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Short Communication

# Gulf of Mexico offshore ecosystem services: Relative valuation by stakeholders

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ABSTRACT

While efforts to integrate ecosystem services into the management of coastal and terrestrial systems continue to advance, similar efforts for deepwater environments are still in the early stages of deliberation. To begin closing this gap, two workshops were held to engage participants in a discussion on ecosystem services provided by the deepwater Gulf of Mexico, and to facilitate the relative ranking of offshore ecosystem services using a non-monetary valuation scheme. Both workshops relied on a balanced representation of ocean users from multiple industry sectors, government and non-government organizations with interests in the deepwater Gulf. The following findings were made: (1) participants recognized the benefit of being able to rank multiple ecosystem services rather than limiting their attention to those services that were closely related to their respective constituents' interests; (2) both workshops yielded similar results, with food, raw materials (including hydrocarbons), and recreation being among the top three ranked ecosystem services; (3) participants in both workshops distinguished between direct (provisioning and cultural) and indirect (regulating and supporting) services; (4) there was a preference among participants to focus on ranking the direct services; and (5) participants of the workshops expressed that the role of the indirect services needed to be considered when designing monitoring and/or mitigation measures to protect the sustainability of the direct services. These results can be used in future discussions to further vet the viability of using such a non-monetary valuation scheme to assist in guiding the development or implementation of scientific and socio-economic indicators to monitor and maintain the health of ecosystem services in order to try to meet stakeholder needs.



## 1. Introduction

Ecosystem services are defined as the benefits people obtain from ecosystems [1] or, equivalently, the contributions from ecosystems that support, sustain, and enrich human life [2,3]. They are divided into provisioning, cultural, supporting, and regulating services [1] and can directly (e.g., fish harvesting) or indirectly (e.g., algal growth for fish food) benefit humans. Some ecosystem services such as food exploitation or transportation may be readily valued and recognized for their connection to human well-being. Other ecosystem services however, such as biological or waste regulation may be less clearly valued and understood [4–6].

Several studies discuss the potential uses of ecosystem services frameworks to support environmental management choices, including the consideration of ecosystem services trade-offs across spatial and temporal scales [7–10]. A prerequisite to applying such frameworks is the reasonable understanding of what services may be provided by different ecosystems, and how these services could contribute to human well-being. Both factors rely on the knowledge of complex scientific processes and indicators that are not always readily understood or available. Human actions in turn may also affect ecosystems and ecosystem services, thus proposing a combination of ecological and socio-economic measures to identify changes in the provision and value of ecosystem services [7,11–13].

Because of the complex interconnectivities between humans and ecosystems, linkages between the natural environment and

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human well-being can be difficult to express in quantitative or scientific terms. This situation can be compounded when examining the deep-sea environment, where data and scientific knowledge are generally less abundant than in coastal or terrestrial regions. Nevertheless, recent work has begun to capture the relationship between offshore systems and human well-being. For example, Armstrong et al. [14] catalogue and explore, through a review of the literature, the presence and values of ecosystem goods and services provided by the deep sea. They conclude that a significant amount of work still needs to be done to better understand the biodiversity, structure, and function of the deep-water system before offshore ecosystem services can be properly identified and addressed. Werner et al. [15] developed an approach that facilitates the qualitative assessment of offshore ecosystem services by linking them to the key ecological components of the deep sea, a method that promises potential but also highlights the need for improved knowledge on offshore ecosystem diversity and functioning.

Preserving the ability of the environment to provide valued ecosystem services is one of the overall objectives of environmental management. International standards and policies are being developed to meet this goal, but often lack a structured framework for capturing stakeholder input. In particular, the integration of ecosystem services into the management of deep-water marine systems has been limited by the absence of organized forums that could help determine the priorities placed on ecosystem services by multiple ocean users. To begin closing this gap, two workshops were organized to discuss offshore ecosystem services in the deepwater Gulf of Mexico. The workshops were meant to provide an informal forum to:

1) Aid the identification of offshore ecosystem services that are occurring or anticipated to occur in the deepwater Gulf;
2) Initially test a method to quantify, in non-monetary terms, the relative value of the identified offshore ecosystem services.

"Deepwater", for the purpose of this analysis, includes regions on the outer continental shelf, continental slope and in the abyss. Nearshore and coastal systems such as salt marshes, river outflows, wetlands or barrier islands were excluded from the workshop discussions.

## 2. Methodology

Two workshops were held to engage participants in a discussion about the deepwater Gulf of Mexico, its role in providing ecosystem services, and the interconnection between the offshore environment and human well-being. The first workshop took place on September 29th, 2013 in Houston, Texas and the second on November 21st, 2013 in Tampa, Florida. Both workshops relied on a balanced representation of ocean users consisting of participants from multiple industry sectors, government and non-government organizations with interest in the deepwater Gulf. Participants at the Houston workshop included representatives from recreational fishing, commercial fishing, oil and gas development (ExxonMobil), energy and ocean policy consulting, wind energy research, one Federal agency (National Oceanic and Atmospheric Administration), and three non-government organizations (Ocean Conservancy, Gulf of Mexico Foundation, Coastal Conservation Association-Texas). Participants at the Tampa workshop included members from recreational fishing, commercial fishing/seafood industry, aquaculture research (Mote Marine Laboratory), the diving industry, oil and gas development (ExxonMobil), the pipeline industry, two federal agencies (National Oceanic and Atmospheric Administration, Bureau of Ocean Energy Management), and one NGO (Conservation International). The number of participants in each workshop was between 9 and 10 not counting the workshop facilitators, a size which benefitted a group discussion and maintained focus on the workshop goals. Individual participants did not overlap between the two workshops, and results from the first workshop were not shared during the second workshop prior to completion of the valuation exercise.

To introduce the relative valuation process, both working groups were first presented with a list of fifteen offshore ecosystem services (Table 1) and asked to rank these services using the Relative Valuation of Multiple Ecosystem Services Index (RESVI) approach [16]. Application of this approach entailed answering the question: "If you were given one dollar, how would you spend this dollar to ensure the continued provision or enhancement of offshore ecosystem services?" Each participant could either assign his or her dollar to one ecosystem service alone, or divide it among as many ecosystem services as he or she desired. Under this approach, the relative value of each ecosystem service could be

**Table 1**
List of offshore ecosystem services (based on Yoskowitz et al. [2] and Farber et al. [7]).

| Ecosystem functions and services | Description | Examples |
|---|---|---|
| ***Supportive functions and structures*** | Ecological structures and functions that are essential to the delivery of ecosystem services | |
| Net primary production | Conversion of sunlight to biomass | Algal growth |
| Dispersal of organisms | Seed and larval transport | Larvae dispersal by currents |
| Habitat | The locations organisms use | Spawning grounds |
| ***Regulating services*** | Maintenance of essential ecological processes and life support for humans | |
| Gas regulation | Regulation of the atmospheric and oceanic chemical composition | Downwelling of oxygen, carbon burial |
| Climate regulation | Regulation of global climate processes | Heat transfer and storage |
| Biological regulation | Species interactions | Preventing species invasions |
| Waste/pollutant regulation | Removal or breakdown of non-nutrients | Dilution and breakdown of hydrocarbons or human waste |
| Nutrient regulation | Cycling, recycling and maintenance of major nutrients | Nitrogen and phosphorus for phytoplankton growth |
| ***Provisioning services*** | Provision of natural resources and raw materials | |
| Food | Human consumption of organisms | Fish via commercial or subsistence harvesting |
| Raw materials | Abiotic resources used by humans | Hydrocarbons, wind/wave energy, sand |
| Genetic resources | Genetic resources | Temperature stable compounds, oil dispersing compounds |
| Medicinal resources | Substances for use in pharmaceuticals | Anti-cancer products |
| ***Cultural services*** | Enhancing emotional, psychological, and cognitive well-being | |
| Recreation | Rest, refreshment, and recreation | Boating, diving, fishing |
| Science and education | Scientific and educational enhancement | Field studies, excursion areas |
| Spiritual and historic values | Spiritual or historic information | Archaeological sites |

determined by each participant and on average (i.e., for all participants combined).

Following the initial RESVI exercise, participants engaged in a discussion about offshore ecosystem services and their experiences with the relative valuation approach that they had just performed. Each working group's input was captured in a revised list of ecosystem services, i.e., some ecosystem services were added to Table 1 based on the respective (i.e., Houston or Tampa) group's consensus, while other ecosystem services were dropped. A second RESVI exercise was conducted using the revised list of ecosystem services.

## 3. Results

Both workshops followed the same format so that results could be compared. During the first RESVI (RESVI 1) exercise of each workshop, food, raw materials (including hydrocarbons), habitat, and recreation were among the top ecosystem services ranked by the participants (Table 2). Spiritual and historic values, genetic resources, and several of the regulating services (e.g., biological and nutrient regulation) were among the lowest ranked ecosystem services at both events.

Workshop participants used their one dollar to rank multiple services rather than one service alone. Out of the fifteen ecosystem services from Table 1, the participants divided their dollar among five to fifteen services, showing that they recognized the benefit of ranking a suite of ecosystem services rather than one single service.

Following the RESVI 1 exercise, discussions were held to capture the groups' experiences and feedback. Emphasis was placed on how the initial list of ecosystem services in Table 1 should be modified to enable a better, more meaningful valuation from a stakeholder perspective. Participants in both workshops distinguished between direct ecosystem services that are directly used, consumed, or enjoyed by stakeholders, and indirect ecosystem services which may impact the delivery of the direct services. As an example, food provisioning is considered a direct service that can be dependent on several indirect services such as habitat, biological regulation, and net primary production. There was a preference among the workshop participants to rank only the direct services, combined with the recognition that the role of the indirect services should be considered when designing monitoring or mitigation measures to protect the provision of the direct services.

Based on the input received from the workshop participants, most or all of the regulating and supporting services in Table 1 were dropped during the second RESVI (RESVI 2) exercise of each workshop. Some provisional and cultural services were added (transportation, existence, aesthetics), and other services were redefined to better express their meaning as perceived by the workshop participants (e.g., derivative/biochemical products took the place of medicinal and genetic resources). The modified list of ecosystem services was slightly different between the two workshops, with the Houston workshop considering an additional three services (waste/pollutant regulation, nutrient regulation and existence) that were not considered during the Tampa workshop (Table 3). Results from the RESVI 2 exercise again placed food, raw materials, and recreation among the top ranked ecosystem services.

**Table 2**
Summary of RESVI 1 results for both workshops.

| Ecosystem Services | Combined ranking | Houston ranking | Tampa ranking |
|---|---|---|---|
| **Food** | 1 | 1 | 1 |
| **Raw materials** | 2 | 2 | 2 |
| **Habitat** | 3 | 4 | 3 |
| **Recreation** | 4 | 3 | 7 |
| **Gas regulation** | 5 | 6 | 6 |
| **Net primary production** | 6 | 8 | 4 |
| **Climate regulation** | 7 | 5 | 9 |
| **Science and education** | 8 | 10 | 5 |
| **Waste/pollutant regulation** | 9 | 9 | 8 |
| **Dispersal of organisms** | 10 | 7 | 15 |
| **Nutrient regulation** | 11 | 12 | 11 |
| **Medicinal resources** | 12 | 11 | 12 |
| **Biological regulation** | 13 | 13 | 10 |
| **Genetic resources** | 14 | 14 | 13 |
| **Spiritual and historic values** | 15 | 15 | 14 |

## 4. Discussion

Both workshop events successfully met the stated goals to (1) aid the identification of offshore ecosystem services provided by the deepwater Gulf of Mexico and (2) initially test a methodology to determine the relative value of the identified services using a non-monetary valuation scheme.

An encouraging observation made during both workshops was that participants chose to take a holistic approach, i.e.,

**Table 3**
Summary of RESVI 2 results for both workshops.

| Ecosystem services | Combined ranking | Houston ranking | Tampa ranking |
|---|---|---|---|
| **Food** | 1 | 1 | 1 |
| **Raw materials** | 2 | 2 | 2 |
| **Recreation** | 3 | 3 | 3 |
| **Science and education** | 4 | 5 | 4 |
| **Transportation**[a] | 5 | 4 | 7 |
| **Derivative/biochemical resources**[b] | 6 | 7 | 5 |
| **Spiritual and historic values/aesthetics aesthetic and cultural**[c] | 7 | 10/11 | 6 |
| **Waste/pollutant regulation** | 8 | 6 | n/a |
| **Nutrient regulation** | 9 | 8 | n/a |
| **Existence**[d] | 10 | 9 | n/a |

[a] Support that ecosystems provide to human transport (including providing a medium for transport).

[b] At the Houston workshop this service was named Biochemical Resources, while at the Tampa workshop it was called Derivative (or derived from ecological components) Resources. In spite of this difference the definition provided by participants is the same: Genetic resources, medicinal resources, food additives, etc.

[c] At the Houston workshop, participants decided to maintain the "spiritual and historic values" category and added a category called Aesthetics, while at the Tampa workshop these two categories were combined and renamed Aesthetic and Cultural. For this reason two rankings are provided for the Houston workshop; one per each category.

[d] Value people place on something simply because it exists.

recognized the benefit of ranking multiple ecosystem services instead of considering only a few services related to their respective constituents' (or sectors') primary interests. This observation suggests that independent of their sectorial representation, participants at both workshops were aware and appreciative of the interconnectivities between healthy ecosystem services and human well-being.

Another important commonality between the two workshops was the distinction between direct (provisioning and cultural) and indirect (regulating and supporting) services by the workshop participants. Direct services are considered goods and services that can be directly used, consumed or enjoyed by people, while indirect services are considered functions or components that underlie a healthy ecosystem and may be a prerequisite for the direct services to occur. Though this definition is intuitive, it should be kept in mind that it is based on the participants' perception of the offshore ecosystem services considered at the workshops discussed here. For different environments, such as the coastal margin, services may be categorized differently; as an example, regulating services such as storm or erosion protection could potentially be perceived as direct services by stakeholders due to their direct benefits to humans (and industries) in coastal communities.

Participants at both workshops expressed that a relative valuation of ecosystem services should focus on services that stakeholders can relate to, thus making the valuation more meaningful to stakeholders and easier to accomplish. Both workshop groups perceived that ranking the direct services was fairly straight forward, while ranking the indirect services was more difficult and could potentially bias the valuation. For example, habitat (a supportive service) is intricately linked to the abundance of fish for food, so that valuing both (habitat and food) might introduce a redundancy that could express itself at the cost of other services in the relative valuation. This realization is in agreement with earlier studies identifying "*double counting*" in ecosystem services valuation as a real concern and recommending to distinguish between direct and indirect services (also referred to as "final" and "intermediate" services) for the purpose of ecosystem-services valuation [17–19]. Despite these concerns, it was recognized by the workshop participants that the indirect services should be considered when designing monitoring or other measures to protect the continued provision of the direct services. For example, decrease of fish habitat could foreshadow a decline in fish catch and should be monitored where and when habitat is known to be at risk.

Though the RESVI approach has been used in the past [16], it has not previously been applied in an offshore marine context as described in this paper. During the Houston and Tampa workshops, every effort was made to achieve balanced input from ocean users, i.e., to involve a representative distribution of participants from diverse industry sectors, government and non-government organizations in the valuation process. The consistency of the top valued ecosystem services at both workshops may indicate the value of the highest ranked services (food, raw materials and recreation) to stakeholders in the region, and could provide a basis upon which future work may continue.

A limitation of the approach presented here is the limited group size, which was chosen to benefit open discussions in an informal setting. Further testing of the methodology is recommended. For example, testing of the methodology in a larger setting may be warranted, but should consider that a larger workshop size would leave less room for dialogue and explanation of the valuation process. Possibly, performing a longer series of small workshops could also be a viable alternative. Independent of the size and frequency of the workshops, facilitators should consider that achieving a meaningful valuation outcome relies on including the full spectrum of available stakeholder sectors in each of the workshops, and that representation by different interest groups should be approximately balanced.

## 5. Conclusions

A methodology was tested to help understand, in non-monetary terms, the relative value of offshore ecosystem services in the deepwater Gulf of Mexico as perceived by multiple ocean users. Several conclusions can be drawn from the valuation results and the discussions that arose during two independent workshops. First, workshop participants took a holistic approach, i.e., recognized the importance of a multitude of offshore ecosystem services to ensure human well-being. Second, participants perceived that a relative valuation of offshore ecosystem services should focus primarily on the provisioning and cultural services, which they considered "direct services" that people are able to use, consume, or enjoy. Third, two provisioning and one cultural ecosystem services emerged among the top three ecosystem services at both workshop events; these services were food, raw materials, and recreation. Fourth, workshop participants recognized the role of the regulating and supporting services in maintaining healthy ecosystems and ecosystem functions, but considered these services "indirect" and a prerequisite for the direct services to occur. Lastly, both workshop groups emphasized that the valuation results were only a first, beginning step toward informed environmental management. They acknowledged that a better understanding of the impact of direct and indirect services would be beneficial to better understand which ecosystem services to protect in the long term.

The approach described in this paper attempts to begin to bridge the gap between traditional economic valuation methods and qualitative means for opinion gathering by introducing a relative, quantitative process that relies on the combined input by a balanced group of ocean users with interests in the deepwater environment. The fact that workshop participants strived to attain alignment rather than pursue conflicting agendas indicates that there is a willingness to collaboratively maintain the services provided by the Gulf of Mexico offshore ecosystem.

Workshop discussions revealed the general understanding that the identification of data gaps, monitoring efforts, and other scientific measures to maintain ecosystem services health requires the combined experience and knowledge from the academic community as well as the diverse stakeholder groups present in the Gulf. It is hoped that the results from the workshops described herein will motivate discussions on how such measures can best be attained and how successful communication between stakeholders and scientists can be achieved.

The methodology described in this paper may provide a means to determine priority ecosystem services as seen by ocean users, which in turn can inform data collection programs, scientific research, or other environmental management measures. Future tests of this methodology, such as, for example, additional valuation workshops in a similar or larger setting than presented here, may be useful to further validate the viability of this approach.

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