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CONNECTING HUMANS AND ECOSYSTEMS IN TROPICAL FISHERIES: SOCIAL SCIENCES AND THE ECOSYSTEM-BASED FISHERIES MANAGEMENT IN PUERTO RICO AND THE CARIBBEAN

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Abstract

The current state of the biodiversity and ecosystems of the Caribbean is a complex predicament developed from the historical interactions of human populations. Resource and ecosystem conservation requires an understanding of the human and natural dimensions of the problems and a research and conservation strategy that unifies both experiences. We believe that the current emphasis on ecosystem-based fisheries management (EBFM) approaches—among the fisheries management community—present the greatest opportunity to achieve this. EBFM aims to protect the structure and quality of habitats, maintaining ecosystem integrity and function, with a precautionary approach, and recognizes "limits to production" and seeks to "control rates of extraction." On a theoretical level, the EBFM must operate under the **social-ecological system** framework ("a coupled human-environment system"). Much is said about the need to incorporate the social sciences into EBFM strategies, and lip service is paid to the importance of the human dimension, but in reality, that is seldom achieved, if ever. Furthermore, there are no specific plans or models to approach this human dimension in principled, formal ways. This paper discusses the current use of EBFM in the Caribbean and presents a handful of recommendations to make it work.

Keywords: ecosystem-based fisheries management, fisheries, conservation, connectivity and social sciences

Resumen

El estado actual de los ecosistemas caribeños se encuentra en una difícil situación como resultado de las presiones de uso a través de la historia. La conservación de los recursos naturales requiere de la comprensión de las dimensiones naturales y humanas del problema, así como el desarrollo de una estrategia de investigación y conservación que unifique ambas experiencias. El manejo de pesquerías basado en el ecosistema (EBFM, por sus siglas en inglés) presenta una gran oportunidad para lograr esto. El EBFM busca proteger la estructura y la calidad de los hábitats, manteniendo la integridad y función del ecosistema, empleando un enfoque precautorio y reconociendo los límites naturales y económicos del recurso pesquero. Teóricamente, el EBFM debe operar bajo el marco del **sistema ecológico-social** ("un sistema humano-ambiental acoplado"). Se ha hablado mucho sobre la necesidad de incorporar a las ciencias sociales en las estrategias del EBFM, pero han quedado como promesas incumplidas, ya que es difícil encontrar planes concretos que logren incorporar efectivamente la dimensión humana al manejo de las pesquerías. Este artículo discute el uso actual del EBFM en Puerto Rico y el Caribe, y presenta un puñado de recomendaciones puntuales para lograr su funcionamiento.

Palabras clave: Manejo de pesquerías basado en el ecosistema, pesquerías, conservación, conectividad y ciencias sociales

Résumé

L'état actuel de l'écosystème caribéen se trouve dans une situation difficile à cause des pressions exercées par la population à travers leur histoire sur son utilisation. La conservation des ressources naturelles nécessite une compréhension des dimensions naturelles et humaines du problème, ainsi qu'une stratégie de recherche et de conservation réconciliant les deux expériences. La gestion de la pêche basée sur l'écosystème (connue par son sigle anglais EBFM) offre une grande opportunité de grandes perspectives pour y arriver parvenir. L'EBFM cherche a vise à protéger la structure et la qualité de l'habitat, en préservant l'intégrité et le fonctionnement de l'écosystème, en mettant l'emphase sur la prévention et utilise une approche préventive, et en reconnaissant les limites naturelles et économiques de la pêche en termes d'exploitations piscicoles. Théoriquement, l'EBFM doit opérer dans le cadre du **système socio-écologique** (une liaison entre le système humain et l'environnement). En dépit de nombreuses discussions, presque rien n'a été fait dans une perspective d'équilibrer les stratégies de l'EFBM et les sciences sociales, car il est difficile de trouver des plans concrets permettant l'intégration des dimensions humaines dans la gestion de la pêche. Cet article traite de l'utilisation actuelle de l'EBFM à Porto Rico ainsi que dans la Caraïbe, et présente une poignée de recommandations visant à favoriser son efficacité.

Mots-clés : Gestion de la pêche basée sur l'écosystème, pêches, conservation, connexion et sciences sociales

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A Brief Introduction to the Caribbean Fisheries

Ecosystems and coastal and marine resources of the Caribbean are currently in a difficult predicament. At the local level, and at the largest macro level, that of the Caribbean as a large marine ecosystem (LME), or as a massive region, such as the Wider Caribbean, biodiversity and habitats are threatened by a number of root causes, such as: economic development, population growth and policies that favor industries, tourism and large scale agricultural development. These threaten watersheds and the quality of the coastal waters and the condition of marine ecosystems. The insular and marine ecosystems of the Caribbean are high in biodiversity that sustains a number of economies and societies since pre-Columbian times. Agriculture, industries, military installations, harbors and commercial development, tourism, and urban growth have impacted coastal and marine resources through the deforestation of watersheds, destruction and degradation of habitats, sedimentation of coral reefs, destruction of mangrove forests, removal of wetlands and coastal lagoons, and the pervasive pollution of estuaries and coastal waters.

Ocean, terrestrial and atmospheric forces and processes have shaped the conditions of the Caribbean as a LME from the local to the regional scale. These include: the massive plumes of freshwater from the Orinoco and Amazon rivers that contribute to thermo-, halo- and pycnoclines, currents, hurricanes, tectonic activities, volcanic processes, Saharan dust, winds, climate change, nutrients, and planktonic diversity in the marine waters. These processes are responsible for the diversity, productivity and abundance of harvestable marine organisms, one of the region's key resources. Fisheries resources are under pressure, and a number of species and stocks are overexploited and considered overfished (Mohammed 2007). Indeed, the history of the Caribbean has been described as the ravaging of keystone species such as marine turtles, manatees and reef fishes that resulted in habitat deterioration, mass mortalities of certain species and the fishing down the food web effect (Jackson 2001, Jackson *et al.* 2001, Roberts 2007).

Fishing and fisheries play a critical role in "the economic, nutritional and cultural well-being of Caribbean countries" (Fanning *et al.* 2011b, McConney and Salas 2011). In fact, coastal identities often revolve around the fisheries complex and the local histories and cultural traditions of coastal and marine resources exploitation (Griffith *et al.* 2007, Valdés-Pizzini and García-Quijano 2009, Price 2005). Regional, international and local economic development targeted marine fisheries, and promoted import substitution through increments in technology, capitalization and fishing effort that ironically resulted in better and more intensive fishing endeavors that overexploited of a number of stocks (Mohammed 2007, Valdés-Pizzini 2007). Fanning *et al.* (2011a) offered an excellent description and appraisal of the Caribbean fisheries that merits to be quoted in full here:

> The fisheries of the Caribbean region are based on a diverse array of resources. Those of greatest importance are for offshore pelagics, reef fishes, lobster, conch, shrimps, continental shelf demersal fishes, deep-slope and bank fishes, and coastal pelagics. There is a variety of less important fisheries such as for marine mammals, sea turtles, sea urchins and seaweeds. These fishery types vary widely in state of exploitation, vessel and gear used, as well as the approach to their development and management. However, most coastal resources are considered to be overexploited and there is increasing evidence that the pelagic predator biomass has been depleted… The fisheries using the widest variety of gears are primarily artisanal, or small-scale, using open, outboard-powered vessels 5-12 m in length. The most notable exceptions are the shrimp and groundfish fisheries of the Brazil-Guianas shelf, where trawlers in the 20-30 m size range are used, and the tuna fishery of Venezuela, which uses large (>20 m) long liners and purse seiners. In many countries, there has been a recent trend toward more modern mid-size vessels in the 12-15 m range, particularly for large pelagics, deep-slope fishes, and lobster and conch on offshore banks (Fanning *et al.* 2011a:15-16).

On a local level, and considering specific resources and stocks across political boundaries, the situation is much more complex and difficult to assess. However, it appears there is a declining trend in the Caribbean, albeit with significant localized variability, and the scientific community believes that there is—in the region—a decline in the mean trophic level, showing an increase in catches in the beginning, and a stagnant declining trend afterwards (Agard and Cropper 2007:27-30). The trend of targeting species at progressively lower levels of the food web, from top predators to lower level consumers, herbivores and detritivores, is a phenomenon known as “fishing down the food web” (Pauly *et al.* 1998, Pauly and Palomares 2005). This overall trend has been demonstrated in southeast Caribbean (Agard and Cropper 2007, Mohammed 2007). The current status of a number of stocks features a declining trend in catches, reduced sizes of individuals and a limited capability to sustain current levels of fishing effort. In other words, some of the most important commercial species appear to be overfished at the regional scale, for example: the Caribbean spiny lobster, *Panulirus argus* (Ehrhardt *et al.* 2011), queen conch, *Lombatus(Strombus) gigas* (Appeldoorn *et al.* 2011), groupers (Sadovy 1994) and some species of deep-water snappers (Heileman 2011).

The overall situation of Caribbean fisheries, and the potential for the conservation of a number of species that do not face critical problems of dramatic overexploitation, such as flyingfish and some pelagic fishes (Fanning and Oxenford 2011), have led the Centre for Resource Management and Environmental Studies (CERMES) at the University of the West Indies in Barbados, to pursue strategies for ecosystem-based management for marine resources in the Caribbean, with special attention to fisheries. Funded by a number of international organizations and donor agencies, this effort attempts to develop the science and practice of ecosystem based fisheries management (EBFM), through research, analysis, capacity building, planning and implementation of pilot projects and programs in governance that promote the principles and objectives of that management strategy (Mahon *et al.* 2011). From Cuba (Baisre 2007) to Trinidad and Venezuela (Agard and Cropper 2007), the island-nations, countries and territories of the Caribbean are impacted by population growth, tourism, coastal and industrial development, and the ensuing deterioration of the health of habitats, stocks and populations, as well as the loss of biodiversity (Burke and Maidens 2004, Sweeney and Corbin 2011).

The current state of the biodiversity and ecosystems of the Caribbean is a complex predicament developed from the interactions of human populations (and their cultures) and their history of occupation through out the region. Thus, it requires an understanding of the human and natural dimensions of the problem and a research and conservation strategy that unifies both experiences. We believe that the current emphasis on EBFM (Pikitch *et al.* 2004) approaches among the fisheries management community present the greatest opportunity to achieve this. At the local level and regional levels, researchers, conservationists and resource managers increasingly speak of the possibilities of system focused, adaptive management and a comprehensive strategy that puts marine ecosystems, including humans, at the center of the scientific and conservation debate.

The Possibilities of the EBFM Approach

Over the past 30 years scientists have struggled with the incorporation of the ecosystem into the analysis and management of fisheries (Longhurst 2010). The idea has metamorphosed into a number of principles and terms, including the current usage of EBFM. This approach contends that the appropriate understanding of fisheries (namely, stocks, populations and the extractive activities) requires the incorporation of an ecosystem-oriented reasoning, incorporating humans—their history, culture and complex social institutions—into the analysis. In fact, according to FAO, the ecosystem approach to fisheries must address "the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems" (FAO 2003:14). One of the goals is to achieve sustainability, balancing societal objectives and incorporating in the analysis the biotic, abiotic and human processes, as well as their uncertainties. Simply stated, fishing must satisfy human (market, communities, firms, individuals) needs with a minimal impact to the ecosystem's functions such as altering the food web, trophic or species relationships, thus assuring the renewability of the stocks and the conservation of the ecosystem's components. Fishing provides such important food and economic resources to the region (and the world for that matter), and as such, it must continue (Fluharty *et al.* 1998). Thus, management is the only option to deal with fishery ecosystem problems.

EBFM entails a fundamentally different approach to fishery management: "essentially reversing the order of management priorities to start with the ecosystem rather than the target species," with a fitting primary objective, to "sustain healthy marine ecosystems and the fisheries they support" (Pikitch *et al.* 2004). The information required for these endeavors goes beyond (in both degree and type) the data used for traditional single species stock based management approaches (recruitment, biomass, mortality, fecundity etc.), to include topics such as critical habitats, indicators of environmental condition and ecosystem status, social scientific and economic data, system resilience, knowledge of ecosystem processes at different scales, and the temporal and spatial links (or connectivity) between critical ecosystem components (Pikitch *et al.* 2004, Mumby 2006). These new information needs often require databases of novel data types (such as indicators of the condition of stocks), which has challenged the capacity and creativity of scientists and managers and motivated the formation of large scale multidisciplinary initiatives. Of these novel data needs, social scientific data is probably the most alien to traditional fisheries managers and the one that is lagging the most in terms of database development and research fund investment. It is also one of the most urgent: *Homo sapiens* is the keystone predator species in marine ecosystems. Thus, social scientific data is at least as important as fish biology data for management. However, very little information about the social, historical, cultural, and economic context of fishing is currently used, and/or readily available to be used, in fishery management actions.

The implementation of the EBFM—in any context (the Caribbean

LME, for example, or the Puerto Rican fisheries)—requires a framework and a practice that incorporates the historical process of the fisheries (due to its evolution from former institutions and practices), should be democratic and participatory, requires the use of the "best available knowledge" (both science and local forms of knowledge), must have a holistic approach (encompassing all behavioral dimensions: biological, economic, social, cultural, governance), and must engage in adaptive management, a process that enables managers (and participants in the fishery) to make adjustments and develop new strategies for maintaining sustainability (Bianchi and Cochrane 2011:41, FAO 2003). In addition, some authors suggest that the EBFM must be "based on maintaining ecosystem health and productivity and focusing on system resilience" (Appeldoorn 2011:147). To achieve endurance (maintaining ecological and economic services), sustainability and resilience, the practice of EBFM should be able to protect the structure and quality of the habitats, maintain ecosystem integrity and ecological functions, employing a precautionary approach, and recognizing "limits to production" to "control rates of extraction" (Appeldoorn 2011:149-152). On a theoretical level, the EBFM must operate under the **social-ecological system** framework ("a coupled human-environment system") suggested by Chapin *et al.* (2009:7, see also Berkes and Folke 1998:4-5).

Although, the debate on EBFM seems to be recent, the origins can be traced to the last 30 years in the international community, where scientists and practitioners of conservation struggled to define and implement such a conservation (and research) strategy (Longhurst 2010:265-277). The debate can be followed in the peer-reviewed literature, in the gray literature and disquisitions by fisheries managers and government officials, and books devoted to the topic (see for example, Christensen and MacLean 2011). A recent volume edited by the Centre for Maritime Research (MARE) in Amsterdam, makes a thorough case for the application of the ecosystem-based management approach in the Wider Caribbean (Fanning *et al.* 2011a).

The main argument of this article is rather simple. The elegant and important phrase EBFM describes a desired goal that is rather difficult to achieve by managers and scientists, who still embrace traditional forms of fisheries management, or for those who follow the rules, regulations and policies set by fisheries management agencies. The fate of fisheries stocks is too important (biologically and politically) to leave it to considerations other than the hard science of stock assessment, or to pilot projects testing the possibilities of an integrated approach in which humans are key players. Throughout the Caribbean region, government agencies and NGOs are advancing towards that goal (Fanning *et al.* 2011a). However, the day-to-day exercise of managing local fisheries is still based on the local politics and conditions (not necessarily the well studied social conditions), and the scant data on the stocks' health based on extraction rates (for example, calculations of the catch per unit effort and maximum sustainable yield). Much is said about the need to incorporate the social sciences into EBFM strategies, and lip service is paid to the importance of the human dimension. Furthermore, there are no specific plans or models to approach this human dimension in principled, formal ways, except for the concerted effort to incorporate socioeconomic monitoring into coral reef management (Bunce and Pomeroy 2003).

Is this a healthy approach to tropical marine fisheries? Our response is negative. Tropical ecosystems and the socioeconomic dynamics of the Caribbean, for example, require an alternative approach in which the full human dimension is incorporated into the analysis, modeling and decision making process. The social sciences are in a unique position to contribute to the debate through a holistic approach, one that views humans as part of ecosystems, as a species and as historical (social, cultural and economic) subjects. But the enormity of the task requires an effort well beyond the knowledge of our disciplines; it requires the participation of scientists, managers, resources users and other stakeholders willing to learn the art of interdisciplinary and transdisciplinary thinking (Thompson-Klein *et al.* 2001). These forms of analysis and problem solving unifies the knowledge that creates, understands and integrates data into holistic, comprehensive, dynamic and parsimonious models of ecosystems, represented as complex processes that ***connect*** landscapes, seascapes, ecological and physical processes, biodiversity, and human behaviors and actions. Currently there is, in our view, a disconnection between the "natural" sciences and the social sciences in engaging—as partners—in research and implementation of the EBFM. In the Caribbean, and specifically, in Puerto Rico (where most of our research has been conducted) that goal has not been achieved, despite the recognition of the potential of EBFM.

Connectivity

The key word here is *connections* and its biological variant, *connectivity*. Valdés-Pizzini "stole" the idea from James Burke, an expert in Middle English, who baffled viewers for many years in the British Broadcasting Company (BBC) documentary series *Connections*. The series (as well as Burke's frantic insistence on the validity of the approach) opened us to the prospect of connecting spaces, places, energy, people, nature, species, technologies, texts, ideas, policies, landscapes and temporal scales. A closer look to that list reveals the similarity or congruence with ecosystems and ecological processes. It also reveals their relevance to the understanding of fluctuations within the systems, and variations regarding our knowledge of them. Ecologists use connectivity to describe "the spatial continuity of a habitat or cover type across a landscape" (Turner *et al.* 2001:3). Connectivity also refers, in landscape ecology, to the gradients and patches of habitats, their physical linkages, and how species and populations traverse the spatial configuration in different life cycles, trophic relations, and temporal scales (Turner *et al.* 2001, Sobel and Dahlgren 2004). Fisheries biologists also employ the concept to describe the genetic links between populations in a regional context (Cowen *et al.* 2006). There is a lengthy epistemological discussion on pitfalls and opportunities of the use of natural sciences concepts in our disciplines. Here, we argue that connectivity and landscape are also (almost) concepts used by the social sciences, which are amenable and suitable for metaphors, models and actually useful heuristic devices to construct the interdisciplinary knowledge and practice of EBFM. Connectivity and landscape are also terms and cognitive categories employed, defined and described by resource users, and are essential components of the perceptions of the social ecological system (Valdés-Pizzini and García-Quijano 2009).

Valdés-Pizzini proposed the idea of using connectivity as a master concept during a workshop on marine reserves sponsored by the National Park Service in the U.S. Virgin Islands (Rogers *et al.* 2007), an idea already developed earlier by McConney *et al.* (2003). A number of participants had previous experiences with interdisciplinary and transdisciplinary projects and efforts, and received the idea of a greater connectivity with enthusiasm. The idea was included in the workshop's proceedings:

> We also recognize that "connectivity" has many meanings and applications, both social and ecological. We explored this core concept for ocean stewardship in the widest possible context of multiple scales of time and space, and in its many manifestations including: Ecological—food web, competition; Geographical—ocean currents; Natural history—larval dispersal, settlement habitats; Social—people to nature, within human communities; and Economic—fisheries, tourism (Rogers *et al.* 2007:1).

Indeed, the proposed use of the term connectivity made the first page of the document, but the remainder of the discussion only referred to connectivity in the biological and ecological sense, except for one rather cryptic research question suggested by the participants: "What connections should be explored further in marine reserves to advance knowledge in social science, economics, ecology, oceanography, and fisheries science?" (Rogers *et al.* 2007:21). The critical task of weaving and entangling the multiple dimensions listed by the participants, in the understanding and management of marine reserves remained without discussion, or consequence. Yet, scientists and managers insist on the need and importance of the incorporation of an EBFM, but the guidelines needed to achieve that goal are lacking. We reproduce here the original flow chart diagram designed during the workshop, to illustrate the complexity of the task, as well as the connections between the social and "natural" processes inherent in the planning, design and effective implementation of either marine protected areas (MPA), or fisheries management regulations and actions (see Figure 1). The flowchart illustrates how processes, both human and environmental are inextricably tied, and must be considered and understood as whole, undivided (physically and abstractly) entities. The chart contains more questions than answers, and we hope it elicits more comments and alternative connections in future discussions and debates.

Question, Questions, Questions…

Social scientists of the theoretical and applied persuasion have a critical role of asking the appropriate questions, and help fisheries stakeholders in asking and answering them. In this article we present critical questions we need to answer to build a framework for the appropriate incorporation of EBFM, from the perspective of the social sciences in the Caribbean region. We do not have answers to all the questions, but we are certain that the future of the strategy dwells in the thorough and complex process of answering and debating those questions, and in pursuing a strategy to unify diverse forms of knowledge and practices conducive to a inter or better yet, a transdisciplinary endeavor that could enable an ecosystem-based conservation strategy.

Does traditional fisheries management provide an accurate picture?

Tropical fisheries are often managed using theoretical and applied tenets of fisheries imported from temperate biomes that usually target single species (Pikitch *et al.* 2004). But tropical fisheries are multi-species contexts characterized by the use of diverse fishing strategies (multi-gear), and small-scale producers with a number of socio-economic and extractive strategies. Small-scale tropical fisheries are also complex social worlds dependent on a large variety of species, temporal variability, jobs opportunities ashore, anthropogenic activities in the marine and coastal waters interface, and relative abundance to sustain the social communities in which they are inserted (Griffith and Valdés-Pizzini 2002, Griffith *et al.* 2007). In other words, the *functional fishery ecosystem* includes the larger socioeconomic and historical contexts of fishing and human activities around the coast. These contexts are connected to the marine

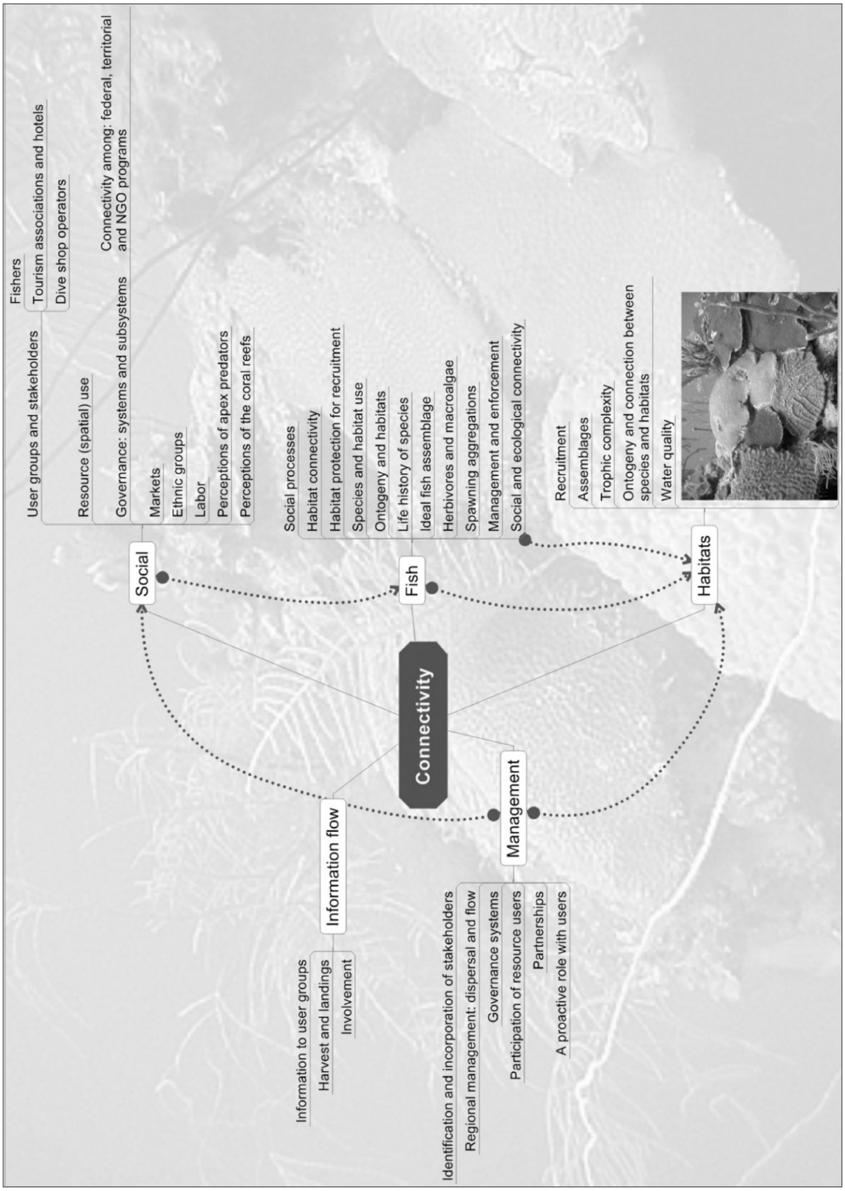


Figure 1. Flowchart of connectivity.

ecosystems through coastal human populations.

Fisheries biology has, however, been the dominant form of production and application of knowledge in that context, with its assumptions and limitations, often founded on ideas based on large scale (commercial and industrial) fisheries using a single gear and targeting a handful of species, and discarding those not wanted, as by-catch. The science is based on the understanding and measurement of the abundance of the stock, its behavior in reference to the level of fishing mortality (fishing effort), recruitment, reproductive strategies, immigration-emigration, and total mortality of the stock. Plotting catch versus effort provides scientists and managers with a description of the condition of the stock at that time, a portrait that may be enhanced with information on the size, age and sexual maturity of the individuals caught in the fishery.

Is the portrait accurate? Or is the portrait drawn with the lines of simple charts and graphs missing a matrix of historical data on effort, social processes, markets and the economy, management decisions, stochastic processes, turbulence in natural and in the social systems, ruptures in the connectivity of populations and habitats, the effects of natural hazards, the role of variability in nature, and the intricacies and vulnerability of data?

The application of an EBFM requires that attention be paid to the social (human) component, that is central to the analysis of the stock (as in the case of fisheries), as this unit is defined in reference to the extractive process (fishing mortality) that shapes its form and content. However, human actions (and social processes) are measured with surveys on fishers' behaviors, attitudes, preferences, and patterns of resource utilization. While connected to habitat and species, there is seldom a theoretical connection made between human behaviors documented by "traditional" or classic social science methodologies, and the assessment of the stock, the understanding of habitats, and ecosystems modeling. Fortunately, fisheries science has lately moved toward the study of essential fish habitats (which in the United States of America jurisdictions is a technical and a legal category under the Magnuson Stevens Fisheries Conservation Act), ecosystems and the ecological impact of fishing activities on the ecosystems. The mandated connection to larger ecosystems and processes has opened a new window of opportunity to formally make the urgently needed connection to the social processes that govern human activities, fishing and otherwise, in the World's oceans and coasts.

What about the human dimension?

A major change in the paradigm of fisheries biology and management is the incorporation of the human dimension in the evaluation of the fishery and the design of management strategies (see De Young *et al.* 2008). However, lip service is only paid in the majority of contexts where this possibility is discussed, or mandated by law. Social sciences, broadly defined, have not made a systematic effort in matching its own interests with the needs of managers and fisheries biologists, who study the cohorts, recruits, spawning stocks, stock biomass, and variations on the theme of the maximum sustainable yield. The natural sciences have done a dreadful job heading into the other direction. Despite these qualms, it is fair to say that both fields have traveled far into the process, and that today we are beyond the first steps after the Magnuson Stevens Act (for U.S. jurisdictions), which required the incorporation of the social sciences in fisheries management. Without abandoning our guiding principles and intellectual loyalties, both camps engaged in interdisciplinary and transdisciplinary efforts to tackle the hurdles imposed by the complex process of fisheries management.

Fisheries management remains a human and a biological endeavor that crisscrosses a diversity of facets of the human and ichthyologic components of ecosystems, entangled by food webs, ontogenetic processes, markets, productive processes, habitats, niches, and policies. History is perhaps the common ground and a field of potential productive interactions. It also provides and opportunity for the engagement of interdisciplinary and transdisciplinary efforts that look at fisheries in a truly holistic and encompassing manner.

Understanding the cultural processes within the spatiotemporal context of nature is critical to the analysis of fisheries; and thus, the role of the social sciences in working with the natural sciences in the design and implementation of an EBFM. It is, to borrow a concept from geographer Carl Sauer, the *standorstproblem*, or the problem of location and processes in landscapes, and that of the human footprint on nature. Nature is, in this view, considered something constructed and modified by culture and vice-versa. That is precisely our view of fisheries: stocks and the biology of fish are concepts that could, in the case of specific and particular physical and historical contexts, be understood only in light of the human processes that shaped the current form of nature, biomass, and resources.

The connection between historical process and the predicament of today's fisheries became more salient for the scientific community in recent years (Jackson 2001, Jackson *et al.* 2001). As the fisheries management establishment moves towards EBFM (and adaptive management), there is a need to develop innovative ways of looking at fisheries data and seek new forms of analysis and solutions. Understanding the connectivity between the ecological, human, and managerial systems on diverse spatiotemporal scales is, in our view, a *sine qua non* condition of this new paradigm (McCay 2009). Accordingly, history and culture provide data and theoretical models for the understanding of the status of the stocks and the potential of fisheries.

We need to include here a caveat emptor on the use of history in fisheries management. Indeed, we think that the historical analysis must be an important component, and a prerequisite for the elaboration of the EBFM, as stated earlier. But scientists (both social and natural) need to have a more critical stance on the application of the historical and archeological methods and "data" in fisheries management. Historical data is not all of the truth, and the "historical record" and "events" are not facts, but interpretations of documents and records (see Jenkins 2003). Too often we see the plotting of historical trends on a chart with numbers and landing data, pretending to be a historical analysis. Such pretension is also common in the indiscriminate use of chroniclers' relations and narratives. What is needed is a critical and comprehensive historical strategy that incorporates the historical record with geological and archaeological data, to produce cautious reconstructions and interpretations of possible paleoenvironments (from a micro and regional perspective), tactics, strategies and practices of resource utilization, conservation and utilization ethics, the structure of the stocks, and the cultural and social ways in which the resources and the ecosystems (or their proxies, seascapes and landscapes) were cognitively perceived, constructed and represented (Dahdouh-Guebas and Koedam 2008). Caribbean researchers are aggressively moving into the historical and archaeological records, to document the trajectory of ecosystems, such as the mangrove forests or the natural and social history of some species, such as conch (Posada *et al.* 2007) and marine turtles (Antczak *et al.* 2007), since pre-Columbian times.

Are Social Sciences the answer?

Social science disciplines are strategically positioned to play a critical role in the process for the formulation of EBFM strategies. There is an urgent need to integrate different types of information into the fishery management decision-making process, and the social sciences offer a smorgasbord of options: spatial analysis, economics, valuation of resources, archaeological reconstructions, historical depictions of fisheries, ethnographies of extraction and consumption, sociologies of labor and value, human behavior, and even the reconstructions of diasporas and transnational fluxes of labor and fishes. The productive intersection of these multiple forms of knowledge and actions is still, in our view, far from reality as we all engage in our own forms of analysis, interpretation and building of sets of solutions based on our findings and scientific (and managerial) paradigms. Our paradigms are, to put it mildly, safe cocoons in which we all can continue producing ideas and conclusions. To move forward we need to engage interdisciplinary and transdisciplinary forms of research and practice. That is, breaking the walls of our own disciplines sharing knowledge and experiences with other colleagues, build ideas, projects and solutions by multidisciplinary teams in which each discipline representative features a porous membrane that allow the absorption of ideas from other fields, world views and even epistemologies. Otherwise, the human component as part of the ecosystem (fisheries, fishers, communities, economies, markets, cultures, social networks and governance) does not make sense, and does not amount to much in the pursuit of solutions.

Is the fisheries management system prepared for non-linear processes?

Order in a system is often threatened with what theoreticians call “a strange attractor.” In the social sciences and the analysis of social systems an attractor is a “non-repeatable happening” or an event while a strange attractor is defined as a sudden shift in the historical interactions. When a strange attractor appears, there is a sudden bifurcation and a switch in the performance of the system. Mosko argues, “disorder … is not merely an abrupt rupture from order, but part and parcel of a process of structured, sequential bifurcations” (2005:15). Bifurcations may appear in the form (and process) of cascades of bifurcations, showing different paths in social process, distancing them from the original steady state of order, we presume.

In fisheries, strange attractors also occur, usually in the form of sudden events that transform or impact the assumed orderly process of governance, scientific analysis and management. Fisheries managers are not prepared to cope with ruptures in the order of things, as they assume that compliance and order are constants in the system. Let’s review a handful of specific cases from our research in Puerto Rico. In 1981 the federal government pushed hard, jointly with Commonwealth officials, for the development of a marine sanctuary (one of NOAA’s many forms of MPA, headed by the Office of Marine Sanctuaries) in La Parguera, Southwest Puerto Rico. The proposal and process came at the worst possible moment, where the relations between local and federal jurisdictions were strained, and in the middle of bitter political and environmental contentions that included the occupation of Vieques Island by the U.S. Navy (Valdés-Pizzini 1990, 2006, Fiske 1992). This event triggered a change in the attitudes and political praxis of the local fishermen (see also Gutiérrez-Sanchez *et al.* 1987, Pérez 2005) that precipitated a boycott, from the fishers of the region, against the local government fisheries-dependent statistics program during a few years (Valdés-Pizzini 1990). Such a boycott has the potential of triggering a cascade effect in the political actions of the fishers (Griffith and Valdés-Pizzini 2002), as well as interruptions in the flow of information and the construction of catch and effort models, that translate in distorted views of the stocks, despite mathematical corrections of these estimates. Privately, some social scientists warned government officials of the possibility of recurrence and the need to integrate fishers in the decision making process.

The fisheries research laboratory (FRL) of the Puerto Rico Department of Natural and Environmental Resources (DNER) produces key statistics on the landings, gears employed, types of catches and sizes and weight of the main species captured in Puerto Rico (see Matos-Caraballo 2008). The staff of the statistic program also produces reports and papers on the output of the fisheries by years or series of years. The information is based on biased data, based on estimates provided by the fishers, who many times fill out tickets at the moment they have to be sent to comply with the requisite. The FRL staff agreed that misreporting is common and that the landing's data are not reliable for stock assessment purposes (SEDAR 2009). Both, the Commonwealth and the Federal government agencies also rely on fisheries independent data, to supplement the characterization of fisheries stocks.

Reports from the FRL demonstrated a strange attractor in 2006: the passing of the Fisheries Regulation (Number 6768 in 2004), which angered fishers to the extent that they refused to provide landing's data (Matos-Caraballo 2008, García-Quijano 2006). The report also documented two other attractors that changed the way in which the local fisheries operated: (1) a continued increase in the price of fuel and (2) the imposition of a 7% sales tax by the Commonwealth, both increasing dramatically the cost of production, and according to their estimate, reducing fishing effort locally. Part-time fishers, as observed by the port agents, retired from the fishery, or fished illegally, without commercial fishing licenses. Numerous events that are changing the structure and shaping (in many different ways) the fishery have been documented. Changes in the labor market have also impacted the number of fishers and the level of effort. However, these observations were made in a cursory manner and without any cross-reference to economic data on the labor market.

How can you manage the fish when you do not know how many there are?

Walters and Martell (2004) raised that rhetorical question in debating the need for quantitative models, objectivity and predictions in fisheries management. Despite the hurdles and difficulties imposed by fisheries as complex systems, the authors argue that scientists making choices on alternatives for management must have indeed some assumptions on "what will happen in the future" if some choices are taken. Choices, decisions, actions are also taken based on some basic presumptions on behavior, which tends to be accurate for fishes, with much less precision for human populations and their preferences and their choices. Human behavioral choices are also culturally (and politically) shaped and constrained, and it is in that context that they must be analyzed.

One of the characteristics of the data traditionally used for fisheries management is that it is linear and general. It shows trends in catches (and effort) over a period of time, depicted in time series, without any spatial reference. Relations and processes are situated in a spatiotemporal scale. In other words, a stock is distributed over an unmeasured spatial area (ecosystems, habitats) over a period of time, and fishing (effort and yield) is the result of a number of choices and actions in specific coordinates in space. Effective fisheries management requires an understanding of effort and how it is distributed through space (Walters and Martell 2004:7). Fortunately, spatial analysis and modeling are becoming important tools in fisheries management.

One of the tenets of the scientific method is the use of experiments to test options, stimuli and designs. Fisheries management is lacking a process of experimentation of management options, due to the cost, temporal implausibility, and level of effort it requires. A historical approach for fisheries has been called for at different levels: to understand trends, to examine the shifting baselines syndrome, to reconstruct the life-history of species, stocks and ecosystems, to reconstruct patterns of effort, to build models of fishing effort over time, and its impacts on the ecosystem.

Walters and Martell's (2004) book, *Fisheries Ecology and Management,* brings to the forefront important problems in the understanding of fisheries. However, it also takes for granted management decisions and choices as the result of a rational analysis that often takes into consideration the tenets of zero-sum game. More important for this discussion, is that they argue that between the data (and models) and the final decisions there is a thought process that evaluates *status quo* (no action) as a rational choice given their personal and social histories. While the argument is elegant and valid they miss the rich landscape of institutional and social culture and behavior that lies in the middle, which is historically and culturally specific. Managers are also actors whose actions may also trigger surges in effort, or declines in certain types of fisheries. Their decisions are culturally bound, and there is an urgent need to study decision makers and choices from a cultural and historical standpoint (Pérez 2005), and from the institutional and structural perspective (Jentoft 2007).

What about the invisible hand of the market?

Abstract and virtual markets where rational buyers and sellers interact following well known patterns of supply, demand, prices, and rational choice exist in the analysis of fisheries scientists, mostly by economists. If there is effort, and resources are invested in production, in order to have an output in the form of yield, then economics and the market are essential components of the analysis of fisheries. In fact, modern fisheries strive because of the real markets at the various levels in which they exist: local, national, regional and global. The market (as an abstraction) determines the flow (in terms of direction and magnitude) of commodities, the possibility of rent and profits, the potential for investment in production and the increase in the capacity of producers and the composition of capital, and the continuation of fishing effort, *ceteris paribus*. That is, if the conditions remain constant or unchanged. In the specific case of fisheries, the "constant" is the ability of nature (the relationship between stock and recruitment) to maintain a flow of fish into the system: a quantity that varies according to a number of variables (and processes). In that context, the system is understood in terms of the maximum sustainable yield curve that sets the limits of the system, the ceiling of production, and the moment in time when fishing is not profitable and the stock cannot continue to produce for the next generations (Iudicello *et al.* 1999, Grafton *et al.* 2006).

The market is also an institution embedded in human culture and thus operates under a number of culturally and socially defined assumptions, over a long historical duration. Anthropology, for example, takes a holistic view at the market from a number of theoretical perspectives, but the discipline tends to underscore the importance of the cultural elements that often defy economic assumptions of rationality and efficiency. In fact, markets and economic production in fishing are conceptualized as systems in which the rational thing to do is to overfish, and the depletion of existing resources is culturally bound to the workings of traditional capitalist and post-industrial economies and societies (Iudicello *et al.* 1999:38). Global markets, on the other hand, determine the fate of fisheries in distant places, as there is an increase in the demand for fish in the industrialized world, a pattern of consumption that dislocates traditional / local markets and production systems (Clover 2006).

The real market, however, is not a condition, nor a variable or a process of interest in the current forms of fisheries management. In the case of the U.S. based fisheries the market exists as an entity separate from the inner workings of the fisheries, and the laws of supply and demand reign supreme under a number of laws and statutes. The National Marine Fisheries Service and the Regional Councils that regulate—jointly with the states and territories—the fisheries operate under the National Oceanic and Atmospheric Administration (NOAA), which is under the Department of Commerce that protects the markets. Thus, the priorities in the system are to affect and regulate production (fishing effort) and not the market, which dominates a vast global landscape of exchanges and relationships in the economy. Most of us working for these agencies have the mandate to improve the market conditions and provide new opportunities to the producers through the development of buyers and tastes for by-catch or underutilized species. In a nutshell, it is not in the mandate of the regional fisheries management councils to regulate the market, except for the prohibition of certain species considered overfished or threatened with extinction.

On a larger, holistic view of the fisheries, markets (the real ones) are important mechanisms to improve consumption, to shuffle commodities, to develop new tastes for new species or forms of cooking and gastronomies, to create dependency on certain species, to satisfy demand for banned species, to alter the pattern of culturally defined fish consumption, and to create new opportunities for businesses within the frameworks of the fisheries. How markets operate in Puerto Rico, the U.S. Virgin Islands and the Caribbean region, and what is their influence in fish consumption and the regulation of certain fisheries remains unknown.

How can we incorporate habitat degradation in the analysis of fisheries and stocks?

There is scientific information that confirms how agriculture, urban development and industrial pollution have adversely impacted the terrestrial and marine environment since the nineteenth century (Warne *et al.* 2005). Deforestation has caused erosion resulting in the sedimentation of seagrasses and coral reefs, the dramatic loss of mangrove forests and the degradation of estuaries (Heatwole 1985). The loss of more than 60% of the mangrove forests, the degradation of wetlands, species loss and the alteration of habitat connectivity and trophic webs must have taken a toll on local fisheries (see Valdés-Pizzini 2007). Coral reefs are in a difficult situation due to a constant loss of live coral cover during the last ten years (García-Saís *et al.* 2005). Environmental scientists are not the only ones to notice this: professional fishers have long been telling us that they have observed clear spatial-temporal correlations between land use changes and pollution effects near the coasts and changes in the health of fishery ecosystems and the abundance of fishery species (García-Quijano 2006, 2009; Griffith *et al.* 2007).

Gil-Agudelo and Wells have documented such processes and their impact for the Caribbean region (2011). They describe, in some detail, the sad predicament of our region impacted by a number of pollutants such as: sewage (domestic and industrial), heavy metals, hydrocarbons, agrochemical and sediments (2011:71-77). These pollutants deteriorate the health of the ecosystems, have a matrix of impact on aquatic life, and ultimately impact human populations and fisheries adversely. In their view, EBFM must prioritize the problem and deal with the source of pollutants, as the key management strategy for the recovery of the ecosystems (Gil-Agudelo and Wells 2011:83). Land-based activities have a detrimental effect on the quality of the waters and the condition of the marine and coastal habitats of the islands of the Caribbean archipelago. According to Sweeney and Corbin there are several hotspots of pollution in the Caribbean, and the impacts of habitat destruction and coastal erosion on the marine biodiversity are damaging the overall capacity of coastal and marine ecosystems (2011:59-66). We have a clear picture of the situation at a regional scale, and for each island-state or territory we have at our disposal reports from government agencies, international organizations, NGOs and independent researchers on the detrimental impact of land-based activities on the coastal ecosystems, driven by government policies, capital investments in real-estate development and tourism, and population growth (an increase in the human footprint in the region from local to foreign influences). Now what? Valdés-Pizzini summarized the issue—in the context of the local fisheries—in, a recent article in the following manner:

> The main question is: How can we incorporate the erosion of the environmental base of the fisheries, into the process of assessing the stocks and analyzing the predicament of the local fisheries? It is evident to us that a number of human processes, on a historical scale, diminished the capacity of the ecosystems to produce fish regardless of the process of fishing mortality. Models in fisheries must take into consideration the transformations in the ecosystems and those changes that alter the structure of the trophic web, as well as the availability of species (in both diversity and biomass) and their potential for recruitment and reproduction. Dramatic changes in the environmental base also have the potential of altering ontogenetic processes of many species. The processes described here also have an impact on associated habitats,

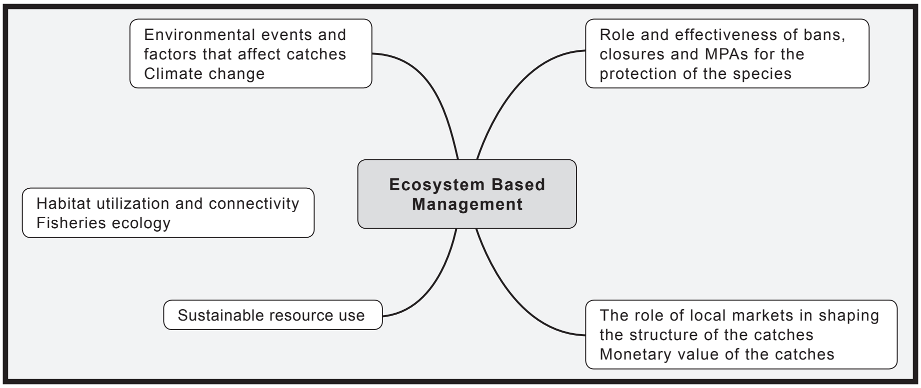
> such as beaches, seagrasses, deepwater reefs of the shelf drop-off and pelagic waters. Again, if estuaries, mangroves, and coral reefs play a critical role in the life history, health condition biomass, and diversity of species, then their state is a factor in the current condition of fish populations and stocks (2007:41).

Answering that question is critical for EBFM in tropical and insular settings where human activities on land have a direct impact on the local, inshore fisheries. Fishers are willing to accept that there has been an increase in effort, and that a number of newcomers into the fishery may have adversely affected some species. In other words, they admit that overfishing is a factor affecting fish stocks, and they are partly responsible. But they also expect scientists and managers to acknowledge that coastal development, erosion, sedimentation, habitat loss and pollution are important processes that must be incorporated into the analysis of the fisheries' predicament, and therefore, in the management and conservation of the stocks. Recent depictions and assessments of the health of the coral reefs in the Caribbean region (Mora 2007), and the U.S. territories (Garcia-Saís *et al.* 2005, Rothenberger *et al.* 2008) have documented the impact of coastal development and agriculture on coral reefs and associated habitats, and consequently on fish populations. But, has the information been translated into variables (or data) suitable for fisheries management?: we do not believe so.

Is research needed?

A recent study (not yet published) by the University of Puerto Rico Sea Grant Program, on the research needs of the region, for the conservation of the coastal and marine resources identified EBFM studies as one of the key priorities in fisheries science. The top priority was the need for "improvement of data collection to maintain baseline information, and stock assessments." Indeed, the need for information on the stocks and the building of strong databases on both commercial and recreational fish stocks was a major concern. For the purpose of this article, we constructed a conceptual map of those concerns raised by the respondents, and the needs identified, which are linked to the EBFM matrix, and may be summarized as follows: (1) effectiveness of MPAs and other management strategies, (2) environmental processes and events, (3) habitat connectivity, (4) the role of the markets and the economic value of the catch, and (5) sustainable use of fishery resources. Indeed, more research is needed, and the construction (and implementation) of an EBFM strategy will require more work and debate in the future, as well as testing through pilot projects.

Figure 2. Fisheries management concerns expressed during the study of research needs of the Caribbean region.



Why (and how to) incorporate social considerations into ecosystem-based management?

That is an obvious question, raised by McConney and Salas (2011) in the Fanning *et al.* (2011a) volume on EBFM for the Wider Caribbean. Both authors present a comprehensive review of those variables and processes that must be incorporated into the EBFM, from the standpoint that it "strives to balance diverse social objectives" (see FAO 2003), and that the use of coastal and marine resources "take place in the context of socio-ecological systems (SES)" (McConney and Salas 2011:100). Their analysis focuses on the need to consider a number of social factors (sans the pure economic analysis), from an applied social science perspective: stakeholders (as per the EBFM participatory dimension), social institutions (behaviors), communities (as the foci of social relations), power and politics (governance), social structure (behaviors and social networks that define the human interaction), culture (beliefs, values and behaviors), participation (again, the central role of stakeholders in the conceptualization of this management strategy), adaptive capacity (a trait of SES and ecosystems relations), livelihoods and poverty (the core of the economic activities, at the individual and firm levels), knowledge (a critical, and yet, misunderstood variable shaping behaviors in the coasts and the waters) and conflict (a constant and a hurdle to participation and governance; McConney and Salas 2011:103-109).

McConney and Salas argue, in a cursory manner, that the success of EBFM depends on the incorporation of the social dimensions, or better yet, to connect the natural order with the social dimensions to conceptualize the system as a SES and its inherent complexity and uncertainty

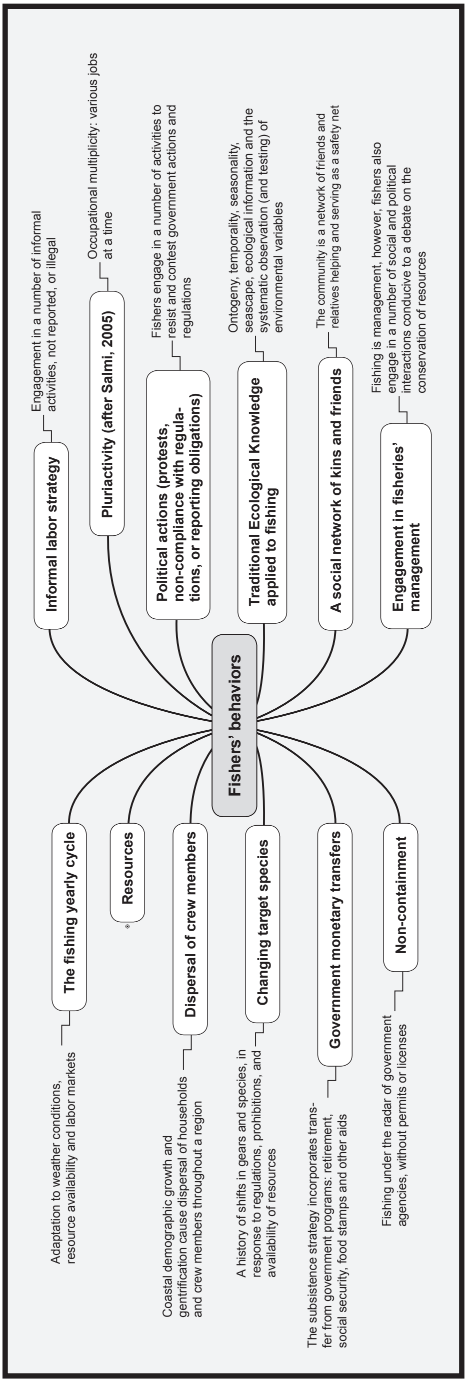


Figure 3. Social complexity of fishers' behaviors.

(2011:109). We have two concerns: (1) the social dimensions—including the economic variables—are (like any other ecological variables) extremely complex, variable and difficult to incorporate into EBFM, that is, in the process of managing the fisheries, and (2) there are no serious and systematic efforts to accomplish the latter, perhaps due to the overwhelming magnitude of the task, or the lack of a strategy to accomplish it. In a recent report on the SES of La Parguera, the authors presented a diagram showing the complexity of the social dimensions related to one group of stakeholders, for which there is abundant information: the fishers (Valdés-Pizzini and Schärer-Umpierre in prep.). We reproduce the diagram here, to present an image of the difficulties that need to be considered to incorporate this particular dimension into EBFM.

On the second concern, we argue here that the social sciences and the natural science keep traversing the management waters following separate courses, without combining forces to tackle specific issues. While Fanning *et al.* (2011a) speak volumes for the need of both forms of knowledge there is a dearth of efforts to achieve that. In fact, the bibliography lacks solid literature on the social sciences of the region, except for a handful of references on stakeholders and social issues of MPAs. For example, a number of articles dealing with species dwell on fisheries biology, while ignoring (or not incorporating) social science research, as in the case of spiny lobster, *Panulirus argus* (Ehrhardt *et al.* 2011), queen conch, *Lombatus (Strombus) gigas* (Appeldoorn *et al.* 2011), some species of deep-water snappers (Heileman 2011), and large pelagic fishes (Singh-Renton *et al.* 2011), to name a few. Each one presents a void in the social data or attends to this void with a general comment on the importance of social issues for the specific fishery examined.

Is there anything good to report?

The answer is a cautious yes. As stated earlier, the solution to the incorporation and application of EBFM will not happen overnight as it requires commitment, the design and implementation of pilot projects, hypothesis testing and modeling, incorporation of a critical historical approach, and the design of an interdisciplinary (or better yet, transdisciplinary) agenda to face the challenge. We are interested in pursuing that agenda in the future, and in building the foundations for the design and implementation we have worked on, or participated in projects and programs heading towards that goal. It seems appropriate to provide a short list of efforts in which these matters are being considered in Puerto Rico, and are indeed preparing the foundation for the implementation of EBFM:

1. The Coral Reef Ecosystem Studies Program (CRES), NOAA-

University of Puerto Rico in Mayagüez. Researchers from marine science and anthropology fields studied La Parguera, to understand coral reef ecology, and the coupling of species and habitats. The program also studied the relationship between the marine and coastal habitats, and the human activities in the watershed. CRES supported a study of the traditional ecological knowledge of local fishers, which provided information on cognition, resource utilization, the historical uses of the area, and the coupling of fishers, species and habitats, in other words, the connectivity between the human dimension and the ecosystem as such (Valdés-Pizzini and García-Quijano 2009).

2. The Caribbean Coral Reef Institute (CCRI), NOAA-University of Puerto Rico in Mayagüez supported research on the historical and institutional processes and mechanisms that facilitated stakeholder participation in the design, development and implementation of MPAs (Aguilar *et al.* 2006). The CCRI also supported efforts of the Interdisciplinary Center for Coastal Studies (CIEL), jointly with NGOs, the municipality and government agencies, to develop a management plan with the stakeholders' participation, which became members of the plan's steering committee. For this a management board was formed with members from the different stakeholder's groups in the municipality. This effort, funded by NOAA required public participation and consultation in the development of the plans. The principle for the preparation of management plans requires the incorporation and interconnection of socioeconomic and historical data in the design of the goals, objectives and work plan. In fact, the DNER Division of Reserves and Refuges has incorporated socioeconomic monitoring (SocMon) methods to gather information for reserve management and planning purposes.
3. The Caribbean Fishery Management Council (CFMC), NOAA, supported the preparation of a protocol to test a model for the incorporation of fishermen and other stakeholders into the process of fisheries management, at the territorial level.
4. The CCRI supported a pilot project for the assessment of the SES of La Parguera using the results of the CRES program, as well as other sources. In our view, the model and procedure, designed by NOAA's National Centers for Coastal and Ocean Sciences (NCCOS), places at the forefront the human dimension as the assessment is guided by societal objectives. This process forces the practitioners to connect the human dimension and its expectations of the larger complex ecosystem.
5. NOAA supported the preparation of a study for the description

and analysis of the fishing communities of Puerto Rico (Griffith *et al.* 2007). The study links behavior, culture and practices to the management decisions and regulations, both federal and territorial.

Final notes on the possibility of an EBFM strategy

In summary, the key elements for the construction of a sound EBFM are: a strong participatory governance; conceptualization of management as a social process; incorporation of processes often labeled as external (such as the markets, natural variability and natural events), acting upon the fishery; and the need for an interdisciplinary research agenda in which the social sciences have a critical role to play. Many countries in the Caribbean, including Puerto Rico may be heading into that direction (Fanning *et al.* 2011a, Appeldoorn 2008). However, the human factor, although thoroughly considered in the debate, it still is an afterthought in the actual management of species regulated by the standards of fisheries sciences. Although managers recognize the importance of including the human dimension in management, they seldom read or incorporate the reports and sociological interpretations of the fisheries (see for example Matos-Caraballo 2008). Our colleagues in the scientific community underscore in their writings the importance of the human dimension for the management of the local fisheries (Appeldoorn 2008, Ault *et al.* 2008) but there is no conceptual connection between management and the data on the human dimension, despite some theoretical collaborations (Appeldoorn *et al.* 2005). Symes and Phillipson (2009) remarks for this situation in the European Community merits to be quoted, as it is applicable for the United States:

> Rather than serving as an active influence in shaping fisheries policy, social issues are seen rather more as the irritating consequences of policy. At best they are considered late in the policy process and usually dealt with in an *ad hoc* manner (2009:3).

Moreover,

> Allied to the scarcity of relevant social data on the fishing industry is a lack of awareness among fisheries administrators of the social ethos, context and relationships of the fishing industry and of the fishing community. This would explain the apparent paucity of ideas when it comes to developing a strategic approach to the social sustainability of the fisheries (2009:4).

It appears that the art, science or alchemy needed to make EBFM happen remains a mystery. To solve it we propose to develop a project for the conceptual management of the Puerto Rican fisheries with the participation of stakeholders (managers, scientists, fishers). The main goal is to develop a model for fisheries management based on the EBFM, a model based on the connectivity model presented here, and revised and tested by the participants. The basic tenets of the project are derived from our examination of the literature, and the lessons learned with fisheries management, social and scientific research, and the lessons learned from our participation in co-management, stakeholders' collaboration, MPA management, regional council deliberations, and the design and implementation of management plans. This non-linear, non-traditional and open process (or model) will be the product of deliberations and decisions made by the participants related to the incorporation of diverse data sets, the formulation of innovative forms of analysis and representation of the data, and democratic decision making in the safe environment of an experimental project. The first challenge consists in taking the key recommendations of our colleagues in the natural (see Sadovy 2005, Appeldoorn 2008, Sale 2008), and social sciences (Jentoft and McCay 1995, Salas and Gaertner 2004, Jentoff 2007, Pomeroy and Douvere 2008), in regards to the potential application of the EBFM, and of democratic governance in an appropriate model. The second challenge is to engage in an interdisciplinary effort, or better yet, a transdisciplinary undertaking that requires a joint form of research and learning under flexible and open mechanisms to develop knowledge that is socially robust (Thompson-Klein *et al.* 2001).

In resource management, engagement in this form of learning and doing requires "consilience", a term popularized by Edward Wilson to describe the search for the intrinsic unity of knowledge that remains fragmented and divided by disciplines, experiences and practices (Roux *et al.* 2006). Consilience is needed to create a "community of practice" that shares and co-produces knowledge and solutions. Stephen Jay Gould, in his last book, *The Hedgehog, the Fox, and the Magister's Pox: Mending the Gap between Science and the Humanities* (2011), takes on E.O. Wilson's interpretation of the concept of consilience. The concept was originally developed by British naturalist William Whewell, in the 19th century, to call for a "single, simple and elegant structure of explanation" (Gould 2011:209), based on the process of "jumping together of disparate facts" (2011:247). For Gould, (natural) sciences and the humanities must work together; jump at unison, to solve complex problems characterized by contingency and emergence, that is, by non-linear complex processes. Fishery scientists (and practitioners of "live" sciences related to fisheries) and social scientists must jump together at the complexity of the task, seeking consensus. Consensus will emerge from: "independent contributions, knitted together by serious and generous dialogue among truly different, and equally valid, ways of knowing, each responsible for a swatch on wisdom's quilt" (Gould 2011:255).

The third challenge consists in leading such community of practice to think in innovative ways, and stray from the traditional way in which fisheries management views economic behavior of the fishers (see Salas and Gaertner 2004). Perhaps fishers have, cognitively and in their practice, a particular schema or model of economic success that challenges the traditional notion of rational economic behavior, as García-Quijano has suggested (2006). The fourth challenge consists in the preparation of a joint (transdisciplinary) model (graphical, mathematical, logical, or other) that could be applied and tested in the real world.

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