helps us integrate socio- economic principles into the objectives of our program and present our issues in a meaningful way to local government officials." It was evident that many of the NEP representatives were already well informed of ESV and held strong opinions on its perceived promise in at least general terms. Other comments included: "The general public in the US has generally regarded our natural resources as being free and limitless in the purest sense; clean water, clean air, etc. By being able to better articulate and also quantify in economic terms why enhancing, restoring, preserving, and/or protecting these resources is critical provides for a more compelling and holistic discussion." "Historically, environmental campaigns have typically been framed around esthetic/intrinsic values or nuisance/public health issues. Environ- mental issues need to be framed in new ways that are relevant to the general public and stakeholders. People need to know that ecological services protect them from harm, form the foundation of the

economy, keep the planet in balance, and help to maintain people's quality of life. Framing issues in terms of ecological services has the power to engage the public to drive the success of environmental initiatives." "Environmental agencies need to do a better job in assessing ecological services (especially non- monetary valued services) based upon the values that are impor- tant to the stakeholders. Changes in ecological systems resulting from particular actions need to be better understood and commu- nicated to the public and decision makers to assist them in making informed environmental decisions." Other NEP representatives, while optimistic, were equally pragmatic about what role ESV might play in their programs. "Any additional substantive informa- tion we can get - when it comes to trying to make a case for ecological restoration is useful. Ecological services are often hard to define or for people to understand. However, if they can be expressed in a way that people see a personal benefit, they would be useful. There is a need to understand the "true cost" of activities (such as changes in land use), which could include ecosystem services considerations." "The limiting factor to environmental initiatives is usually not lack of public appreciation of the values of the services. The challenge is how to incorporate that value, to monetize it in some fashion in the decision making process; for example, in exploring the ecosystem value of bivalve or seaweed harvest for nutrient remediation. The challenge is how to give credit to expanding these services in lieu of less valuable, more expensive but potentially regulated nutrient control actions. We need to go beyond identifying the service to identifying those who will pay for the service."

#3 Do you think a measurable characterization of what ecological services need to be sustained (e.g. crab fishery or flood protection) can serve as an effective means to communicate environmental protection objectives to decision-makers?

Have you used such a characterization to communicate environmental objectives; what?

Yes–7 ½14

No–½14

Responses to this question ranged from skeptical to a majority of responses highlighting services such as recreation and provi- sioning that are relatively easy to value. One response expressed doubt that the ecosystem services *concept* per se, provided sub- stantive information enhancement. "Ecosystem services are

14 The half is reference to one response that was partially in agreement, and partially not.

another version of setting goals and targets. For example, rather than restore x number of acres of tidal wetlands, the goal is maintain x volume of flood control capacity. It is not entirely clear how this is a game changer in actually protecting or restoring wetlands." In contrast, several responses focused on the value of an ecological service, though it became clear that the difference between an economic assessment and an ESV assessment was not immediately apparent to some—to wit, that an economic assess- ment would be subsumed by the more thorough ESV assessment. One NEP used dollar amounts in their CCMP to show the value of specific ecosystem components such as agriculture, commercial fisheries, and tourism. Another tried to use the estimated value of enhanced recreational opportunities to characterize benefits asso- ciated with habitat restoration. One NEP successfully used statis- tics on the recreational monetary value of the estuarine system as grounds to generate support of policy makers for an innovative funding source to support protection initiatives. A 2% real estate transfer tax on all

real estate transactions occurring within the Estuary watershed is credited to a dedicated fund. The revenue is then used to fund land protection and acquisition activities. The program has generated hundreds of millions of dollars and is considered very successful. Despite the large amount of money spent to help sustain identified ecosystem services the NEP reports difficulty meeting their environmental protection initiatives. This need, together with their successful experience using ecosystem services has led them to conclude "the more supporting documentation and value we can affiliate with these resources, the better." Another NEP reported the use of ecological services associated with sea grasses (or lack thereof) as the basis for assigning benefits to proposed CCMP implementation actions and in assessing the overall ecologic health of their estuary. They noted that sustaining and enhancing the ecological services provided by sea grasses was adopted by the Florida Department of Environmental Protection as the basis for TMDL targets in their estuary. Modeling the watershed's nutrient loadings and their impacts on water quality/sea grasses and communicating these impacts to decision makers is helping to meet the Program's goals to "attain and maintain water and sediment of sufficient quality in order to support a healthy, macrophyte-based estuarine lagoon ecosystem, and which supports endangered species, fisheries and wildlife, and to achieve heightened public awareness and coordi- nated interagency management of the lagoon ecosystem that results in the accomplishment of the afore-mentioned goals." It should be noted that "sea grass" is an assessment endpoint rather than an ecosystem service, but represents the NEP's measurement criterion for multiple services associated with sea grass species' success. This response also noted that the way marine dissolved oxygen criteria is written to ensure fish survival also demonstrates how indicators associated with the provisioning services of ecosystems are integrated into existing regulatory processes. Most typically, NEPs communicate to stakeholders and the public about ecosystem services qualitatively. Illustrative is the example provided by an NEP of characterizing the importance of an oyster fishery in terms of economy, recreational values and cultural/historical significance, but without assigning quantitative values. Freshwater mussels were framed in terms of the water quality and habitat forming services they provide, and about all the "important services" of the tidal wetlands in the Estuary.

#4 Have you ever used ecosystem services as you define them to make a decision?
Please describe the ecosystem service/s and the decision, and how it made a difference.
Yes–4 No–4

Responses to this question reaffirmed that ecosystem services were used largely qualitatively. When employed quantitatively it is largely in association with established recreational or provisioning services. With the exception of the Florida TMDL development process described above in question #3, the NEPs indicated that ecosystem services were mostly employed to support planning and project prioritization. Several NEPs indicated that ES have not been quantified to the extent needed to consider in decision making to date. The concepts are discussed (nitrogen removal, habitat value for fisheries, carbon sequestration, etc.) but until these values are better quantified, they are difficult to use. "For all practical purpose in our Atlantic coastal region this is a relatively new concept which we have begun using in our NEP related materials. It is and will become increasing imperative as we move forward with expansion of our current suite of indicators espe- cially as we advance our Climate Ready Estuaries15 initiative and our wetlands monitoring and assessment work." One NEP reported that they prioritized restoration activities and projects around general concepts of which activities return the greatest ecosystem services per investment. They stated that work was being done to better quantify those services in order to better inform the decisions. Another NEP has used the concept generally, to

support and justify the need to take action. As an example, they noted a study on the value of water quality dependent uses of the estuary: fishing, boating, beach-going – consistent with the widely understood provisioning and recreational services. An NEP initiated a project to develop an ecosystem based management plan that involves conducting a needs assessment based on ecosystem services. The science behind this plan is an ecosystem based approach. The initial phase of stakeholder involvement and bound- ary identification is complete. The second phase is an ecosystem services needs assessment that will be used to develop a list of ecosystem based management projects. The plan will be used for prioritizing funding opportunities and meeting ecosystem restora- tion goals. An NEP reported that its estuary was once abundantly populated with a species of scallop that was decimated by Brown Tide in the 1980s. This prompted community leaders, bay men associations and eventually enforcement agencies and the local municipalities to come together and address possible anthropo- genic causes of the problems being experienced by the estuary. The NEP was created to control the Brown Tide and restore the bay scallop population back to historical levels. A Brown Tide Manage- ment Plan was developed and this eventually morphed into the NEP CCMP. The NEP is still devoted to researching harmful algal blooms and conducting bay scallop restoration activities, but now has a broad reaching management plan addressing many other issues impacting the estuary system. "This highlights the importance of a single species, and its value, in sparking the decision to develop a grassroots movement that, in this case, eventually blossomed into of a multi-decade, multi-million dollar partnership."

#5 Can you imagine circumstances that would cause you to explicitly consider ecosystem services in a decision you might make (e.g. legal obligations, personal values, economic con- cerns, organizational goals, significance)?

What might those circumstances be?

Yes–8 No–0

Generally, support for the concept was universal; however, few distinctions were made between qualitative and quantitative uses. "For an NEP, goals would be a primary use of ES. For some of our local government partners, ES values would be very useful for land use decisions." "The value of having ecosystem services behind the decisions made is important and can lead not only to a more productive and better managed ecosystem but can also lead to more

15 Climate Ready Estuaries is a program supported by the EPA to assist estuarine areas of the USA prepare for and adapt to climate change.

funding and partnership opportunities because the decisions being made are science based. We can also use ecosystem service informa- tion to prioritize which projects to pursue, partner with, and/or help fund." Responses reinforced the perception that ES were largely viewed as congruent with ecological protection generally, and which would be readily recognized by the general public.

"Most decisions made by the estuary programs are based on ecosystem services considerations since each program's CCMP's ulti- mate goal is to enhance and sustain the ecosystem services provided by their respective estuaries." "The very state of the region's economic and ecological future is based on how we protect and restore our water-bodies, which are (and contain) our most valuable resources; beaches, shellfish, multitude of aquatic-based recreational activities etc..

Putting a dollar value to these resources is an effective way of gaining support for legislation & the adoption of local land protection ordinances, and also provides a case for outreach messages encoura- ging all user groups to practice good stewardship."
One respondent stated "[Using ES] is easy to envision in a general sense, to highlight the value of a proposed action. It is not clear how it would function in meeting legal obligations (e.g. CWA attainment of WQS). It is possible that part of an argument for a TMDL may be that the resulting improvements would allow for more swimming, fishing, and public access."
#6 Does the use of measures of ecological service condition correlate in any way with a project's success?
What other factors, including risk assessment information, if any, show positive correlations?
Yes–6 No–1
Possible–1
Responses to this question illustrate the range of familiarity with ES concepts among the NEPs, ranging from simple doubt in the concept, though narrow conceptualization equivalent to the dockside value of catch and recognition of potential, to creatively envisioning applications. "If an improvement in ecological services can be demonstrated resulting from the implementation of particular actions and changes, then a positive correlation is assigned and the project is deemed a success. This is implied within the ecosystem- based management actions of the NEPs." "Many times, projects (particularly habitat restoration and large-scale research projects) cost a great deal of money and require buy-in from many entities in order to attain match and other forms of support. Being able to say "by spending $1mil on this project we are potentially going to generate $3mil in revenue or habitat value" goes a long way. So just being able to demonstrate the potential value and outcomes of a project upfront may increase the chances of a project being funded and being able to successfully complete a meaningful project." "ES could be correlated qualitatively with improvement or stabilization indices; i.e. status and trends of eco-system health." "Using an oyster reef restoration project, for example, in an area that had historical oyster reefs, we might consider the services the "new" reef might be providing (e.g. water quality, fish habitat, shoreline stabilization, commercial harvesting, bio-indicator, recreational fishing spot, etc.). We know what services the product should be providing so we can now measure the success of the new oyster reef after it has been created. Some possible services to show success are: are the oysters filtering adequately (if not, the position of the new reef might not have been placed right in order to maximize water uptake with current water flow patterns), and can the oysters be commercially harvested (if not, there might not be oyster growth due to high salinities from historical altered freshwater inflows). Possibly a better way to approach the project is to try and plan out how the project can meet the ecological services prior to implementing the project. By recognizing what ecological services an ecosystem component should be producing will allow you to correlate the success of a project."

#7 Which means to characterize ecosystem services is potentially most constructive: Why?
A quantitative monetary value–3 A narrative qualitative value–0 Both–5
"The costs of protecting or restoring the service can and should be expressed in $." "Everyone understands the concept of a dollar (scientists, decision makers, and economists). The downside is if the dollar amounts are to be used for compensa- tory mitigation purposes, where the dollar amounts might not be entirely relevant." "Property owners and municipal man- agers would be more responsive to a monetary value character- ization whereas property renters in metropolitan areas, might be more swayed by narrative values (more emotional)." "It depends on the service.

Some services lend themselves easily to monetary values, while others don't. Some services directly tie into the human economy while others are less evident through indirect linkages. Should these services be valued lower because their immediate utility is in support of the ecology and habitat than to Wall Street? There are also quantitative ways to assign units, credits or scores to ecosystem services without the use of monetary values. InVEST recognizes the market values of some services and applies scores to others. These units/scores may have monetary value, but it is not always helpful to assign static monetary values up front. In carbon trading markets, for example, units of carbon are auctioned to determine the price per unit. This price can fluctuate in real time with the supply and demand of the market. Price should also fluctuate with changes and losses, like those expected with climate change, and with economic recessions. Static values, like those assigned to resources in the New Jersey Natural Capital study cannot cope with these types of changes in supply and demand, without rerunning the costly analysis." "Both – quantitative monetary value is needed to compare alternatives, assign cost benefit values and determine economic impacts from changes to the biophysical components of the ecosystem. A qualitative value is needed to describe the biophysical components that cannot be valued in dollars but still provide valued services to the public who need qualitative information to help make informed decisions on the impacts of proposed actions. As the saying goes "a picture is worth a thousand words." So that a shared picture of a smiling fisher- man with his string of fish (qualitative) is often as important to decision makers approving expenditures for a restoration pro- ject, as is an economic valuation study that assigns a monetary value of millions or billions to the ecosystem where the project is to occur. It all depends on the values the public holds highest." "They are of equal importance. An understanding of the range of ES provided, as well as monetary value, would be useful for different purposes. In some cases, giving a resource a monetary value can be a very effective means of establishing the importance of that particular resource. Other times, provid- ing a case statement or narrative which includes the historical importance and inherent value that some of these services provide can be more effective than just saying "this costs this much, therefore it is important." "While both are critical in any characterization of ecosystem services, what has been missing beyond the commodities aspect is the economic value of eco- system function in the big picture. One of the primary economic drivers for [us] is tourism and if the natural systems fail; i.e. poor water quality leading to eutrophication leading to episodic algal bloom and the constant presence of sea nettles, etc. it limits the public's ability to use the resource. This will have tremendous economic consequences on a number of levels. The same type of scenario can also be posed for the loss of tidal and non-tidal wetlands."

ANEP ESV web-based and phone survey #2 Results

#1Were you aware that ANEP partnered on a project to explore the utility of ecosystem services valuation for NEP estuary programs? (13 web survey responses)
Faintly aware–4
I recall ecosystem service presentations at ANEP national meetings in recent years–8
No, I was entirely unaware–1
(8 CoP Responses)
Faintly aware–1 "Not vividly, they did help in understanding the ESV work occurring in other NEPs."
I recall ecosystem service presentations at ANEP national meetings in recent years–7

“Yes, the DE bay work was excellent, and the level of effort demonstrated how challenging and rigorous an ESV application would be.”
#2 Have you used the concept of “ecological service” in decision making or framing information for stakeholders on the tradeoffs between social, economic and environmental objectives? (13 web survey responses)
Yes–8 No–5
(8 CoP Responses)

1. Framing scenarios for planning and public dialog.
2. In a qualitative way. The climate change project is using coastal wetlands to illustrate ES storage capacity for flooding. Wetlands provide flood control service, and we’re examining restoration of ecosystems to replace lost capacity. Key is “tying it to awareness that people already have.” Effective use of ES with stakeholders is linked to building from their “points of aware- ness” and “finding hooks to hang the hat.”
3. In our recent report ESV constituted about 25% of the weight in our decision making. Indian River—our biggest indicator is sea grass. It is the basis for all habitat restoration projects (e.g. storm water, and how it affects pollution conditions and sea grasses).
4. ESV has helped to identify the hidden costs and consequences of economic development in the watershed on water quality and in particular recreational services. We use it to frame issues and ground the discussions in values that are important to audiences. It can be useful, but care needs to be taken with the general public because the ESV discussion can be nuanced and technical – and require a considerable time investment to be useful. We don’t push the concept into the press because it is too detailed for superficial coverage. Using ESV help to develop stakeholder's mindset beyond immediate advantages perceived from development.
5. We have used the concept in discussions about habitat protec- tion and managing storm surge in the context of wetland losses. A qualitative use of ESV contributed to good results in this discussion. “The way you feel about ES provided depends upon whether you live there.” Folks look at services based upon their relationship to area affected.” Quantitative valuation of this service is hard, but it is necessary if it is to be used to inform and address permit applications. Specific applications such as considering the value of an acre of wetland vs. the services associated with dredging would be valuable. However, we aren’t able to conduct the quantification of ESV necessary to provide this level of informed data.
6. Yes, by tallying the water treatment benefits of bivalve filter feeding, and framing as offsetting costs to sustain water quality, we have helped to build awareness and support for the value of investing in bivalve shellfish preservation and restoration.

Initially, the approach involved an estimate of the value of water quality dependent uses of [the] Sound. The valuation numbers were startling to many and were very valuable in putting into perspective the potential costs of water quality improvement projects. The challenge is that good, local data to derive valuations are often lacking.

7. Yes, adapted it in new planning process for the ecosystem management plan. It offers a means to highlight benefits from ecological protection that are not otherwise readily valued by conventional cost benefit economics.

#3 Can you imagine circumstances that would cause you to explicitly consider ecosystem services in a decision you might make (e.g. legal obligations, personal values, economic con- cerns, organizational goals, significance)? If yes, what? Other- wise enter "no."

(13 web survey responses)

1. Yes, to communicate the full value of undisturbed ecosystems in cost benefit assessments for proposed development
2. Yes, Prioritizing restoration projects, recommended legislative action, presenting values as part of public information, meet- ing CCMP obligations.
3. Maybe not a decision, but the information is very valuable when talking to people about tradeoffs and benefits of money spent on public efforts schools v wetlands sort of thing.
4. Yes, based on our organizational goal to focus on habitat diversity and function.
5. Maybe, we are in the process of developing a list of services that nature provides and will calculate their economic value. This will help us prioritize actions to protect and restore the most important ecosystem services. We are doing this work through the Social Science Advisory group.
6. I'm not sure I understand the question. Just about everything NEPs do, and, thus, most decisions we make, are built around the protection or restoration of one or more ecosystem services. Perhaps there's some nuance to the term I am not getting. Do you mean economic value of ecosystem services?
7. Yes, we used ecosystem services and HEA and REA as part of our oil spill NRDA process
8. Most of our work is based on such services. (maybe)
9. The development of a science based estuary wide monitoring program and in creating a biological condition gradient frame- work
10. Yes, in setting habitat restoration goals and educating about the social benefit of restored habitats.
11. Yes, recognizing the economic benefits of restoration and a healthy environment would cause that to be a consideration.
12. Not sure what you are asking here. (no)
13. Yes, I could foresee a situation where we were trying to justify construction of a restoration project and one of the factors would be ecosystem services.

(8 CoP Responses)

1. If f on a project-by-project basis resources exist to make a case for using ES (e.g. flood control—ecological restoration of a wetlands can save $600K in damages) then, yes, we would certainly employ ESV information. Concrete applications for ESV and examples are necessary. Specific applications are easier to quantify, but even so require financial means to do so. An obstacle is that there is not wide recognition or a lot of exact quantification that services exist and benefits flow.
2. Identifying and organizing priorities for the community, coor- dinating government activity, and for marine spatial planning.
3. Yes, we used it for understanding priorities for wetland restoration, trying to reconnect and restore impounded wet- lands to make accessible for the fishery.
4. Yes, use with NEP Board to explore opportunities for adaptive management and to organize programs. Quantitative measures for ESV are not real solid, however the logic

is tractable. In examining clam flats, and targeting the reopening to highest productivity wetland is a good model for us. The logic transfers to other services such as recreation.
5. It costs money to restore open water to wetlands, and a good ESV of wetlands would be useful.
6. Too many to list. I think the most immediate useful application is for prioritizing how to best invest scarce dollars for restora- tion or enhancement. If one species or habitat furnishes five key services and another species provides for one key service, then equal cost projects might be steered toward the former (or in more strategic locations, etc.). There are also circumstances where our increasing knowledge of ecological services might cause us to second guess management paradigms. For example, hypothetically, if we increasingly value the importance of coastal marshes for flood protection, and the best marsh for keeping pace with sea level rise and sustaining protection is Phragmites, then should we continue to invest a lot in Phrag- mites eradication in front of coastal developments just because it is an invasive? There are other non-native species that appear to promote good water quality, what will managers do if we start to value them? Finally, NRDA does not adequately tally ecosystem service losses during oil spills, etc. Getting better numbers might lead to expansion of injury decisions.
7. Yes, tentatively. We have to keep in mind that most water quality decisions are based on Clean Water Act requirements. ES can't be considered in those decisions unless explicitly included in statute, regulation, or policy. This is not the case, or it is very constrained.
8. Yes, primarily in the area of planning, for examining status and trends and moving toward forecasting and scenario development.

#4. Have you used other sources to understand and explore how ecosystem services information could be relevant to your NEP? If yes, please identify the source/s. Otherwise, enter "no."
(13 web survey responses)

1. The Millennium Assessment
2. EMERGY, build out analyses, Estero Bay Agency on Bay Manage- ment. We had grant application submitted to EPA Region IV for an ecosystem services topology and are developing one for Gulf of Mexico partnership for decision support systems for man- grove/seagrass/salt marsh systems.
3. Yes, we have look especially at other efforts to quantify LID storm water benefits. Needed to help convince folks to move away from standard engineering
4. No
5. In 2008, we contracted with the World Resources Institute, Meridian Institute, and NOAA Fisheries to identify the most important regional ecosystem goods and services. This work was done through a series of interviews with key stakeholder groups. The purpose of the study was to help us define what a "healthy Sound" is; prioritize indicators for measuring and monitoring the status of the Sound, and to focus strategies and actions.
6. Perhaps it would be helpful if you included your definition of "ecosystem services" at the top of the survey. I think of ecosystem services as some ecological function that has value to humans. Given that very broad definition, I'm not sure what other sources you

would be referring to.
7. No, other than in the context of our oil spill NRDA process
8. Yes, various web found.
9. MD has significant resources in this arena.
10. Yes, a variety of internet searches… funded an emergy analysis for one waterway
11. No
12. No, not yet.
13. No

(8 CoP Responses)

1. ORD Research Team.
2. VIMS, Carl Hershner, Eco Based Management., collaboration with Albemarle/Pamlico NEP, Steve Yaffe at the U of MD.
3. Harte Research Inst., published lit in the report, and Dr. Jorge Brenner, a post doc and huge asset and resource.
4. Nothing stands out. Lots of publications are increasingly using the concept.
5. Bob Costanza's publications (with Dennis King and Lynn Lewis —Nature & Journal of Env. Mngt. 2009), Manomet at the Center for Conservation Sciences, Crooked River Watershed Study— looking at what the drinking water market would be for Portland ME; and how ESV has evolved from just water to include carbon credits, which have been used to raise money to fund restoration.
6. Rex Caffee, an economist at LSU Seagrant.
7. Yes
8. ORD has provided a lot of guidance, Paul Englemeir at VA Tech conducted a study on how ES spatial analysis of A/P can be used, funded by USGS.

#5 Which of these answers best fits with your basic impres- sion of ecosystem services information?
(13 web survey responses; 8 CoP Responses)

1. The information is useful and we've used it productively. Total¼ 8; 3 web responses; 5 phone responses (two of them split with response #5).
2. It is not much different from an economic resource value assessment. Total¼ 4.5; 0.5 web response (split with response
#3); 4 phone responses
3. It is a good concept but the science is too immature for current ease of use. Total¼ 3.5; 3 web responses; 0.5 phone response (split with response #2)
4. The value of the information it provides does not warrant the effort to obtain it. Total–0.5; 0 web response; 0.5 phone responses (split with response #5)
5. The concept is good and valuable, but resources do not allow our development of it at this time. Total¼ 4.5; 3 web responses;
1.5 phone responses (split with responses #4 & #1)

#6 Decisions regarding economic development in previously natural areas are informed by

analytical and deliberative processes like cost benefit analysis and risk assessment. Do you think that the introduction of information on the value of ecosystems services to these processes would substantively alter the outcome of the decisions? If yes, why? If no, why not?
(13 web survey responses)

1. Yes, in some circumstances I think it can hold persuasive cpower.
2. Yes, the greater the depth of information using different approaches, the better the decisions.
3. Perhaps, it will depend on how "real" the public and decision makers end up thinking those benefit values actually are
4. Substantially alter? No. Even without ES valuations the ecolo- gical importance of habitats and ecosystems is pretty well understood and that hasn't seemed alter the decisions being made. - I hate to be this pessimistic.
Perhaps. Cost/benefit analyses express a tradeoff between people's desire to use and protect the environment. Unfortunately, the tradeoffs between ecosystem service use and restoration are not well defined. The returns on invest- ment of ecosystem recovery have not been quantified. We also lack of resources to support such analysis. One of the biggest challenges in effectively estimating ecosystem services is the identification of the relevant sample population and then making the policy choice as to which stakeholder groups bear the impacts (positive and negative) of ecosystem recovery strategies. Ecosystem services are a public good. How we choose to have them allocated is a policy decision. However it is clear through preliminary (not peer reviewed analysis) that if these services are degraded our economy and social and culture fabric may decline.
5. It's very difficult to compare the economic valuation of a natural resource to the dollar figures associated with devel- opment. The former tends to be abstract, and the latter, much more concrete and defensible. I'm not sure economic valuation of natural resources will ever be as important as local or political will (which, admittedly, usually has economic con- sideration) in the decision to protect natural areas. Valuation of an ecosystem service might be more effective in cases where that service involves protection of real property, assets or industry (for example, a wetland that provides flood protection).
6. First, I disagree with the premise of the question if you are talking about government permit decisions, which are driven by what is required in regulation and law. Some regulations may require alternatives analysis where ecosystem services could come into play. Private entity decisions are however driven by some level of cost benefit analysis and risk assess- ment, but ecosystem services are not part of their thinking, again unless required by regulation.
7. Absolutely.
8. Yes over the long term.
9. Not at this point. the concept is still too new. It would provide opportunity to begin to make changes or to look at develop- ment in a slightly different manner.
10. Yes. However, it would alter the outcome somewhat, not substantively.
11. I actually don't know. I think, from my answer above, that I myself am a little

unclear as to how it differs from an economic resource value assessment. So, I simply don't know the answer to this question.

12. Yes, if used correctly. Even if they don't stop or alter the actual economic development project, it could be used to influence a substantial mitigation project.

(8 CoP Responses)

1. If it's the right info to make a case it can be very powerful. It is not a sole determinant, but it can tip the scale. If it's not well documented or too theoretical it's not too useful. Its greatest value is at a targeted scale. We don't have the resources to do the analysis and synthesis. There is a pressure toward imple- mentation, and fewer resources are available for planning and research.

ESV is another way to see the value of the natural resources. It helps us guide where there can be positive tradeoffs. Growth will occur, where can we target the credits to developers to minimize impact to services? Developers can be directed through payments for offsets. We undertook to incorporate ESV in planning work we conducted in 2007. We went to stakeholders to provide input through surveys linking ecosys- tems to desired services. It was not monetized, but we hope to be able to do this eventually. The study provides some indica- tion of the scale of relative value among identified services. "The concept is difficult to communicate to the general public." It helps when you have a good communicator and message.

2. It is beneficial. How much influence it has on the outcomes of contested development projects is not clear. At least if helps to inform developers on the impact of their projects.

3. The value of ESV is that we understand how value is generated for society. The exact # value can be problematic, it's a little squishy. ESV is good information, but it's not likely to be by itself convincing to those who don't want to be convinced. The technique is least developed for arriving at precise values, and thus, the quantitative aspect is least reliable. The process of concluding the ES stack is important for framing the multiple services ecosystems provide and helps establish their marginal value. A key point to understand is that ESV can be used in different way, both quantitative and qualitative. We discussed conducting an ESV on a tidal impoundment, and the numerous services it provides, however we determined that we don't have the resources to do it.

4. Yes, ESV will help to balance input to cost benefit assessments, which do not presently consider ecological values. It would have as much importance as the political system will allow.

5. see earlier responses.

6. Local development decisions very much are the outcome of plans of development that reflect, or should reflect, a public vision of the community. Ecosystem valuation can help inform and shape that vision and subsequent development plans.

7. Its improving the benefit analysis for ecological systems. We have a nitrogen study under way that may lead to something. It's too early to say with any certainty. Many decision makers do not look beyond support for business development at any perceived cost to the environment. For these people, if you don't offer data with $ cost attached, then you may not be able to make a persuasive case.

Appendix B. Information on the research provided to identified experts

The Use of Ecosystem Services Information within the EPA National Estuary Program

Background
The research methods used in this study include a combination of standard survey assessments, case studies, and interactive participation between the researcher and members of the sample population (action research). The study population of 28 National Estuary Programs (NEPs) is small, and somewhat heterogeneous, but clearly demarcated by subscription to a national program associated with the U.S. Environmental Protection Agency (EPA). Additionally, the NEPs self-identify through a national association, the Association of National Estuary Programs.

The NEPs were selected as the study population because they are well defined, and are all managed through a decision-making process that relies heavily on stakeholder involvement, interactions and consensus. This process relies on the transparency, effective diffusion, and use of information to substantiate and shape objectives, as well as to manage operations and to assess performance.

To summarize NEP management objectives is difficult because they are not uniform. The pollutants of greatest concern are typically nutrients & sediments. Most NEPs, but not all, address heavy pressure on natural systems from land development. More recently they have begun to also examine the effects of global warming. The NEPs vary in size and program details, but all must raise a substantial part of their budgets locally, and for the most part can only afford to fund their highest priorities.

The research goal is to explore whether the use of ecosystem services' information has been used to substantively improve environmental outcomes through improving the information used for decisions (e.g. cost-benefit analysis and the strategic targeting of financial resources).

As demonstrated through the published literature on ecosystem service valuation, this concept is more targeted to the academic and research communities than it is to environmental managers. There is a rapidly growing literature on the how ecosystem services information can be used, however, there is very little literature citing actual use and experience with the concepts for program planning and operations management.

Research Method

The process this researcher used to conduct the research is as follows.

Presentations on the topic of ecosystem services were made to the Association of National Estuary Programs (ANEP) at two meetings in 2008. The researcher worked closely with NEP managers to shape the presentations to NEP needs. Following the November 2008 NEP meeting the researcher discussed with the ANEP Executive Director, Dan Berman (Morro Bay, CA)

advantages for allowing a committee of the ANEP to self-select and advance the discussion of ecosystem services among NEPs.

The ANEP Board agreed to the formation of a self-selected group and Mr. Berman notified the ANEP membership of the opportunity. A questionnaire was prepared in 2009 by a sub-committee of the participants, including members on the ANEP board in conjunction with this researcher. The information collected was to help prepare agendas for follow-up conversations that were formalized into a "Community of Practice" (CoP).

Two CoP conversations were convened by this researcher. Subsequently, a final presentation was made to the ANEP at their December 2010 annual meeting on applications for coastal assessment of ecological services. A final survey was administered in 20011 to the members of the ANEP community of practice by phone interview, except for the Peconic Estuary Program, which was in transition with no one available. Two NEPs, Tampa Bay, and the Partnership for the Delaware Estuary, demonstrated most extensive use of the ecosystem service valuation concept, and were developed into case studies.

The executive directors of the remaining other NEP member organizations of the ANEP were contacted by email on three separate occasions over a period of four weeks in August and September 2011, and requested to respond to an on-line web survey.

Findings

The first survey, administered in 2009 over a period of 6 months to any of the NEPs that could be engaged, included about a third of the NEPs. The results follow below.
1. Have you knowledge of the approach (or doctrine) of ecosystem services being used in decision making? **Yes_7_ No 1**
2. Does the concept of "ecological service" offer any advantage in framing social and economic initiatives to meet environmental objectives for stakeholders? **Yes-7 No-1**
3. Do you think a measurable characterization of what ecological services need to be sustained (e.g. crab fishery or flood protection) can serve as an effective means to communicate environmental protection objectives to decision-makers? **Yes-7 ½ No½ No-0**
4. Have you ever used ecosystem services as you define them to make a decision? **Yes-4 No-4**
5. Can you imagine circumstances that would cause you to explicitly consider ecosystem services in a decision you might make (e.g. legal obligations, personal values, economic concerns, organizational goals, significance)? **Yes-8 No-0**
6. Does the use of measures of ecological service condition correlate in any way with a project's success?
Yes-6 No-1 possible-1
7. Which means to characterize ecosystem services is potentially most constructive:
3-A quantitative monetary value.
0-A narrative qualitative value.
5-Both

The second survey was administered in 2011, partly by phone to the 9 NEPs who had engaged in the CoC, and the remainder by internet survey poll (13).

- 9 ANEP members received phone interviews.
- 19 ANEP members were invited to take an on-line survey, 13 completed it.
- Overall ANEP response rate was 78%; on-line survey response rate was 68%.
- Did your NEP use the concept of "ecological service" in decision making or framing information for stakeholders?

  Yes (17-77%) 8/9 No-5/0 (on-line/phone)
- Basic impression of ESV information **(on-line/phone)**

  (8.5-36%)3/5.5- Valuable, we use it
  (5-22%)3/2- Valuable, resources don't allow our use of it, at this time.
  (3.5-16%)3/.5- Good concept, science too immature to be useful now.
  (.5-2%)0/.5- Value of the information does not warrant effort to obtain it.
  (4.5-20%)4/.5- Its not much different from resource economic assessments.
- Uses Identified by NEPs for ESV
  - Incorporated into planning process or program management for ecosystem management – (3)
  - Quantitative estimate of ecological service to validate project/budget. – (3)
    - ✓ water quality related uses of estuary to validate improvement projects
    - ✓ value of bivalve filtering to validate shellfish protection and restoration
    - ✓ estimate of stacked services from tidal wetlands to validate conservation of wetlands.
  - Identifying community priorities – (2)
  - Communicating environmental effects from development and human activity – (2)
  - Future trends and scenario development

Conclusions

1. Over the course of three years working with the NEPs this researcher has seen a marked increase in the number of NEPs that have shown interest in working with ecosystem services as a planning and operations management tool. Willingness to respond to a survey on the topic grew from 8 in 2009 to 22 in 2011 – a factor increase of 2.75. I conclude that resource managers, as they become familiar with the ecosystem services concept and how it has been used by their peers, show an active interest in its application.

2. Most NEPs, while showing preference for using ecosystems services (ES) data quantitatively, do not. They have used the data qualitatively to characterize the value of ecosystems and their parts. The surveys suggest that a combination of perceived cost to use the concept and the concept's immaturity as a science are the major obstacles to greater quantitative use.

3. There is a strong perception that ES offers an improvement in the information available for planning and communication of program objectives. However, there is also the perception that quantitative data on ES is difficult to source, and expensive to provide tailored to a location. The expense of developing a thorough assessment of ES values for any given location, and the difficulty with the transferability of ES data between ecosystems may represent significant hurdles to the use of quantitative use of ES information.

4. A fifth of the NEPs who replied did not see a substantive difference between ES data and information that has been collected in the past about the value of resource use such as recreation, fisheries, and the hedonic value of natural beauty; despite the presentation of three sessions on ES and distinguishing it from resource economics at ANEP national meetings over three years. There is a strong similarity in how natural resource and ES information is presented when ES is denominated in currency. The fundamental difference is that natural resource economics is derived from economics data, while ES information is first characterized from ecological structure and function, and then fit to human/social demand for "assessment endpoint" services. The integration of ecological and economic "demand-side" information distinguishes ES information from straight-up economic assessments. That this is not a substantive difference to a fifth of responding NEPs suggests to this researcher that the full utility of ES data – linking ecological structure and function to available ES with economic value, is not fully appreciated by coastal resource managers. This represents an area where further education may be required to generate applications for available ES information – even if only qualitative.

5. NEP managers that have reported efforts to quantitatively use ES data applied the information to validate and justify program priorities or investment. No use of ES data was recorded for use in cost-benefit evaluations, per se, where ecosystem integrity is balanced against desire for economic development (with associated economic benefits). This researcher observes that the value of ES was employed to compare and communicate environmental effects from development and human activity in scenario planning exercises conducted in two NEPs. This means to investigate the benefits and consequences of economic development in demarcated ecosystems is comparable to a cost benefit analysis, and therefore this researcher concludes that ES data has been used in the NEPs in a manner that could inform a conventional cost benefit assessment. This researcher speculates that NEPs may elect not to use ES data in conventional cost-benefit type analysis for the following reasons:
1. NEPs are not regulatory agencies,
2. NEPs function as consensus building organizations, and
3. ES valuation information is not typically quantified explicitly from the area in question, and may be considered too speculative or qualitative to meet QA/QC requirements for cost benefit analysis.

<u>1. Questions to Experts From the 2012 NOAA Conference on Social Science for Coastal Management, held in Charleston, S.C.</u>

2. What is your assessment of the research population and response rate for this study, in the context of the conclusions drawn?

3. Do you think that the information collected in this study can be extrapolated to other organizations involved in the use of environmental information for environmental program management? Why or why not?

4. Do you disagree with any of the assertions made regarding NEPs in the research description, or the conclusions I've drawn from their survey responses? If so, please describe your concern/s.

5. Conclusion # 5 addresses the utility of ES data for valuing ecosystem services in cost-benefit assessments. This thesis researcher does not believe that because cost benefit decisions were not identified as a use for ES data, that it should lead to a conclusion that the information is mismatched or unavailable. Rather, this researcher does not think that the NEPs choose to use the information in this manner. This research shows that ES data is used in a comparable manner for scenario planning. Therefore, this researcher asserts that the ES data could be used to inform cost benefit assessments. Based upon the information presented and what you may know of NEPs, does this conclusion seem to be reasonable or not? If yes, why? If not, why not?

6. Does the information presented by this researcher suggest to you any other conclusions or questions that should be further examined? Or, do you have any comments on the scope or content of this elicitation? If yes, please elaborate.

National Estuary Program Expert Elicitation/survey: text of email outreach

Hi, this is to follow up on the request I made to you at the NOAA Social Science conference in Charleston last month to participate in a short expert elicitation. You were asked to participate because of your knowledge of ecosystem services valuation and coastal resource management. Thank you very much for agreeing to read a short summary of my research on the use of ecosystem services information by the National Estuary Program (NEP), and respond to a small set of questions.

Keeping this brief, and minimizing your time commitment has been a primary objective for this exercise. I've not included details provided by survey recipients, and focused only on the higher-level survey responses, similarly drawing general conclusions for your reflection. I'd tried to strike a balance between keeping the exercise short, and providing sufficient information for you to assess the conclusions I've drawn. The Zoomerang elicitation provides opportunity for you to comment on the design – the match between brevity in research description, and detail of the questions posed to you.

A final report is being prepared for the Association of National Estuary Programs, with greater detail and examples to illustrate conclusions. I will send you this report, which I will conclude following my incorporation of this expert elicitation.

A summary of my survey research to the NEPs and a page of conclusions are attached. I created a Zoomerang elicitation to collect your opinion on five questions about my conclusions. Please visit the site below and complete the survey by April 1, 2012.
http://www.zoomerang.com/Survey/WEB22F696SB8A3

Your input will represent an "expert elicitation" on this NEP research, and as such will be incorporated into my research. I will make all attributions anonymous, but will identify you to the others participating in the expert elicitation, unless you request that I also keep your participation anonymous. Let me emphasize that at no time will your responses be attributed to you directly. There is a line in Zoomerang for you to enter your name. If you prefer to not be identified to your colleagues also participating in this elicitation, please leave it blank. I will, similarly, be unable to identify you as the responder.

Complete responses to the expert elicitation

Complete responses to the expert elicitation
1. *Please enter your name. Your remarks will not be directly attributed to you at any time in any media. If the name line is left blank, you will not be identified to the other five participants in this elicitation - nor will I be able to identify you.* ZC, TS, CF, MR
2. *What is your assessment of the research population and response rate for this study, in the context of the conclusions drawn?* ZC – The use of NEP programs, while indeed pragmatic to your association with that group, also provides a good "pilot" test group for the use of these concepts in decision-making. Of course a larger panel of experts would be nice but response rate seems defensible. TS – Research population is appropriate target given the research question. Response rate seems appropriate and typical given realistic demands on coastal/environmental managers. However the relationship between respondents to survey #1 and survey #2 is not clear - did the same respondents from survey #1 all participate in round 2? CF – The research population seems appropriate. I feel that I cannot assess the response rate for the study. Response rate is a concept I am most familiar with in survey research. The qualitative date gathered through this methodology should be evaluated using a different metric than response rate or the term "response rate" needs to be more clearly defined. MR – Statistician within me would prefer a large sample to small in general. However main real life applications poses their own limitations. The research population of 28 NEP can be subject to meaningful analysis both quantitative and qualitative and should allow for enough diversity. The response rate of 78% overall and 68% online is on the higher side of general expectation for surveys.
3. *Do you think that the information collected in this study can be extrapolated to other organizations involved in the use of environmental information for environmental program management? Why or why not?* ZC – Per the previous questions, generalizability of findings will be difficult due to homogenous respondents, particularly looking at the use of this ESV concept in the context of decision-making - the structure of which is theoretically the same (i.e. all NEPs have a similar/same role). However, using a similar panel from a different "program" (e.g. NOAAs National Estuarine Research Reserve System) could produce rich complementary data. TS - This depends on who the organizations are, and what you mean by "can be extrapolated to other organizations." I agree that NEP use of ES data is fundamentally shaped by the fact that NEPs are non-regulatory and consensus-driven. Organizations with different authorities/jurisdictions/missions may use ES information differently. By "extrapolated" do you mean that results might be generalized to other kinds of organizations/indicative of the broader community of environmental managers? If so I am skeptical. If you mean this somewhat more qualitatively, this information could probably be extrapolated. I think I'd need a bit more information about what you mean here. CF – The summary of information prepared for this expert elicitation is not sufficient for me to evaluate this question. I assume that the full study include detailed literature review, methodology and more complete data could be evaluated to answer this question but that what is presented here does not allow me to confidently judge. MR – It is not possible to clearly state a yes or no in this case. As the investigator mentions in the write up, lessons from the analysis can inform other organization is at different stages of adopting ES. However such extrapolation should be heavily qualified by certain organizational and social position of NEPs compared other organizations
4. *Do you disagree with any of the assertions made regarding NEPs in the research description, or the conclusions I've drawn from their survey responses? If so, please describe your concern/s.* ZC – The use of "ecological service" as opposed to "ecosystem services" seemed out of place. While I get the meaning I think further defining the concept and discussing its role in decision-making can benefit from uniform language.

TS – I don't disagree with anything. Finding #4 is very interesting and you should further explore what "education" would really be necessary to actually change the way managers understand ES. Given that they all sat through three "education" sessions but still understood ES differently, this suggests either a deeper bias/set of assumptions, or the limited impact of education sessions, or some other barrier to understanding. For #5, I'd add an additional explanation for not using ES data in conventional cost-benefit analyses: lack of capacity (which may include lack of understanding, time, or money).
CF – I disagreed with the statement below because I found the listing of findings devoid of the kind of contextual information that I normally associate with case studies. It is hard for me to relate to data that is listed as numbers without more development of responses and quotes. This may be a result of my disciplinary training in qualitative research methods associated with cognitive anthropology. This does not mean your methods are wrong they are just methods I am not as familiar with."The case studies explored details of quantitative estimates of ecological service to validate projects, and use of the concept for future trends and scenario development; but did not add qualitatively to the finding from the surveys." I do agree with conclusion #4. I am currently involved in a project addressing this in the NERRS and have confronted similar issues identified here.
MR – The assertions mades regarding hestitation in using quantitative analysis of ES information could be enriched by highlighting the reason perceived immaturity of the concept. As an academic researcher, I do come across disclipinary biases on all sides- both valid or other wise. A social network analysis of the dynamics between NEPS would also help understand the drivers of tipping in adoption or inertia.

5. *Conclusion # 5 addresses the utility of ES data for valuing ecosystem services in cost-benefit assessments. This researcher does not believe that because cost benefit decisions were not identified as a use for ES data it should lead to a conclusion that the information is mismatched or unavailable. Rather, this researcher does not think that the NEPs choose to use the information in this manner. This research shows that ES data is used in a comparable manner for scenario planning. Therefore, this researcher asserts that the ES data could be used to inform cost benefit assessments. Based upon the information presented and what you may know of NEPs, does this conclusion seem to be reasonable or not? If yes, why? If not, why not?*
ZC – yes, the conclusion you draw is reasonable. I think a combination of two things leads to the reality you outline: the idea that when it comes to actual decision-making, the crux and arguably most difficult part of environmental management of any kind, ecosystem services is not the deciding or most important factor. First, ecosystem services and even more so the valuation of them, is still relatively new. As with anything else new, a curve of adopting its use will be gradual (in other words, I think we are on the right track with ecosystem service valuation, just not quite there yet). Second, and related, is that in the face of uncertainty (i.e. perceptions of ecosystem services/valuation) it is natural to turn to what we "know" (i.e. doing the way we have always done it). The type of information you are getting is invaluable to further moving us down the path you allude to in terms of accepting ecosystem service valuation as a viable means for basing resource decisions.
TS – Yes, it seems reasonable that ES data could be used by NEP managers in cost benefit assessments. Its use in scenario planning, as you describe, does seem somewhat analogous to CBA (though its difficult to state this definitively without knowing the nuances of the scenario planning efforts you describe). However, I think the question isn't so much about whether it could or could not, but why it is or is not being used. You touch on this but I think this is important and should be expanded because - if one believes that there is utility in ES data - the key is to identify barriers to its use and then recommend strategies to overcome these barriers.
CF – It is hard for me to answer this question. I have read and reread conclusion 5 and I am uncertain about the meaning of the conclusion and the meaning of the question. I feel if I had a chance to have a discussion and ask question to clarify your meaning I could answer this question but I can't by reading the material provided.
MR – Cost benefit analysis has a clear definition in the economics profession. It appears from the researcher's findings that NEPs are not current using the ES data for formal CB analysis. Given that there are numerous ways a valid CB analysis can be performed, I would be hesitant in categorizing all current efforts to be comparable. Assuming that their still remain a common thread in the initial approaches to scenario planning that might resemble a CB analysis, the assertion that ES data could be used to inform cost benefit assessments does not sound too unreasonable.

6. *Does the information presented by this researcher suggest to you any other conclusions or questions that should be further examined? Or, do you have any comments on the scope or content of this elicitation? If yes, please elaborate.*

ZC – For me this research is fascinating and I see a lot of links to the work that I am doing with social ecosystem service valuation. I think that your work could benefit by exploring in more depth the identified uses for ESV in the NEPs. While it is interesting to measure understanding and acceptance of the concept I find it more valuable to explore how it is being used as a way to analyze its potential where it is not being used (i.e. in actual decision-making). Lastly, and specific to relationship with my research, I am interested in the identified difficulties with integrating it into relevant processes (conclusions 2 & 3). Our work is trying to push the envelope when it comes to transferability of findings where no primary data exists (e.g. taking findings in Sarasota Bay where primary data exists and applying them using environmental data metrics to say Tampa Bay, where no primary data exists but needed environmental data is available). I am also interested in your last point (conclusions 4 & 5) that lays out the argument that if ESV is useful in situations such as decision validation and priority/investment setting it could reasonably applied on the "demand-side" of decision-making currently occupied by natural resource economics.

TS – I've probably touched on this in the above two items. I guess one important point - in stating your results - will be to qualify that they are based on evaluation of one type of program - there is no comparison here between different types of programs/regulatory agencies/institutional arrangements. (This is ok - just an opportunity for future research.) I think this research is very interesting and valuable and hope that my input has been helpful. Please let me know if there is any way I can be of additional assistance.

CF – I have not done this type of elicitation before. I started the questions on numerous occasions but stopped working when the time and effort to understand the data and questions became overwhelming for the time I had available. I don't doubt that with additional time I could have provided higher quality input but that time was not available to me at this time. I hope that at least some of my brief responses will provide what you need.

MR – More information on the perceived immatured of ES concept and current practices in ES use in scenario planning would be helpful.