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The Role of Ecosystem Services in Community Well-Being

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Abstract

Natural ecosystems provide services to humans that make life possible. Life, as well as the economy, is dependent upon these ecosystem goods and services (EGS). These services also contribute to a "good" or "quality life" by influencing the well-being of individuals and communities. Understanding the relationships among EGS that contribute to and shape well-being is an important task for researchers, decision makers and policy makers. In the past, these relationships were almost completely dependent upon income and consumption of goods. Today, the relationships are based on a more holistic perception including environmental and social attributes. The importance of ecosystem services to community well-being and their interactions are described through examples of communities' perceptions of the importance of various attributes of well-being and the role of ecosystem services in defining public health.

Keywords: ecosystem services, human well-being, indicators, community

1. Introduction

Natural ecosystems provide innumerable services which make human civilization possible. Unfortunately, many, if not most, people believe these services are provided for free and are, therefore, valueless and have no direct traditional economic value [1–3]. We, as a community, may not pay directly for these ecosystem services but we do pay significantly for their loss through infrastructure and policy costs (e.g., construction and operation of wastewater treatment facilities, increased illness, losses in soil fertility and reductions in basic human well-being). Everyday decisions made by communities and their constituents have some effect on

the amount and quality of these services. We, as a scientific community and members of larger governance communities, must emphasize the interrelated aspects of human well-being and the functioning of ecosystems (i.e., natural and human-altered) [1].

Life, as well as the economy, is dependent upon goods and services provided by natural ecosystems [2]. One of society's greatest challenges is to maintain natural ecosystems while promoting economic growth and the quality of life [3]. Ecosystem services like cleansing, renewal and recycling coupled with ecosystem goods like food and fiber, timber, and esthetics have significant tangible and intangible value. Yet, in the name of economic growth, humans stress the environment by disrupting its natural functioning and provision of these basic services in oceans and fisheries [4], wetland resources [5], habitat loss and trophic collapse [6], pollinator declines [7], soil quality and agricultural production [8]. We have changed ecosystems massively in the last several decades [2] in order to meet growing demands for freshwater, food, and fuel (to name but a few commodities). While these changes have clearly supported the needs of billions of people, the changes have caused irreparable losses in ecosystem structure and function (e.g., diversity loss, ecosystem capacity for service generation) as well as our perceptions of place, comfort and well-being [9–11].

Over the decades described above, well-being research has received increased attention as a contributor to "good" or "quality life" [12–20]. Unfortunately, researchers' determinations of what constitutes well-being have largely been ignored by decision makers and governments [21]. While well-being indices are often linked to social and economic policies (with the intent of progress), environmental drivers, particularly ecosystem services, are not included in these human well-being measures despite the proven role that the environment and ecosystem services play in the quality of well-being [22–25]. Examining ecosystem goods and services in relation to sustainability and their contributions to social, economic and environmental well-being becomes clear, particularly when related to basic needs and subjective well-being [11]. In short, regardless of economic utility theory [26, 27] ecosystem goods and services can only be partially "monetized" and a consideration of well-being is necessary to determine a full valuation.

There is no single definition of human well-being but, at a generalized level, it is useful to distinguish between the dimensions of subjective and objective well-being. Broadly, objective well-being includes basic social, economic and environmental needs and can be directly measured [28, 29], while subjective well-being encompasses often what humans feel and think [30]. Well-being, whether individual or group (community), must be treated as a multidimensional aspect focusing on circumstances that can be both objectively and subjectively assessed [31]. This approach requires that elements of emotions, engagement, and satisfaction as well as economics, environmental and social issues be incorporated into our vision of well-being.

The interaction of ecosystem services and community well-being includes the relationship of these topics to global issues as well. Alterations in climate (on large and small temporal scales), biodiversity and general sustainability affect both services and well-being. Community resilience to acute meteorological events [32] represents a major issue involving ecological services, overall well-being and community sustainability. Natural disasters, as well as investments in natural disaster protection, impose significant and long-lasting stress

on financial, social and ecological systems that drive human well-being. From hurricanes to tornadoes to wildfires, no corner of the globe is immune from the threat of a devastating climate-event. Across the globe, there is a recognition that the benefits of creating and supporting environments (built and natural) resilient to adverse climate events helps promote and sustain community well-being over time. The challenge for communities is in finding ways to balance the need to preserve the socio-ecological systems on which they depend in the face of constantly changing natural hazard threats. The Climate Resilience Screening Index (CRSI) [32, 33] is an endpoint for characterizing resilience outcomes that are based on risk profiles and responsive to changes in governance, societal, built and natural system characteristics. The Climate Resilience Screening Index (CRSI) framework serves as a conceptual roadmap showing how acute climate events impact resilience after factoring in the community characteristics. By evaluating the factors that influence vulnerability and recoverability, an estimation of resilience can quantify how changes in these characteristics will impact resilience given specific hazard profiles. Ultimately, this knowledge will help communities identify potential areas to target for increasing resilience to acute climate events and enhancing their sustainability. Other services, such as green infrastructure, can similarly contribute to climate adaptation at a variety of spatial scales [34].

Changes in biodiversity can also affect community well-being by altering the complexity and resilience of natural ecosystems and changing their long-term sustainability. Sustainable development equally includes environmental protection including biodiversity, economic growth and social equity, both within and between generations [35–37]. Reductions in biodiversity and habitat fragmentation decrease gene flow, increase genetic drift and the potential for inbreeding and increase the probability of patch extinction [38]. Unfortunately, the relationship between ecosystem services and biodiversity is often confusing resulting in damaged efforts to create coherent policy formulation [38]. Biodiversity has key roles as a regulator of ecosystem processes, as a major ecosystem service and as an ecosystem good that could be subject to valuation (economic or otherwise). As a result of this potential for valuation in policy formulation, this service can easily impact planning for sustainable community well-being.

2. Characterizing well-being in the context of service flows

Understanding the relationships among ecosystem goods and services that contribute to and shape well-being is a core task for both researchers and policy makers. Our understanding of this relationship has evolved over the last several decades from being synonymous with income and consumption of marketed goods [39, 40] to a broader view incorporating non-economic issues like gender [41, 42], sustainability [43–45], and the environment [44, 46]. Given this evolution of thought, it is amazing that many still view the most reliable measure of human well-being to be income [47]. Yet, the importance of ecosystem services as a driver for well-being has been well established in the Millennium Ecosystem Assessment [23]. The World Economic Forum's [48] environmental sustainability index, Wackernagel's et al.'s [49] national estimates of ecological footprints, and the New Economics Foundation report [50]

all emphasize the importance of the role of environmental factors (e.g., ecosystem goods and services) in the establishment of well-being.

Much of the drive to include ecological information in the estimation of well-being derived from ongoing discussions of whether humans are a part of an ecosystem rather than simply a stressor on ecosystems [51]. This approach termed Ecosophy T is a view of the central role of ecosystems and states that every being, whether human, animal or plant has an equal right to live and prosper [51]. This holistic emphasis requires that the self-realized Ecological Self should not act without understanding how that action will affect other living beings. An understanding of the unintended consequences of actions is the equivalent of the liberal harm principle [52, 53]. To go from an understanding of unintended environmental consequences (i.e., humans as stressors) to an inclusion of ecosystems and ecological understanding in well-being (i.e., humans as part of ecosystems) is a logical and fairly straightforward thought process.

The HWBI framework illustrates the relationship between service flows provided through social, economic and environmental sectors and the domains of HWBI (**Figure 1**). Collectively, the components of HWBI are similar to Maslow's pyramid of self-actualization [54] where basic human needs represent physiological and safety needs; economic needs represent employment, education, wealth, infrastructure, growth and trade; environmental needs represent clean air and water, and low risks of contamination; and, subjective happiness needs represent life satisfaction, freedom, solastalgia [55], topophilia [56], and biophilia [57]. The Human Well-being Index (HWBI) is intended to be used as an endpoint measure responsive to changes in service flows from natural, human and built capital [18].

HWBI was developed as a composite measure based on eight dimensions of well-being (domains) characterized by 20 multi-metric indicators reflecting both objective and subjective measures [18, 58]. The HWBI domains are sub-indices that serve as proxy measures representing various aspects of human well-being (**Table 1**) which are aggregated into the composite index. In a nutshell, The HWBI calculation follows these four steps as summarized by Harwell et al. [59]:

- Indicator scores are calculated as population weighted averages of related standardized metric values.

- Domain scores are obtained by averaging indicator scores related to a specific domain.

- Relative importance values (RIVs) are optional factors that may be included in HWBI calculations to represent stakeholder priorities associated with well-being domains.

- The HWBI is calculated as the geometric mean of equally or unequally weighted domain scores.

Substitutions at the metric level in the HWBI allow for the index to be adapted to include data that more closely reflect characteristics in specific use case applications (e.g., geographical locations or population groups) while maintaining the integrity of the index at the indicator level [59–61].

The HWBI framework is designed to reflect stakeholder viewpoints regarding the relative importance of each of the eight domains. Since the domains are relevant to characterizing
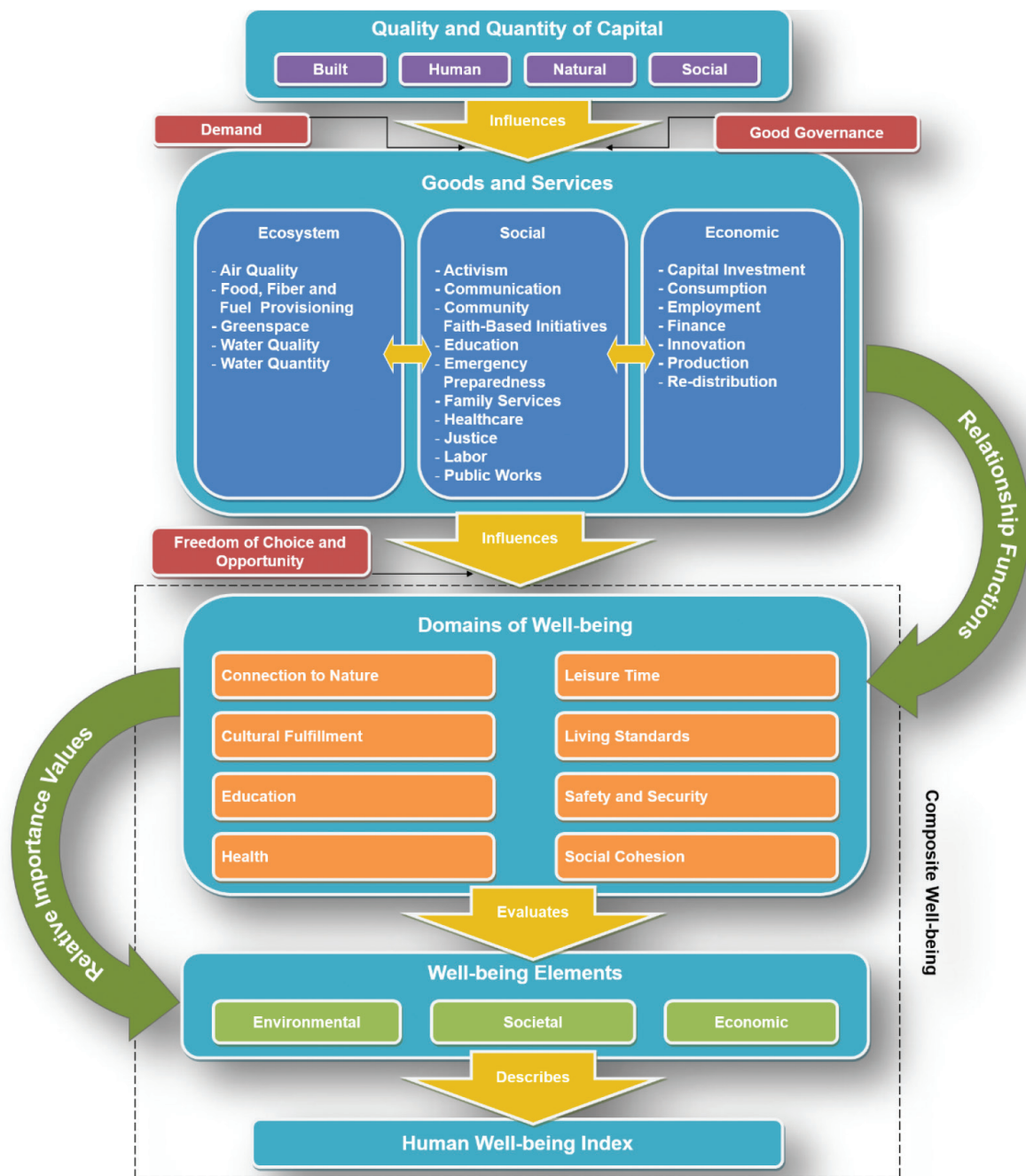
Figure 1. Conceptual model of the human well-being index (from [19, 20]). Model links goods and services (ecosystems, social, and economic) with the eight domains of well-being through relationship functions.

human well-being, regardless of time, space and culture [18], communities can easily "relate" to these well-being dimensions, making prioritization a fairly straight-forward exercise in developing relative importance values (RIVs) as weighting factors to customize HWBI. Applications of stakeholder RIVs utilized in a real community case studies are presented in Fulford et al. [62]. The foundational research in the development of HWBI [11, 25, 63, 64] has also been used to inform community-based landscape planning via the valuation ecosystem services [64].

Domain	Description
Connection to nature	Describes how people feel about nature. It is measured by people's perception of nature and how it affects them.
Cultural fulfillment	Describes people's cultural involvement. Measures include how often people participate in the arts and spiritual activities.
Education	Covers basic skills in reading, math and science. Measures of student safety and health are also included.
Health	Characterizes people's involvement in healthy behaviors, prevalence of illness, access to healthcare, mortality and life expectancy.
Leisure time	Describes how time is spent including: employment, care for seniors and activities that people partake in for personal enjoyment. Measures represent work-life balance.
Living standards	Contains information about lifestyles. It includes measures of basic necessities, wealth and income.
Safety and security	Covers information about perceived safety, actual safety and potential for danger.
Social cohesion	Describes people's connection to each other and their community through measures of involvement in family, civic engagement, and the community as a whole.

Table 1. Description of domains used in the HWBI.

Additionally, ecosystem services have been linked to community well-being priorities based on HWBI domains for the purpose of setting conservation targets for coastal ecosystems to deliver ecosystem and human benefits [65].

3. Linking services to well-being

The HWBI framework demonstrates that ecosystem, economic and social services can be linked to the domains of well-being by relationship functions (**Figure 1**). Summers et al. [66] demonstrated that relationship functions can be derived between services information and well-being domain information at the county level. Similarly, relationships exist among indicators and metrics of well-being domains that were used to develop the ecosystem, economic and social services/well-being relationships (**Table 2**). Achieving balanced decisions requires techniques to examine the potential consequences (both intended and unintended; both positive and negative) on well-being associated with changing services. Summers et al. [66] used an approach for forecasting that employs (1) models derived from ecological, social and economic production functions (e.g., [67, 68]) and (2) models examining how communities feel about decision outcomes [69, 70]. Such models require a framework for linking changes in service production to changes in well-being.

The functional equations for each well-being domain were determined through the use of bidirectional step-wise regression [71]. This process identified main effects and primary pairwise interactions of service indicators and identified predictive variables based on adjusted R^2 and sequenced F-tests [72]. The forecasts for each year in all counties of all states were

Types of capital	Community goods and services	Domains of well-being
Social	Re-distribution (Ec)	Connection to nature
Natural	Production (Ec)	Cultural fulfillment
Human	Innovation (Ec)	Social cohesion
Built	Finance (Ec)	Safety and security
	Employment (Ec)	Living standards
	Consumption (Ec)	Education
	Capital investment (Ec)	Health
	Air quality (E)	Leisure time
	Food, fiber and fuel provisioning (E)	
	Greenspace (E)	
	Water quality (E)	
	Water quality (E)	
	Public works (S)	
	Labor (S)	
	Justice (S)	
	Healthcare (S)	
	Family services (S)	
	Emergency preparedness (S)	
	Education (S)	
	Community and faith-based initiatives (S)	
	Communication (S)	
	Activism (S)	

Ec = Economic services, E = Ecosystem services, S = Social services.

Table 2. Types of capital, community good and services, and well-being domains used to construct forecasting models [66].

compared to actual data for model fit and construction (7 of 10 available years) with 3 years of data withheld for validation. In addition, simple Pearson product-moment correlation coefficients were determined among the eight well-being domains to address likely co-occurrences of changes in multiple domains.

The results of these evaluations are documented in Summers et al. [66] regarding forecast inclusion of service indicators, model fit and validation, and scenario building using the forecasting tools. Overall examples of the forecasting applications are depicted in **Figure 2** where observed and predicted are shown for the 3 years of withheld data for all 50 states (3 years of data not used in construction). Similarly, the strong inter-correlations among well-being domains are shown in **Table 3**. The use of the forecasting regressions in concert with the
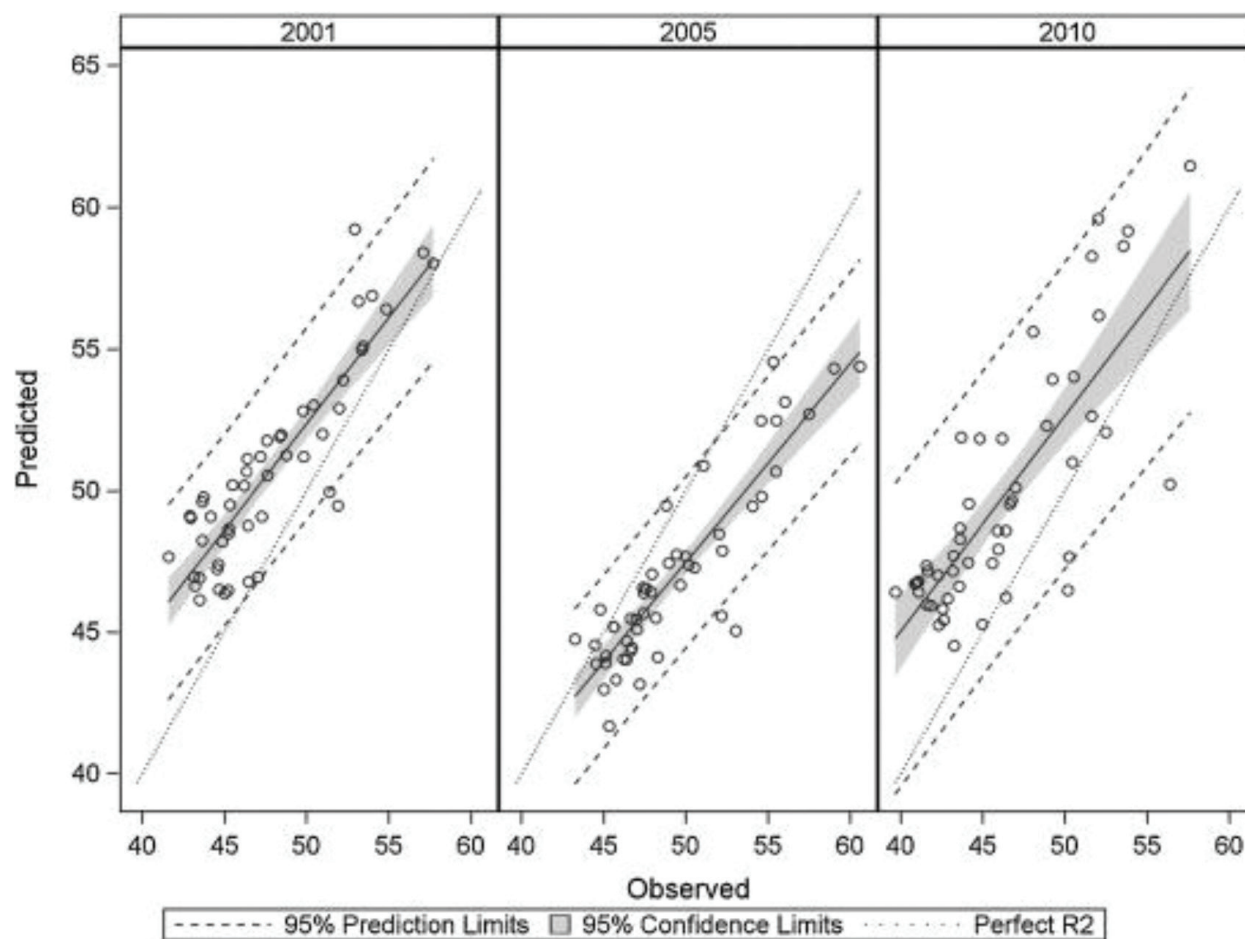
Figure 2. Comparison of observed and predicted values from forecast models for well-being based on ecosystem. Economic and social services (from [66]).

	D1	D2	D3	D4	D5	D6	D7	D8
D1	–	−0.581*	−0.616*	−0.392*	0.075	−0.438*	−0.499*	−0.703*
D2		–	0.415*	0.407*	−0.088	0.334*	0.326*	0.346*
D3			–	0.642*	0.004	0.120	0.605*	0.407*
D4				–	0.157	0.202	0.680*	0.159
D5					–	−0.199*	−0.017	−0.206
D6						–	0.355*	0.104
D7							–	0.387*
D8								–

D1 = Connection to nature; D2 = Cultural fulfillment; D3 = Education; D4 = Health; D5 = Leisure time; D6 = Living standards; D7 = Safety and security; D8 = Social cohesion.

Table 3. Correlations (Pearson product moment) among human well-being domains (* = p < 0.0001; N = 561) (from [66]).

inter-domain correlation permits the evaluation of intended and unintended consequences of specific decisions to augment services or potentially improve well-being domains and overall well-being.

4. Differences in well-being by respondent or community type

Effective measures of human well-being can be useful to decision making at the community level. Community decision-making is based on a shared commitment to achieving realizable improvements in family, child and neighborhood conditions in order to build accountability and capacity to achieve those results. This type of decision-making achieves the best results when it:

- Uses timely, relevant and reliable data

- Authentically involves community stakeholders

- Assists communities in establishing and monitoring progress toward objectives

- Develop a community agenda for investment

- Assesses accurately community resources and assets

- Accurately reflect community priorities

- Engages multiple networks to support well-being

- Reports regularly to stakeholders.

These attributes can be accomplished through effective engagement with community stakeholders. Stakeholder engagement is a necessary process of evaluation because effective use of the HWBI as an assessment tool requires information on the relative importance of the domains of HWBI for any given community (i.e., their community value structure), as well as the baseline value of well-being against which we can measure change.

Using the Relative Valuation of Multiple Ecosystem Services method (RESVI), Jordan et al. [3] queried three respondent groups to determine their overall value judgments related to various ecosystem services. The RESVI method uses an assessment where respondents are (1) briefed about policy questions to be examined with regard to the extent and nature of the ecosystem(s) and services involved, (2) asked to assign relative values to a list of ecosystem services in terms of what proportional dollar value for one service versus another, (3) application of a dollar value based on literature or research for each service type, and (4) creation of an index for all services using reference and relative values determined by the respondents.

The RESVI was used with three respondent groups – programmatic regulators, research scientists, and community stakeholders. The results compared the relative values of eight ecosystem services (**Figure 3**) – habitat functions, water quality regulation, water supply, recreation, flood control, esthetics, biodiversity and climate regulation. The test groups valued
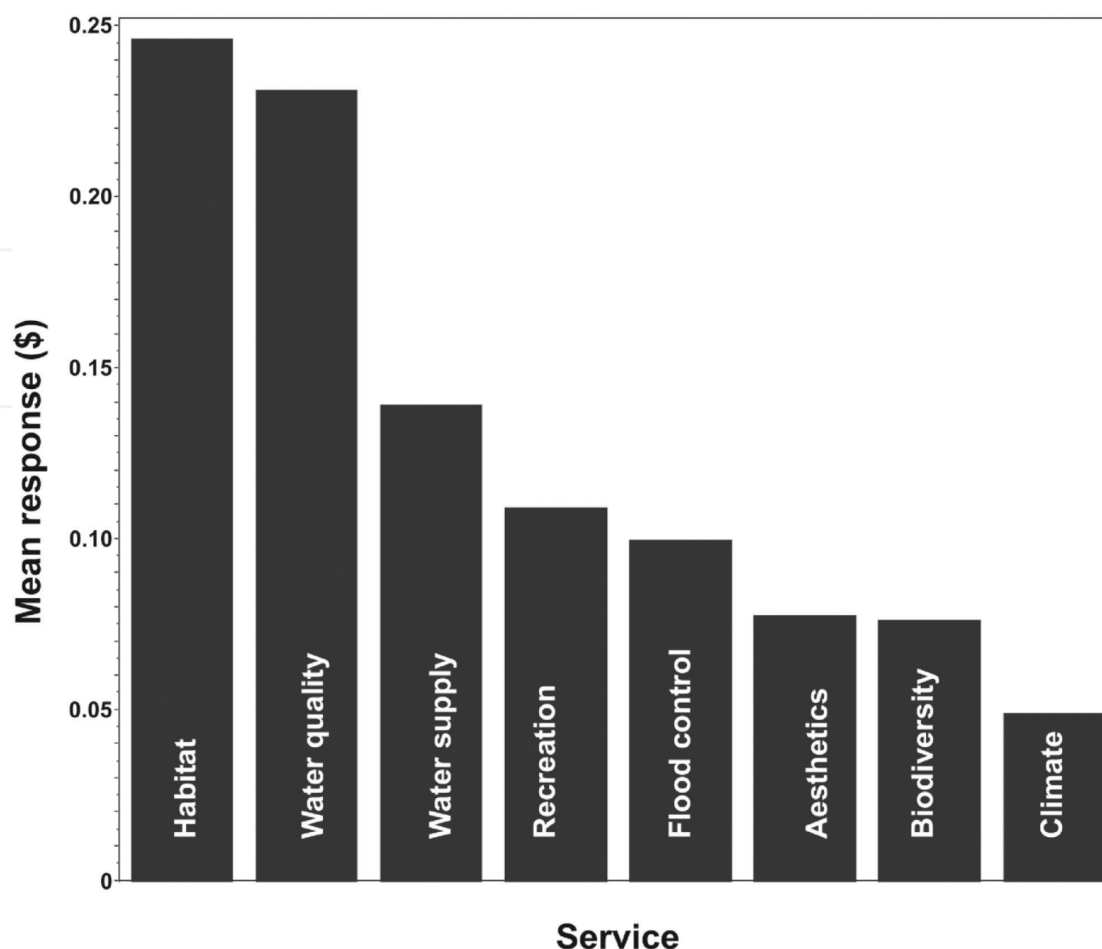
Figure 3. Overall mean relative values for three respondent groups using to RESVI to ascertain relative values of ecosystem services (from [3]).

habitat functions and water quality regulation more than the other ecosystem services by a wide margin. However, some differences were observed among the respondent types with regard to their valuation systems. Regulators tended to more heavily value regulatory services while researchers tended to place higher values on ecosystems functions. Finally, general community stakeholders tended to value services that impacted landscapes.

Similarly, Fulford et al. [62] found that different community types could reflect different attitudes with regard to the relative importance of domains of well-being and the services that drive that well-being. There is an increasing understanding that decisions made by local communities can have significant impacts on community well-being and require a degree of understanding regarding local impact as well as cumulative impact across multiple communities [73–76]. All communities have unique characteristics resulting in the potential for varying views regarding the importance of different ecosystem services as well as the components of well-being. Similarly, different communities can have beliefs and value systems in common. Using a community typology approach, Fulford et al. [62] developed a system to inform decision makers about sustainable decision outcomes based on the similarities and differences of communities' priorities, belief systems, and values. Communities can be divided into one of

eight types, which differ both in their baseline HWBI scores and in the relative importance of the different domains of HWBI (**Figure 4**). The developed approach aids communities by defining meaningful changes in well-being across similar communities through the establishment of reference points that can provide information regarding investment in activities like conservation, restoration of natural capital and mitigation [77–79].

The holistic suite of indicators used in the Human Well-Being Index (HWBI) represent a synergistic measure of the outcome of ecosystem good and services production and delivery [11, 19, 25]. However, measures of well-being and their constituents (e.g., civic engagement, social cohesion, connection to nature) are not always easily understood and are not a direct measure of the delivery of services. The key at a community level is linking these broader well-being measures to community-specific desires and values. Fulford et al. [62] took a comparative approach toward well-being points of references based on an ecosystem goods and services-based community topology and Bayesian model-based cluster analysis [80] The HWBI was compared among community cluster groups to detect patterns in well-being as a function of the ecosystem goods and services community types (**Figure 4**). The key differences among community groups were population density and composition, economic dependence on local resources (e.g., forestry, fishing, agriculture), and to some extent geography. Differences among coastal county groupings indicated both strong and weak similarities resulting in three major clusters among the eight topological types (**Figure 5**). Fulford et al. [62] determined that community decision makers could use the classification system to identify well-being values from which to gauge impact of decisions that could shift well-being.
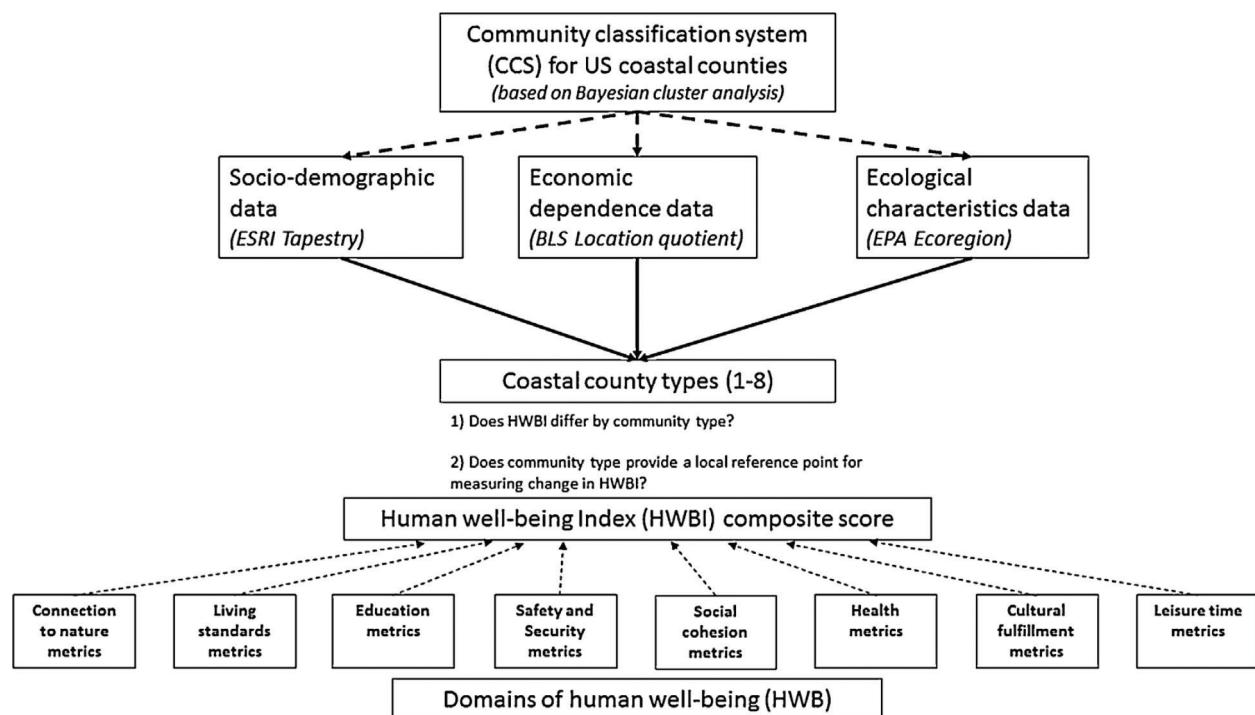

Figure 4. Analytical comparison of human well-being among categorical groups of U.S. coastal counties based on a multivariate community topology (dashed arrows = data dependency; solid arrows = outcomes) (adapted from [62]).
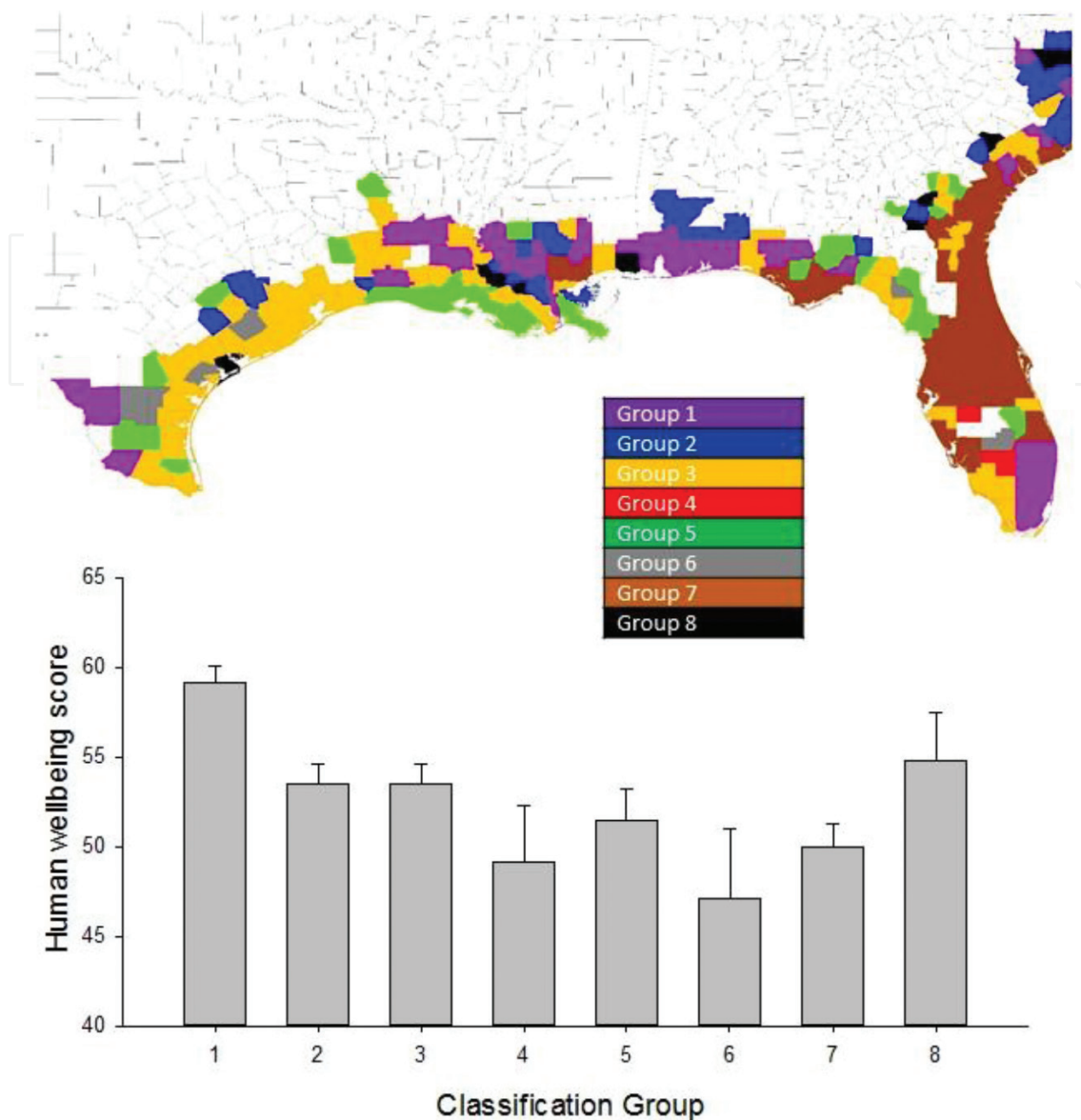
Figure 5. Map showing example of Gulf of Mexico coastal counties separated into eight classification types and bar chart indicating differences in unweighted HWBI composite scores average (SE) by classification group. See [62] for more information on HWBI calculations and group delineations. Community types are represented by 1 = Urban/Suburban, 2 = Rural manufacturing, 3 = Rural farms, 4 = Rural high ethnic diversity, 5 = Rural balance of natural resource dependence and manufacturing, 6 = Rural dependence on natural resources, 7 = Older suburban, 8 = Suburban industrial.

Similarly, Fulford et al. [81] used a keyword-based approach to determine common terminology used by 97 counties in three regions of the U.S. (Gulf of Mexico, western Great Lakes and Northwest) to refer to community fundamental objectives closely aligned with the domains of HWBI. They analyzed strategic planning documents using the eight domains of human well-being described by Summers et al. [19] and listed in **Table 2**. Living Standards and Safety and Security were the most common well-being domains referred to in community strategic plans. Health and Cultural Fulfillment were the least commonly addressed domains in these documents. Major community type (same typology as used in Fulford et al. [62] differences were largely between urban and rural areas with urban community types focusing on Living Standards and Education while rural communities tended toward Leisure Time and Social Cohesion.

5. Examples of linking ecosystem services to well-being and public health

Ecosystem goods and services (EGS) are the result of processes that can contribute to social welfare [82]. Social welfare can easily be translated into elements of human well-being as defined by Summers et al. [19, 20]; particularly, health, social cohesion and cultural fulfillment. Over 50 recent reviews relating human health and ecosystem services [83] showcase the focus of connecting ecosystem goods and services (EGS) with this aspect of well-being. However, fewer studies exist directly linking physical or mental health to natural systems via ecosystem goods and services, tracing the full pathways from ecosystem structure and function to EGS to health [83]. One recent review uses causal criteria analysis (CCA) to link health and EGS [1, 84].

Causal criteria analysis was developed in epidemiology to support health decision making often based on weak but independent information [85, 86]. One study [84] conducted a CCA focusing on the effects of EGS provided by greenspaces on human disease (**Figure 6**). Green spaces included any vegetation with an environment dominated by humans [87] – urban trees, wetlands, and green roofs. The health endpoints included gastro-intestinal disease, respiratory illness, cardiovascular disease, and heat morbidity. Simply put, green spaces can abate floods and storm surge hazards by reducing runoff through natural percolation or physically limiting the influence of waves and storm surge [88]. This type of mitigation can lower human exposure to contaminated flood waters potentially reducing gastrointestinal diseases and reducing conditions that can lead to asthma through mold growth [89]. Green spaces potentially remove toxicants, reduce the prevalence of gastrointestinal disease, trap contaminants and mitigate extreme temperatures [90–94]. CCA results showed sufficient evidence for causality for all tested greenspace-EGS pairings (heat hazard mitigation, clean air, water hazard mitigation and clean water), three of six EGS-health pairings (heat hazard-heat morbidities, water hazard mitigation-gastrointestinal disease and clean water-gastrointestinal disease) and two of four direct greenspace-health pairings (heat morbidities and cardiovascular disease). This work indicates that most current literature supports intermediate pathway connections between ecosystems and ecosystem goods and services as well as ecosystem goods and services and health. However, very few studies support a direct connection between the presence of ecosystems and health outcomes. Of those studies that exist, few simultaneously measure the mediation by ecosystem goods and services (**Figure 6**).

As a specific example, ongoing studies in the San Juan Bay Estuary, Puerto Rico are evaluating the role of wetlands on Dengue fever by means of ecosystem services (e.g., biological control, clean water, and heat hazard mitigation) [95] (**Figure 7**). Ecosystem goods and services associated with heat hazard mitigation may help reduce mosquito biting, oviposition rate, and viral load. Clean surface water provides habitat for wildlife and healthier ecosystems, favoring bio-control of mosquitoes [96–99]. Preliminary findings suggest that wetlands and wetland services are negatively associated with Dengue cases even after controlling for potentially confounding variables (**Figure 8**). Wetlands and wetland services were also found to help reduce temperature which is an environmental driver of Dengue transmission [98]. These findings help support a connection between an important ecosystem in the San Juan Bay area,
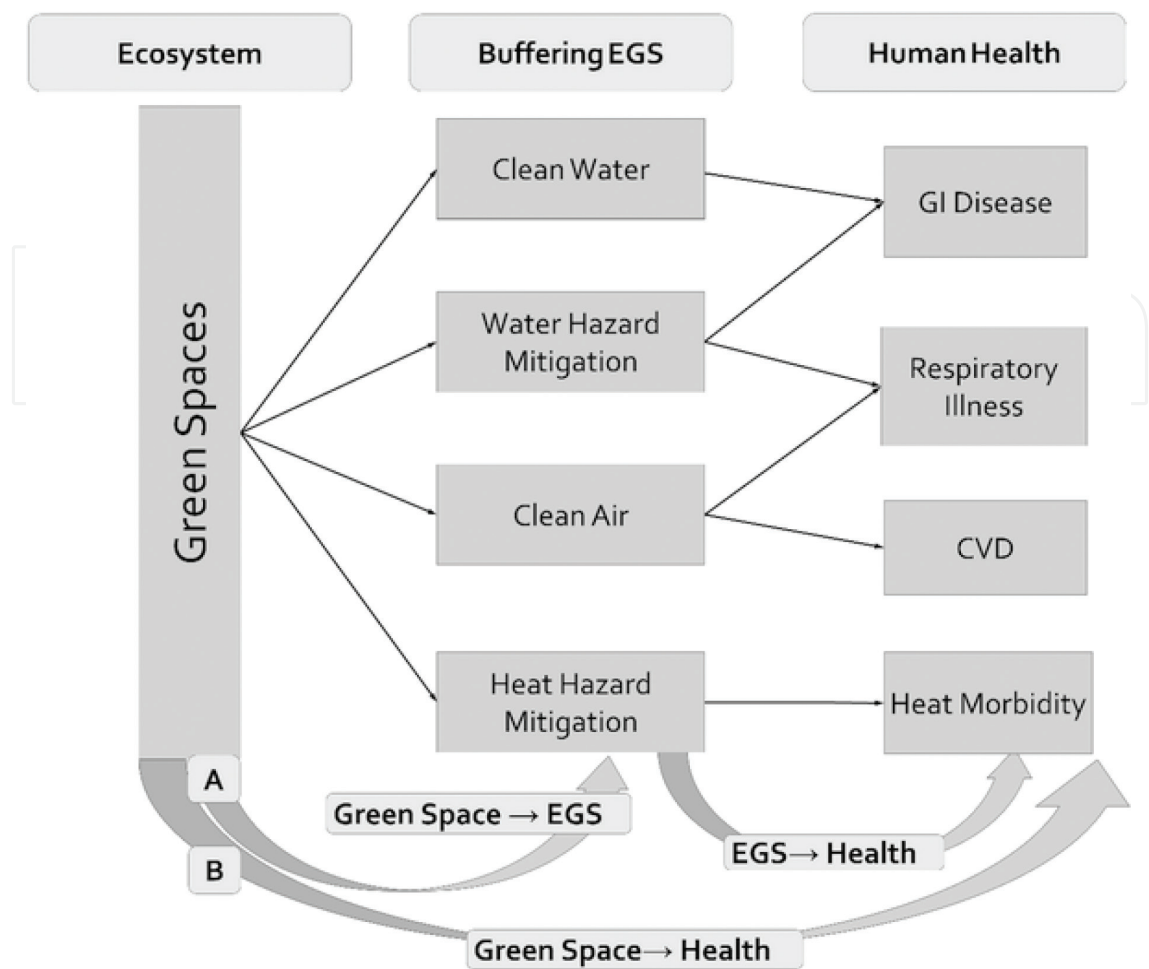
Figure 6. Proposed linkages between green spaces, the ecosystem services provided by green spaces and human health conditions (from [84]). EGS = Ecosystem goods and services, CVD = Cardiovascular disease, GI = Gastrointestinal, A = Intermediate steps linking green space and EGS, B = Evidence linking green space directly to human health outcomes.
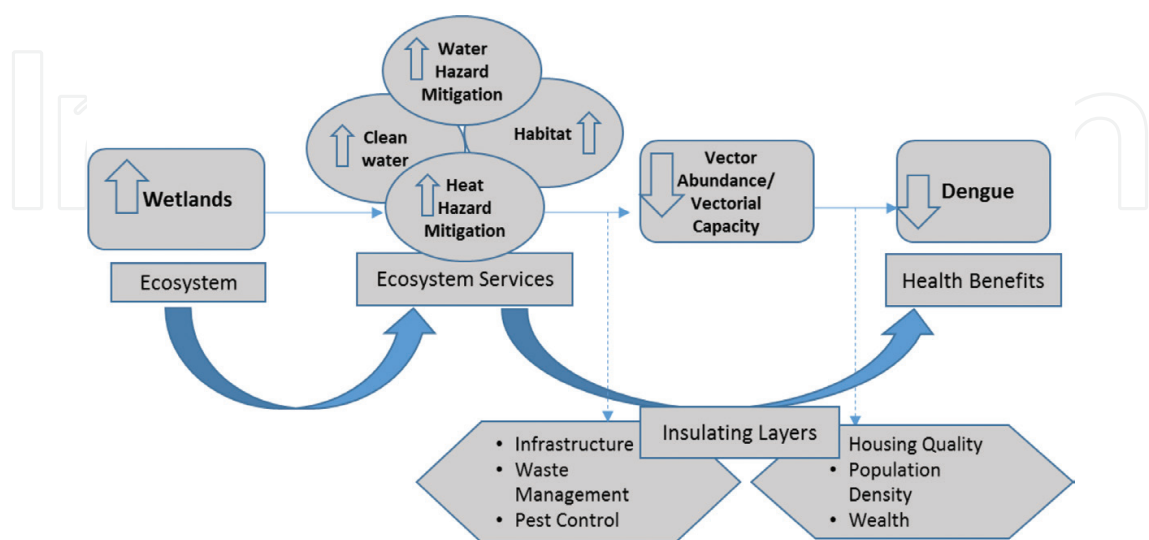

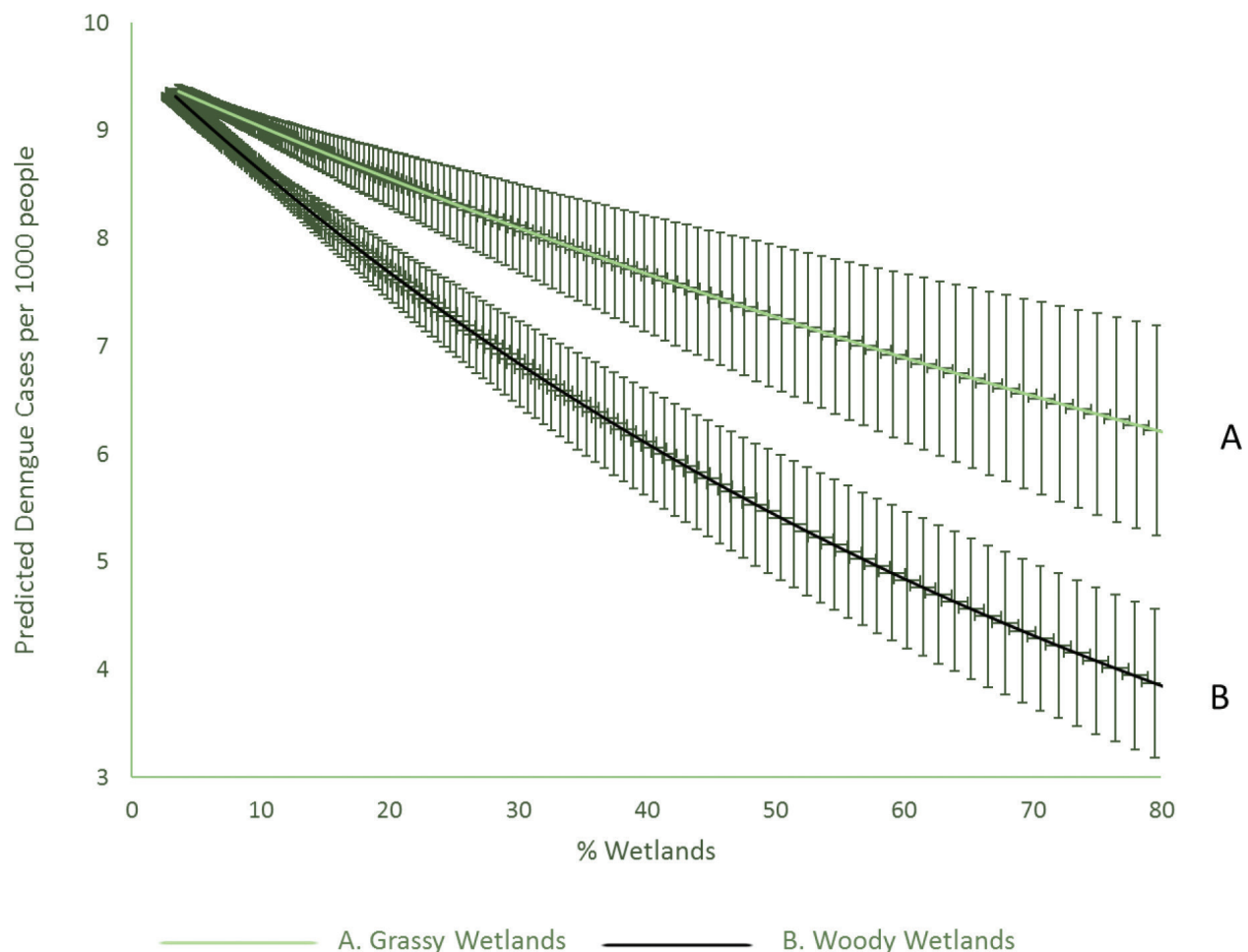**Figure 7.** Hypothesized conceptual model of wetlands and Dengue fever occurrence through wetland ecosystem services (adapted from [95]).

Figure 8. Predicted relationship between two wetland types ((A) grassy and (B) woody) and dengue cases in San Juan, Puerto Rico (Figure adapted from [95]).

and an ecosystem service that directly influences human health. In the future, this and other eco-health research may help inform predictive models to estimate changes in health benefits under different decision scenarios.

6. Conclusions

Many obstacles exist in developing useful and informative relationships between ecosystem services and community well-being including cultural differences in the perception of ecosystem services and well-being, lack of consistently available data to demonstrate a causal connection between services and well-being. This is often the case when combining natural sciences and social sciences data, approaches and interpretations. Even within these disciplines, the integration of data representing indicators to create indices or demonstrate connections is highly contentious. Some policy makers suggest that summary tools (e.g., models, indices, statistical assessments) lack meaningful interpretation and have little value in the real world [100, 101]. Others argue that the time is ripe for pushing these concepts into public policy – that the real world is a complex interaction of social, economic, and environmental activities where focus on

single issues is insufficient to represent reality [102–104]. No matter who we are, or where we live, our well-being depends on the way ecosystems function. Defining, classifying and integrating ecosystem services into community decision making [105, 106] and, hence, community well-being is necessary for a holistic policy view that minimizes unintended consequences [66].

The research described in this chapter provides a management roadmap for linking ecosystem services to human wellbeing, but significant work still needs to be accomplished. The complexity of the relationship between ecosystem services and community well-being signifies an urgent need to develop further the transdisciplinary science of ecosystem management bringing together ecologists, biologists, resource economists, social scientists, and holistic systems specialists. A primary goal of this transdisciplinary research is the development of a valuation system potentially based on well-being and well-being improvement through the provision of goods and service A focus on the underpinning processes is necessary to understand where there are trade-offs and synergies and how these outcomes change with environmental variation. All members of the transdisciplinary team described above need to build a stronger science for stocks and flows, link this work to natural capital studies and create a stronger socio-ecological science that reflects the fact that ecosystems are coupled human-environmental systems.

Acknowledgements

Disclaimer

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