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Coupling of humans, habitats and other species: a study of the fishers' traditional ecological knowledge (TEK) in La Parguera

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Abstract.—For generations, fishermen have constructed, shared, and refined knowledge (Traditional Ecological Knowledge) from their perceptions of habitats and species. Following our earlier work in La Parguera, Southwest Puerto Rico, we argue that fishers have a wealth of information on coastal ecosystem ecology, fish behavior, temporal patterns and spatial distribution. Recent work shows that fishers in other areas of Puerto Rico developed schemas that serve as cognitive models associating fishes, groups of fishes and habitats. This article explores the fishers' mental schema of habitats and the habitat-species coupling using the specific example of mutton snapper or *sama* (*Lutjanus analis*). Traditional ecological knowledge can be an important component of information used in Ecosystem Based Management. Furthermore, TEK can provide unique knowledge and perspectives on local ecology and the health of fishery resources.

Keywords.—Coral reefs and associated habitats, Ecosystem Based Management, Fisheries, *Lutjanus analis*, Traditional Ecological Knowledge (TEK)

Introduction

Traditional Ecological Knowledge (TEK) held by small-scale fishers is the result of decades and centuries of systematic observation, data gathering, experimentation and interpretation. Such knowledge guides fishermen in their daily chores in the water and shapes their perceptions of species and the environment. Since the work of Johannes (1981), the study of fishermen knowledge has been an important tool for the understanding of spatial distribution of effort, species richness and abundance, conditions of ecosystems, and location and characteristics of spawning aggregations (Ames 2003, Berkes et al. 2000). Traditional Ecological Knowledge is increasingly recognized as an important tool for fisheries management, as funding for scientific research is not always sufficient for the task of understanding stocks and populations under fishing pressure and habitat degradation. This is particularly so in tropical fisheries occurring in remote or underfunded regions of the world (Johannes 1998, Pauly 1994, Polunin et al. 1996). In Puerto Rico, where the fishing landings data is not adequate to answer critical questions on effort and the health of the stocks (Appeldoorn 2008), TEK could contribute to an increase of the quality and quantity of our knowledge of the impact of fishing activities on ecosystems, the location of spawning aggregations, and the details of the natural history and ontogeny of certain species that are closely monitored by the fishers (García-Quijano 2007).

What do we know to date about the fishers' TEK in Puerto Rico? Regardless of their geographical area, their knowledge is fairly consistent and present similarities across regions (Ross and Banuchi 2006). Fishers tend to classify fish and shellfish, not based on their market price and quality class, but on the habitats in which they live and their behaviors (Valdés Pizzini et al. 1996, García Quijano 2007). However, we did not have, until recently, a clear view of the fishers' schema (mental model) of the habitats and species coupling. This contribution presents findings of a study of fishermen from the Southwest coast of Puerto Rico, with special particular attention to La Parguera, a rural town in the southern municipality of Lajas. Although La Parguera is a recreation and tourism hotspot, fishing remains an important economic and social activity in the area

(Griffith et al. 2007). The main objective of this anthropological study was to understand the connection between the fishing activities and the coral reefs and associated habitats, in a manner that could contribute to the Ecosystem Based Management of the area. We present a qualitative analysis of the fishers' perceptions and knowledge of the habitats and the species, based on their descriptions of "habitats" and the way they view the trophic relations of mutton snapper (*Lutjanus analis*).

Methodology

We employed informant interviews of 30 fishermen from Aguadilla on the North coast to Guánica in the South; with the largest number of fishers interviewed from La Parguera and the nearby landing centers. We selected key informants from a list of names provided by local fishers, making a special effort to recruit those fishers who were widely recognized by their peers and government officials for their high fishery-related knowledge. A battery of in-depth interviews was used to obtain three different types of information: (1) habitats, (2) species, and (3) the relationship between species and habitats.

To elicit information on habitats and species we queried fishers on the types of habitats they recognized, the names of places corresponding to those habitats, the physical characteristics of the habitats, and the species found at each area. As a guide, we used a list of names fishermen use to refer to habitats: (1) *Yerbales*: seagrass beds; (2) *Matales*: reef-colonized pavement; (3) *Rastreales*: scattered coral in unconsolidated substrate; (4) *Veril*: shelf drop-off; (5) *Placeres*: shallow areas in reefs (or deep water, and in the mangrove forest); (6) *Bajos*: shallow areas on the shelf platform or in the deep water; (7) *Secos*: another category for shallow waters; and (8) *Caños*: channels in the estuaries and mangrove forests. A handful of fishers also added the following: *Arenales*: sand areas; *Salitrales*: salt flats and *Fanguizales*: clusters of muddy areas in the reef and in the near shore waters. The description of the benthic areas used here corresponds to the criteria used to classify the structure of benthic habitats in Puerto Rico (Kendall et al. 2001).

The textual data of the interviews was stored and managed with Atlas.ti, a software designed for qualitative analysis. Descriptions of habitats and the lists of species associated to specific benthic habitats were coded and linked to other relevant information in the data set, such as other species and habitats. We produced "semantic networks" (sets of meaningful relationships between the terms in the data set) of specific items (e.g. coral reefs) in the interviews, and drew graphs with the information associated with specific linguistic terms, that served as nodes or central points of information. The semantic networks (showing "habitats", organisms, and their linkages, and their proximity in the fishers'perception) allowed us to visualize the complexity and "hidden" or not easily observable elements of the data. The results presented here consists of our narrative interpretation of the graphs produced by the software for all the habitats (or physical areas) described by the fishers.

To underscore the importance of the fishers' TEK, we took the example of one species, *Lutjanus analis*, and performed a "network analysis" of the information provided by the fishermen. For this exercise we specifically asked fishermen to list the top ten species of which they knew the most in terms of their behavior, abundance and location in fishing areas. From that list we asked them to select the top five species, following the same criteria. Mutton snapper was in the top species in terms of frequency and rank. We asked fishermen to then provide information on the habitats in which the species were abundant, other species associated spatially, the species that prey on them, and those that they ate or preyed upon. Following Luczkovich et al. (2001) we used UCINET 6.0 (Borgatti et al. 1999) software for the analysis of social networks in the visualization of trophic networks by measuring fishers' responses to the three levels mentioned above. Network analysis resulted in a graphical depiction of the proximity of the organism to the central node of *sama* (mutton snapper). Distance is measured in terms of the number of times that the fishermen indicated that the organism was prey, predator, or an organism associated spatially to mutton snapper. The result is a graph showing the network or "conceptual map" of the trophic relations, according to the fishers.

Results

Habitats described by the fishers

The fishers'schema of habitats is straightforward. First, habitats and species are geographically connected. Second, each habitat has specific physical features and species associated with it. In fact, for each habitat the fishermen listed groups of names of organisms that were unique to that area. Third, habitats have, in most cases, geographical names and are recognized by such names in each area (e.g. the reefs: Margarita, Turrumote, El Hoyo, etc.). Fourth, fishers recognized specific physical features and characteristics of many habitats. Fifth, the fishers provided information on the characteristics of three types of areas that, in general terms referred to shallow areas. These were: *bajos*, *placeres* and *secos*. These three areas occur either on the insular shelf, or at the outer banksshelf. *Placeres*, an old Spanish maritime word for a shoal, is often used for very shallow protected waters inside the mangrove forests and coastal lagoons. However, *placeres* are also very shallow extensions on either the shelf or at the outer banks. *Bajos* or low areas are also shallow extensions in areas of reefs or in seagrasses, and are often associated with coral reefs, and a rich biodiversity of species and marine organisms. *Secos* (dry areas) was perhaps the most ambiguous category, as the fishers had different definitions and use the term to refer to different bottom typess. Overall, there was consensus that it was a shallow area and in most cases, navigation there was rather difficult, mainly during low tide.

In this section we describe the basic attributes that the fishers ascribed to the habitats, including the species associated with them. For each site, the fishermen provided a list of the key species of fishes, invertebrates and other organisms that characterize the area. To synthesize the data, we provide a short description of the habitat and the "ensemble" of organisms that they provided for each site.

Yerbales or seagrass beds were characterized as shallow areas covered by seagrasses (both *Thalassia testudinum* and *Syringodium filiforme*), inhabited by a large number of invertebrates such as crabs, lobsters, and conch. A number of fin fishes were associated with seagrasses, mostly yellowtail snappers, mutton snappers, parrotfish, grunts, and others. *Yerbales* was described as a garden, a forest (meaning richness in biodiversity) and a nursery for a number of species. Although this may be a subjective interpretation on our behalf, the network views generated in Atlas.ti suggest that fishers conceptualize seagrasses as rich and physically irregular habitats where sand patches, corals and muddy bottoms may be also found. Seagrassess are also the habitat connected to other benthic habitats and thus are recognized as playing a key role in marine ecology. Large extensions of seagrasses as well as patches scattered on the bottom connect with other habitats including the pathway to the shelf edge.. In fact, some descriptions of La Parguera, fishers simply refer to the area as a large seagrass bed, interrupted by coral reefs and shoals. The Pitahaya area (West of La Parguera) was the key area named as a seagrass bed, although the fishers described the nearshore areas of Guánica as having seagrassess.

Rastreales (scattered coral on unconsolidated sediments) are considered by fishers as a variation of the seagrass bed, with sparser vegetation and the presence of some hard and soft corals. *Rastreales* are actually a transition zone between coral reefs, segrasses and the shelf edge. They are found close to the seagrass beds but are not an essential part of them. This concept is interesting as it does not have a formal Spanish word, except for the verb *rastrear*, to rake the bottom of the sea with a gear, such as a trawling net. The description that fishers use resembles a bottom with vegetation and scattered corals that have been raked. Information from the interviews suggests that for the fishers the *rastreales* are also a transition to more densely populated bottoms in which coral reefs dominate.

Matales is a Spanish term that evokes an area rich in plants (*mata*) although it uses an awkward plural form. Fishers use the term *matales* for coral reefs. The description and the species named for the coral reefs were many, and the names coincide with the species one expects to find in reefs: (1) Coral reefs have a variety of forms and shapes that define the bottom areas in which they are found: dispersion and concentration of corals, differences in bottom rugosity. (2) Biodiversity encompasses associated organisms including different types of corals, soft corals (some interviewees used the term "plants" or *matas*), and sea fans; sponges; eels; algae; as well as diverse fishes, most of which are of commercial value. For example, fishers mentioned the following fishes: shallow water snappers and groupers, trunkfishes, parrotfishes, grunts and mutton snapper, among others. (3) There is a gradient of density of biodiversity from the shoreline (low density) to the outer limits of the shelf (high density).

Fishers give the shelf drop-off the name of *veril*. The *veril* is defined as an area where the platform ends and deep waters begin with an abrupt change in the topography. In their view it is a continuum of habitats that includes areas either with a steep slope and a sharp change in depth or a sharp slope characterized by a wall and shoals intersecting rocky areas at great depths. Once the *veril* starts, there is a combination of deep water, pelagic fishes and bottom species, found at different depths. The *veril* is also a geographical marker that may lead to other areas, such as the *bajos* and *placeres*. The *veril* was unanimously classified as one of the richest areas, and one with great biodiversity, as fishers recognized the following complexes: (1) pelagic species (tunas, wahoo, marlins, dolphinfish, barracudas, and mackerels); (2) deep-water reef species, such as lobsters, triggerfish, mutton snappers, yellowtail snappers; and (3) deep water snappers and groupers (*Lujanus vivanus*, *Etelis oculatus*, *Epinephelus mystacinus*) and shark species.

The most important results from this procedure were the following. (1) Fishermen recognized all of the areas and provided specific information on the physical characteristics of each "habitat", and the specific geographical names given to each type of habitat (although some indicated that those areas were uncommon in their region, and thus did not offer names). (2) Interviewees provided information on connectivity among different habitats. It is clear from the data that fishers conceptualize habitats as belonging to a continuum of places (a habitat gradient) that links them physically and in terms of the species assemblages that populate the habitats. (3) For each habitat the interviewees provided a description of the species found in each area. Although most of the species provided were commercial fishes they exploit, a number of fishers also listed other organisms found in the area.

Habitats and species coupling: a case study of mutton snapper

Mutton snapper is among the top 15 species landed in Puerto Rico, and represents 2.5% of the landings (Matos Caraballo et al. 2006). Fishermen interviewed in 1998 ranked this snapper seventh in their list of preferred (sought after) species in the area of La Parguera. The spawning migration of the mutton snapper (*la corrida de la sama*) during the spawning season is an important event for the fishers who describe peak abundances for this species from February to May.

Our research produced networks for ten commercially important species and their ecological / trophic relationships, as constructed cognitively by the informants. We measured the level and intensity of the networks by calculating frequencies, which provide a visual sense of proximity among those species with more centrality. That is, species more closely associated (in measurable distance) to the central node of mutton snapper were mentioned the most, and thus have some centrality in the fisher's model of the trophic relations. In other words, network analysis reproduces graphically the knowledge fishers have of predator-prey relations. The closer the names of the organisms are to the center bearing the name of the fish (*sama*, in this case), the higher their prominence in the fishers' mental schema.

That is, they tend to recognize those organisms more frequently than others, and therefore, we assume that they are more evident to them, as they observe nature in their fishing activities.

The main product from our analysis is the "construction" of a series of figures depicting trophic relations (predator, prey, and associated), first, as stated by the fishers in Spanish (Figures 1, 2, 3 and 4) and the complete "conceptual map" with the scientific names (Fig. 5). The sources we examined suggest that there is a high level of coincidence between the fishers' reconstruction of trophic relations, and that to be found in the scientific literature (Nagelkerten et al. 2006, Duarte-Casares and García 1999, Randall 1967). Sharks are one of the key predators of mutton snappers. However, fishermen did not mention other snappers as predators, as the literature suggests. This discrepancy may be due to the fact that fishermen target adult mutton snappers, and thus are not aware on the ontogenetic connection to habitat. Fishers also mentioned barracudas, eels and mackerel as predators (Figures 4 and 5).

According to the fishermen, *Lutjanus analis* is closely associated with other lutjanids and reef fish such as yellowtail snapper, lane snapper, red hind grouper, moray eels, blue runners and trunkfishes (Fig. 5). In other words, it is mostly associated with other predators in coral reefs and associated habitats such as seagrass beds. In terms of prey, the information (Figures 2 and 5) coincides with scientific knowledge, that mutton snapper are euryphagic carnivores that utilize a wide range of foods, feeding on invertebrates (clams, mussels, crabs, gastropods, octopods, hermit crabs and shrimp) and a number of fishes (Randall 1967).

Discussion and Conclusions

A key finding of our research is that ecological thinking is a key component of small-scale fishers' cognition of the seascape. It guides their activities as well as their folk taxonomies. Recent research has pointed out that ecosystem-like concepts for describing the biophysical world are not new; in fact, there are numerous examples of ecosystem-like concepts that guide cognition and behavior in traditional subsistence-oriented cultural groups (Berkes et al. 1998).

In our TEK work in the south coast of Puerto Rico, we also explored fishers'

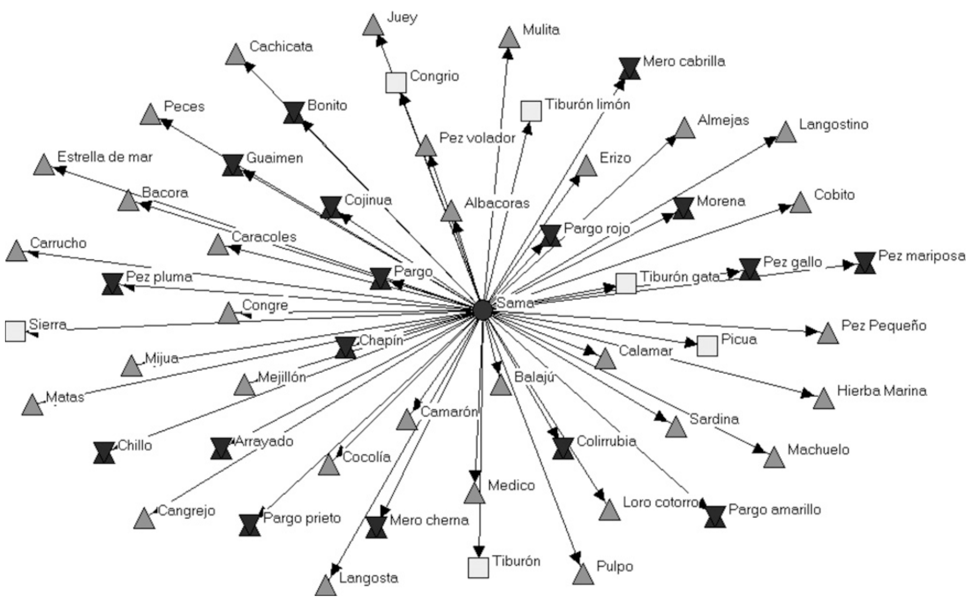

Fig. 1. Network graph showing predators (squares), prey (triangles) and organisms associated to *Lutjanus analis*, according to fishermen.

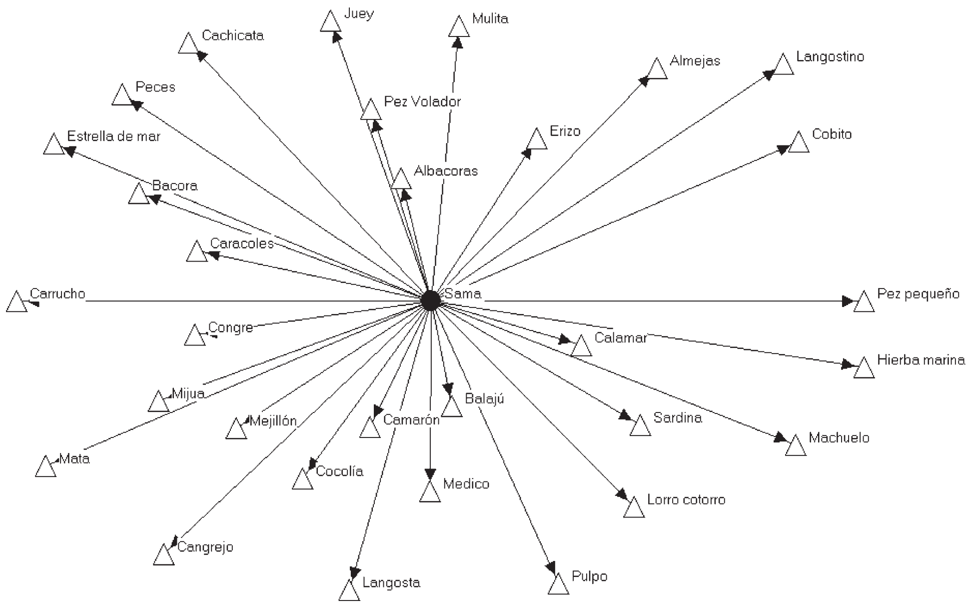

FIG. 2. Network graph depicting prey for *Lutjanus analis*, according to fishermen.

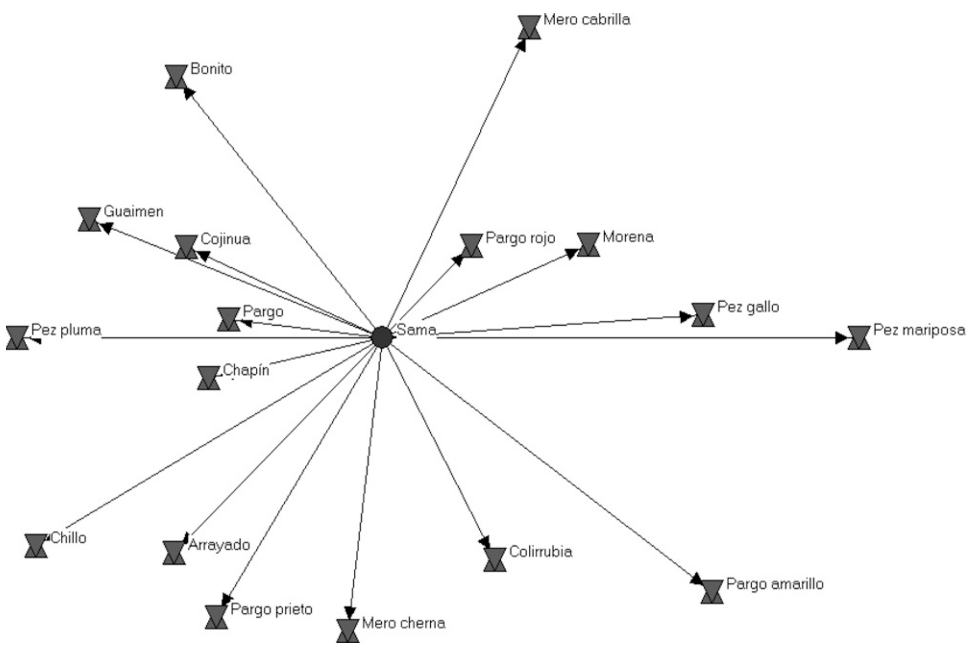

FIG. 3. Network graph depicting organisms associated with *Lutjanus analis*, according to the fishermen.

ecological thinking by the analysis of 'ecological narratives' about fishing and the local environment (Garcia-Quijano 2006; 2009). A prominent topic in fishers' narratives was their emphasis on knowing the fishing areas, simply defined as specific sites where fish can be caught. The ecological parameters (Johnson et al. 1968) of the fishing areas (e.g. bottom / substratum composition, depth, salinity, water turbidity, sediment input, currents, prey species populations, and the species assemblages found) determine what species can be found by fishers and in what quantity. Some localities, such as specific seamounts, reefs, and seagrass beds have been productive fishing grounds over time and are recognized as such (and hence named) by the fishers. When fishers describe a fishing area, and are asked to identify the ecological parameters that define it, they include the type of habitat, defined by the type of bottom substratum, and the availability of food for the targeted species. A fishing area may only be considered as such during certain times of the year due to either seasonality or ontogenic development of specific fishes. Fishers realize that many species are predictably seasonal in their movements between habitats and/or geographic locations and they move their fishing effort between habitat patches as productivity varies seasonally (e.g. Aswani and Lauer 2006).

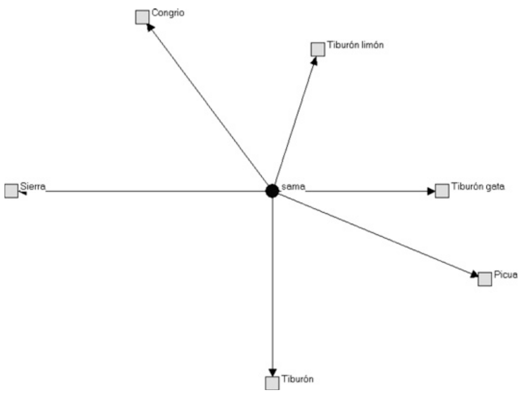

FIG. 4. Network graph depicting predators of *Lutjanus analis*, according to fishermen.

In general, fishers have a good working knowledge of the species and the ecosystems in which they operate, as that knowledge is critical for their success. However, there are also differences in the depth, quality and specificity of their knowledge. First, fishers are limited by the geographical area that they utilize. Most fishers can make a

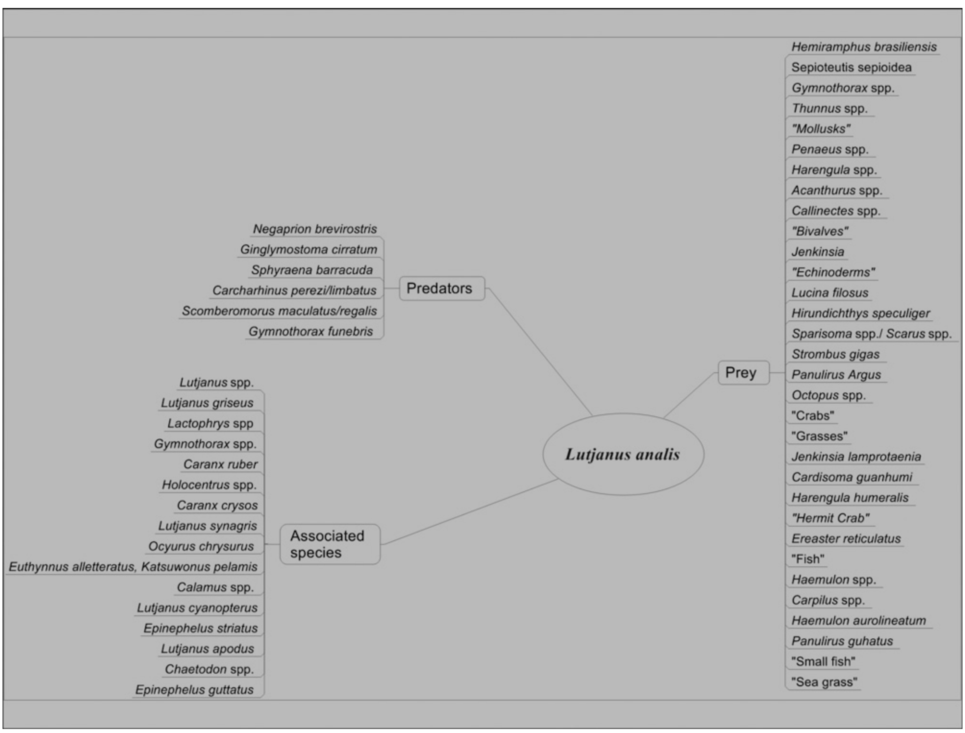

FIG. 5. Conceptual map of the names and scientific names of species and organisms linked to *Lutjanus analis*, as predators, prey and associated species, according to fishermen.

good assessment of habitats close to their home base (i.e. 15 to 20 mile radius). Second, they are limited by their fishing gears and daily activities. Some fishers specialized on near shore and mangrove areas, others in deep water fishing (snapper-grouper complex), and the majority have experience with the fish and shellfish of coral reefs and associated habitats. Garcia-Quijano (2007; 2009) found that fishers selected randomly from license records correlated highly with fishers who were selected for their greater knowledge of key characteristics of exploited species' ecology. This is primarily due to fishers' mobility between types of fisheries over time and, to an extent, their communication with other fishers. Thus fishers in general had a working knowledge of those areas they did not usually exploit, and recognized the key physical characteristics of each area.

As the problems and challenges facing coastal fisheries around the world become both more complex and more urgent, all sources of knowledge including TEK for insight into fisheries ecology and the state of resources should be tapped by resource managers. One of the goals of Ecosystem Based Management is based on an understanding of the ecosystem, and the human interaction with species and habitats, including the knolwedge that resource users have accumulated historically (Helfman 2007). A key insight resulting from our research with Puerto Rican fishers is that, just like fishery scientists and managers, fishers 'think ecologically' when they engage with coastal ecosystems. Recognizing and building on this conceptual common ground can result in increased knowledge sharing and collaborative management with fisheries scientists and government ecosystem managers.

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