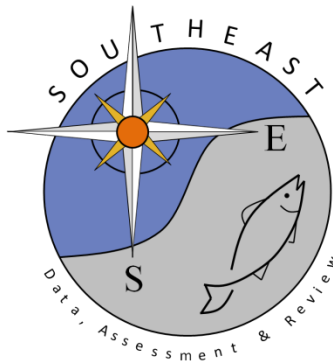


A Social-Ecological System Diagnostics Framework for Better Integrating Social Science Information into the Management of U.S. Caribbean Fisheries

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A Social-Ecological System Diagnostics Framework for Better Integrating Social Science Information into the Management of U.S. Caribbean Fisheries

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SEDAR 103: US Caribbean Application of Alternate Assessment Methods

Summary

This working paper proposes a Social-Ecological System Diagnostics (SESD) framework to enhance U.S. Caribbean fisheries management by better integrating social science information with traditional biological data. While the framework treats human and natural components as a coupled system to improve overall decision-making, this paper specifically focuses on methods and examples for characterizing human components and processes—identifying complementary socioeconomic data inputs to guide management efforts. By leveraging participatory conceptual modeling to map these socioeconomic drivers and identify appropriate metrics and indicators, the framework aims to help managers better understand the human dimensions of the fishery, thereby supporting resource sustainability while minimizing adverse impacts on fishing communities.

I. Introduction

“The point has been made often enough to almost become a platitude: Human behaviour is a key uncertainty for fisheries management, because it receives too little attention in conventional fisheries science and management.” (Wijermans et al. 2019)

To capture the dynamic complexity of fisheries management, this working paper proposes a fisheries Social-Ecological System Diagnostics (SESD) framework building on the well established concept of Social-Ecological Systems (Ostrom 2007, 2009) and its utility for evaluating (or diagnosing) problems and their root causes. Rather than evaluating bio-environmental conditions or human activities in isolation in the context of natural resource governance, the SES approach treats them as coupled, interdependent systems where human and natural components of the ecosystem continually shape one another. The SESD framework expands on the SES concept, to characterize and determine the specific data inputs needed to assess fishery ecosystem status and change, and how these data can be brought together to guide fisheries decision-making and understand the impacts of management actions.

Traditionally, fisheries management decision-making processes have relied heavily on biological inputs (e.g. stock assessment data) to establish fishing regulations that influence human behavior and achieve sustainability goals. One could argue that this unbalanced approach to manage a complex fisheries system is akin to doctors relying on x-ray results alone to diagnose and decide on a treatment for all patients, regardless of the nature of their symptoms. Under the proposed SESD framework, diverse stakeholders, including scientists, managers, and resource users, work together to identify the needed biological, environmental, and socio-economic data inputs that provide the most comprehensive assessment of the system (diagnosis) and inform the managerial course of action (treatment).

Figure 1 presents a visual depiction of the SESD framework emphasizing its multi-scale analytical approach. It adapts a SES core with two primary subsystems: Human Components & Processes (e.g., socio-economic livelihoods, culture, and market dynamics) and Natural Components & Processes (e.g., species population dynamics, habitat health, food webs, and water quality). The intersection of these two domains represents the primary focal point for diagnosis, driven by two key operational levers: 1) Resource use, or the direct extraction, harvest, and utilization of marine fishery resources by human actors, and 2) Management, encompassing the institutional structures, regulations, and conservation policies designed to govern human behaviors and safeguard resource sustainability. These operational levers drive

the key questions that will trigger the SES diagnosis. These core components, the primary subsystems and operational levers, operate through dynamic, circular feedback loops. For instance, shifts in ecological conditions (such as stock depletion or habitat degradation) prompt specific management responses, which in turn alter human resource use behaviors and subsequently trigger new ecological outcomes.

Additionally, the local system is continuously influenced by broader, macro-scale drivers operating outside immediate management control exerting pressure on both human and natural components: 1) Broader Socio-economic Conditions (e.g., global trade dynamics, national economic policies, demographic shifts, and technological innovation), and 2) Large-Scale Biogeochemical Conditions, including climate, regional, and oceanographic cycles and conditions, which impose fundamental physical constraints on the ecosystem's baseline health and productivity.

One of the key features defining this approach is the focus on *data inputs* informing the status of the system and monitoring changes. In Figure 1, boxes exemplifying the socioeconomic, environmental, and biological data inputs that need to be identified to assess the SES provide some examples of traditionally used information to guide fisheries management processes. While these are helpful examples, the primary goal of the SEDS approach is informing the very content of these boxes. Particularly, under the SEDS approach, the identification of the biological, environmental and socioeconomic data inputs should ideally emphasize their force multiplier potential. In other words, the complementary effects of each available data input should be taken into consideration when utilizing this approach to answer specific questions and achieve specific management goals.

The focus of this paper, in the context of the SEDAR 103 objectives, will be on the methods used for characterization and assessment of the *Human Components and Processes* of the SES and, particularly, strategies to identify the socio-economic data inputs that are complementary to biological and environmental data available to better inform and guide management efforts in the U.S Caribbean.

II. Proposed Methods

The proposed application of the SEDS approach involves two main steps: 1) System characterization, and 2) Metrics identification. The methods for completing these steps are

outlined below along with examples relevant to the SEDAR 103 context.

2.1. System Characterization

The primary method proposed for characterizing the human components and processes and contributing to a holistic understanding of the SES is the development of Conceptual Models (CMs) to describe the dynamics of the system and its major drivers and receivers (see Seara et al. 2024). These CMs may be constructed utilizing a participatory approach or can derive from qualitative data and expert knowledge. There is extensive literature that supports this approach and provides examples of conceptual modeling strategies (Harvey et al. 2016, DePiper et al. 2021). CMs can be used to characterize the system more broadly as in Seara et al. (2024) (Figure 2) or can be guided by a specific research or management question (e.g., Rosellon-Druker et al. 2019) and characterize dynamics pertaining to a specific species or ecosystem submodel (e.g., Vasslides and Jensen 2016). In addition, the development of CMs through both participatory approaches or from the collection of qualitative data generates a substantial amount of contextual data that can be used to interpret relationships in the model as well as inform the utilization of the model to achieve management goals.

CMs focused on understanding the human components and processes should have clear linkages to its natural counterparts in the SES. These connections will inform the identification of socioeconomic metrics and indicators that complement biological and environmental data inputs and vice versa. For example, results of participatory CMs developed by Seara et al. (2024) show that impacts on coral reefs from pollution, disease, and climate change constituted major concerns between the multiple stakeholders involved in the project, suggesting that coral reef health and coverage should be considered an important data input for assessing the health of the U.S. Caribbean fisheries. Similarly, Seara et al. (2018) utilized survey data to understand fishers' perceptions of environmental change and subsequent adaptations and found that a substantial portion of the fishers interviewed in Puerto Rico reported having to fish farther away from the coast and deeper into the water in comparison to previous years, suggesting that resource degradation distribution is an important factor to consider when assessing health of local ecosystems and may have an impact on cost and risk for resource users.

CMs should be used as dynamic and adaptive tools capable of informing system change and potentially be used in scenario planning approaches. Extensive and stakeholder validated CMs can be used to evaluate management action effects by taking into consideration the complexity of the system and other pressures compounding or minimizing impacts of specific regulatory

actions. For instance, similar management decisions may have distinct impacts on fisheries economic viability under different cost and market scenarios, and the ability of fishers to adapt to said management decision may depend upon other conditions of the SES. When these are better understood, managers can make more informed decisions to achieve the goals of sustained participation and fishing opportunities (National Standard 1) while minimizing adverse impacts on fishing communities (National Standard 8).

2.2. Metrics Identification

Once the CMs are constructed the next step in the SESD approach is to identify the appropriate socioeconomic metrics and indicators to address the specific resource use and management questions, i.e., that will result in the most appropriate diagnosis for use in decision making. The identification of the appropriate data inputs must be guided by both the research or management question as well as the biological and environmental data inputs available that will, in combination with the socio-economic metrics, result in the most refined system diagnostics. This step in the process will also inform data gaps and opportunities for the use of local and expert knowledge. This process may also generate important qualitative information that can help refine the CMs and inform interactions of the models.

It is important that the identification of appropriate metrics and indicators be heavily guided by specific research and management questions to guide decision making and achieve focused objectives. For instance, this approach can help the Caribbean Fishery Management Council (CFMC) advance its risk assessment and policy through the identification of the most appropriate indicators of favorable/unfavorable socioeconomic conditions for particular species or island communities and ultimately inform the adequate risk value when setting ABCs (Figure 3), deciding on stock or ecosystem assessment priorities, or determining catch limits and closures.

The following section provides an overview of socioeconomic data available for the U.S. Caribbean and a proposed approach to test SESD to address specific management priorities for the region.

III. Applying SESD in the U.S. Caribbean

3.1. Data Available

While socioeconomic data in the U.S. Caribbean has not been consistently and systematically

collected to fit a SESD approach, recent and historic efforts have produced data and information that can be used to test such an approach. CMs characterizing the marine fisheries system have been constructed using a participatory strategy as part of an effort funded by Lenfest Ocean Program between 2019 and 2023 to understand the status of the ecosystem and data available for the development of a Fishery Ecosystem Plan (FEP) for the region (see Seara et al. 2024). These CMs, while not addressing a specific management question, can be used as a starting point to accomplish step one in the SESD process described above. Submodels of the melded CM (which includes models generated by seven distinct stakeholder groups for all three island ecosystems, see Figure 2) can help focus the exercise on more specific research or management questions.

The Lenfest project also compiled available socioeconomic datasets (as well as biological and environmental) for testing hypotheses generated by the stakeholder driven CMs. These datasets can be used to identify existing metrics and indicators that, along with their biological and environmental counterparts, can provide the most appropriate assessment (diagnosis) of the system to inform decision making (treatment) to achieve specific objectives. Socioeconomic datasets currently available for the U.S. Caribbean can be seen in Table 1. While these datasets do not represent an exhaustive list of socioeconomic data available for the region, they are unique in containing multiple collection efforts, thus increasing the number of data points, and allowing for, albeit limited, longitudinal analyses when appropriate.

3.2. SESD Proof of Concept

Ideally, the identification of the appropriate management questions to guide SESD should be developed in collaboration with local managers and other relevant stakeholders. The subsequent collection of information to characterize the system using CMs should then focus on the question or questions developed to inform the identification of data inputs and analyses that will guide decision-making. For the purposes of developing an experimental case study for SEDAR 103, data from the stakeholder driven CMs developed by Seara et al. (2024) were used as the starting point. Submodels of the larger CMs developed by the District Advisory Panels (DAPs) representing the three island systems were isolated to characterize relevant components of the U.S. Caribbean's system and their relationships. For the purposes of this exercise, socioeconomic drivers of the system were prioritized to create a smaller subset of ecosystem elements from which to draw the submodels. Here, two submodels are used as examples: Figure 4, which isolates the Commercial Fishers and Fisheries Resources as two primary components of the U.S. Caribbean SES; and Figure 5, which shows all direct

connections between Fisheries Resources and all other elements in the subset used.

The two figures described above can help to guide the identification of existing metrics and indicators to test and model the hypothesized relationships. It is clear from the submodels that important fishery elements are affected by a multitude of factors that can be characterized as biological, environmental, socioeconomic, as well as more distal natural and human conditions and pressures (e.g., hurricanes and different sources of pollution). For the purposes of this exercise, the socioeconomic elements affecting fisheries resources will be used to exemplify the SESD step for the identification of data inputs.

The socioeconomic elements identified in the DAPs models as directly related to Fisheries Resources were *Socioeconomy of Fishers*, *Fish Market*, *Import Control*, and *Compliance*. The nature of the relationships identified show positive effects of fisheries resources on fishers' socioeconomic conditions and on fish markets. A double arrow linking fish markets and fisheries resources also acknowledges the potential negative effect of markets on resource health. The DAPs also identified the positive influence of compliance and seafood import control on the status of resources. While data on these identified elements have not been systematically collected to investigate their interactions with fisheries resources, the datasets identified in Table 1 as well as other individual data collection efforts (e.g. Seara et al. 2018, 2022) can be used to assess the status and further understand their relationships with the health of fisheries resources and sustainability in general. For instance, an appropriate understanding of market prices (e.g., longitudinal trends) and socioeconomic characteristics of the impacted fleets (e.g., demographics, income, portfolio diversity) at the time of the decision-making process can help shape decisions that consider trade-offs between resource sustainability and impacts to individuals and communities. Decisions that consider these trade-offs are more likely to be better received by fishers and thus increase compliance. Data on these important elements can also be used to develop more effective outreach and advocacy strategies that specifically address the concerns of the fishers. Outreach and Education was identified in the DAPs CMs as an important component affecting commercial fishers, who in turn affect the status of fisheries resources (Figure 4).

IV. Final Considerations

The example described above focused on the identification of socioeconomic indicators using the SESD approach and was used as a proof of concept for the proposed framework to guide

fisheries decision-making in the U.S. Caribbean. A more extensive use of this strategy would also identify the appropriate environmental and biological data inputs and consider their complementary potential. For example, a combination of trends in biomass, market prices, and water temperature may be more useful information for the CFMC to plan for a given species' fishing year compared to the results of a stock assessment model alone.

As emphasized above, the ideal practical use of SESD should be guided by specific management or research questions. While some data is available to further test this approach in the U.S. Caribbean, there currently is a need to create the conditions and resources for the collection of the appropriate data to enable practical adoption of SESD for the region. Once the SES becomes better understood and the critical elements affecting the system are identified and monitored, the data generated can provide a more holistic set of information to guide more effective fisheries management in the U.S. Caribbean.

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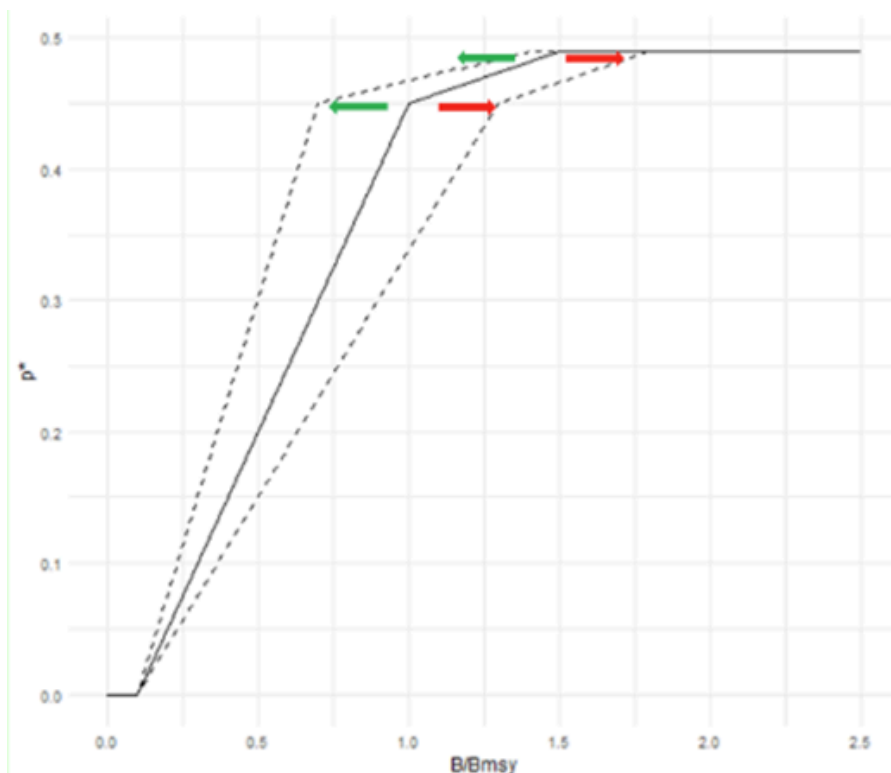


Figure 3. Graphic representation of the use of socioeconomic indicators for assessing different risk values for ABC setting (from Gaichas et al., presentation).

Table 1. Socioeconomic datasets available for the U.S. Caribbean

Dataset	Geographic Range	Data Points/Year
Fishery Census	U.S. Caribbean	Puerto Rico: 2 (1995/96-2019) USVI: 2 (2004, 2010/11 & 2016)
MCRIMP	U.S. Caribbean	Puerto Rico: 1 (2015) USVI: 1 (2017)
CSVI	U.S. Caribbean	<i>Social Vulnerability</i> : 2 (2010 and 2020; except Retiree Migration, 2020 only) <i>Fishery Indices</i> : 1 (5-year average 2016-2020)
Commercial Landings	U.S. Caribbean	Annual (since 1970s)
Conceptual Models	U.S. Caribbean	1 (2020-2023)
Gear Costs and Earnings	Puerto Rico	1995/96-2019

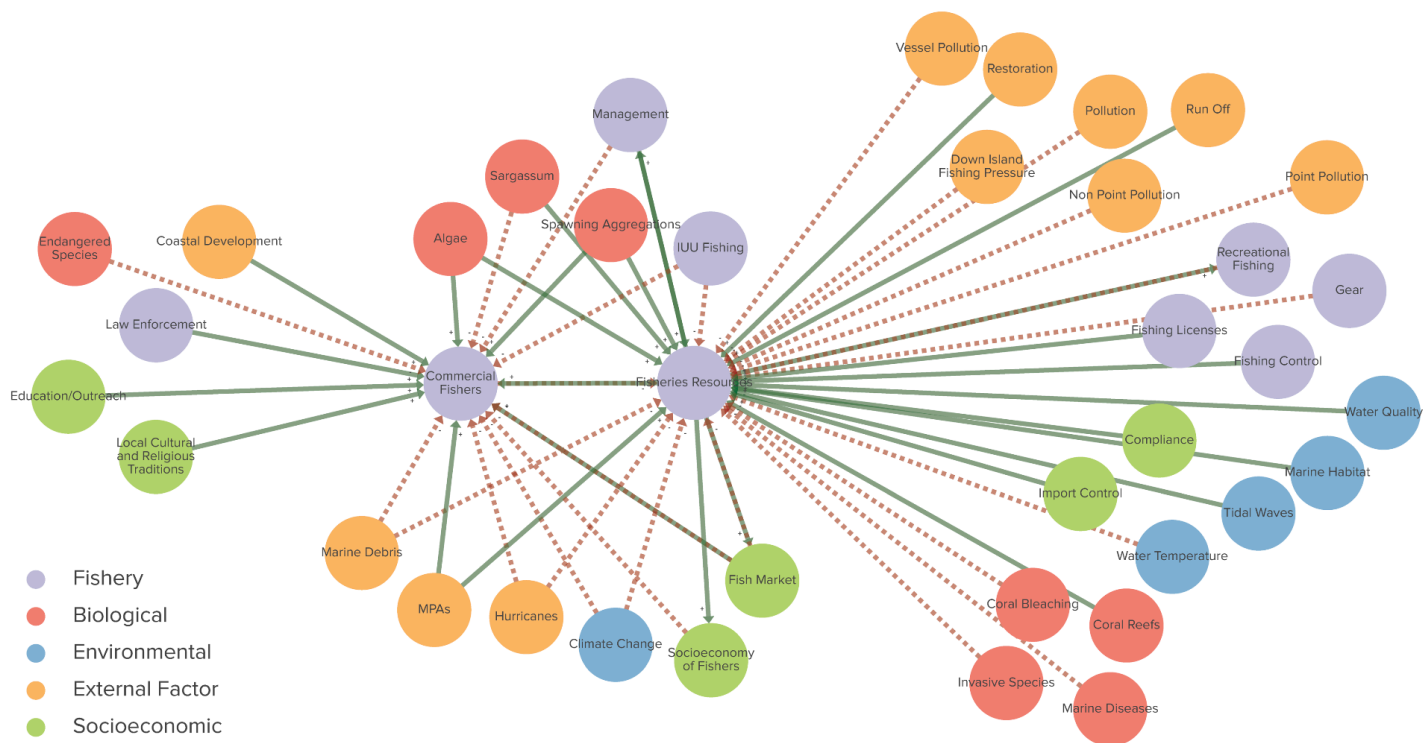


Figure 4. Submodel of the DAPs conceptual model showing direct connections between elements by isolating Commercial Fishers and Fisheries Resources.

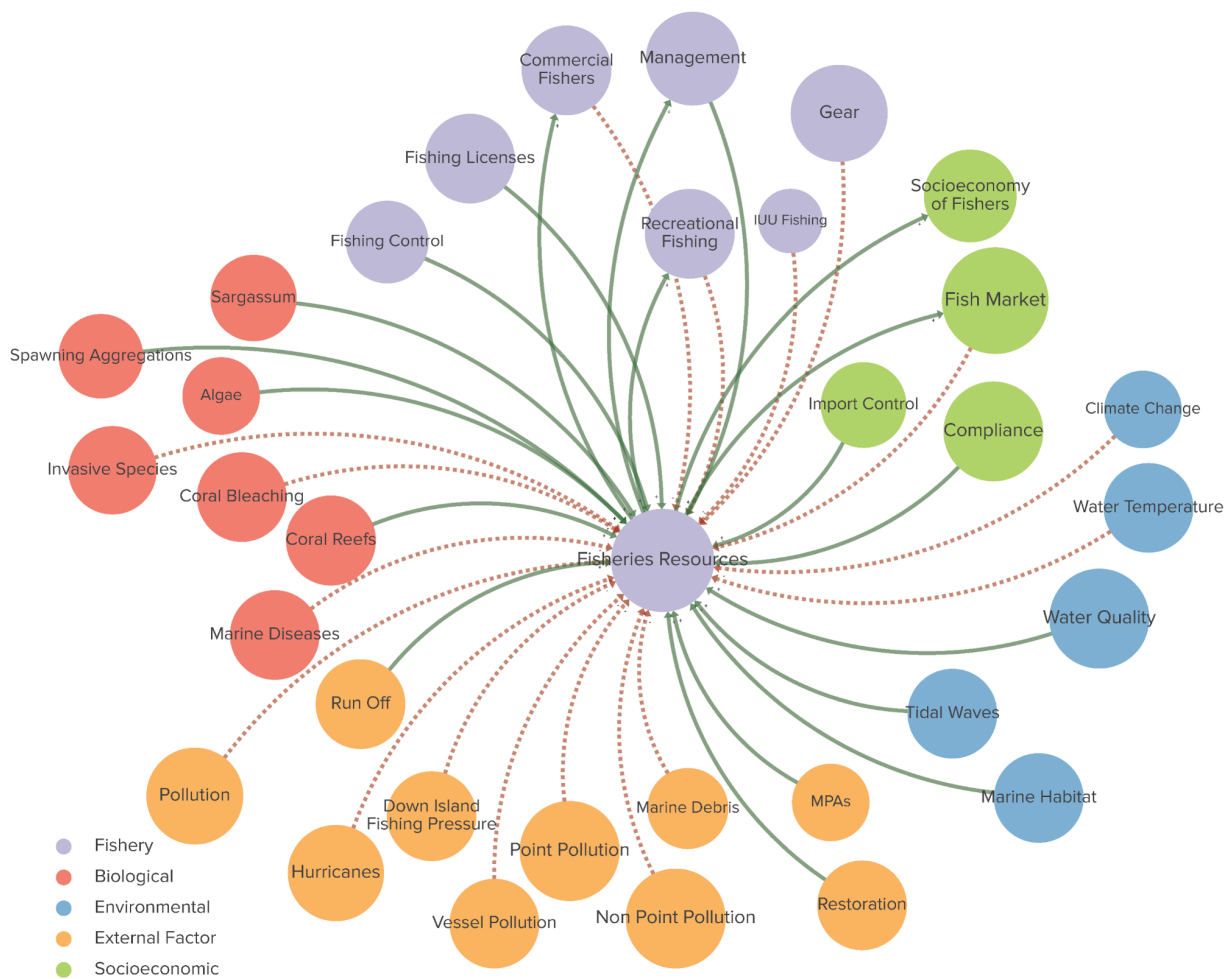


Figure 5. Submodel of the DAPs conceptual model showing direct connections between elements by isolating Fisheries Resources.