Summary of participatory modeling workshops to understand ecological, social and economic dimensions of the Puerto Rican lobster fishery

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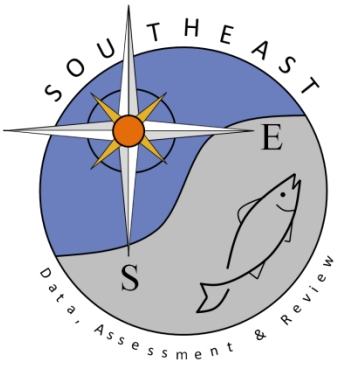
SEDAR91-DW-02

1 November 2024

Updated: 10 January 2025



Please cite this document as:

Agar, Juan, Mandy Karnauskas, Matt McPherson, Kelsi Furman and Manoj Shivlani. 2024. Summary of Participatory Modeling Workshops to Understand Ecological, Social and Economic Dimensions of the Puerto Rican Lobster Fishery. SEDAR91-DW-02. SEDAR, North Charleston, SC. 13pp.

SEDAR91-DW02

Summary of participatory modeling workshops to understand ecological, social and economic dimensions of the Puerto Rican lobster fishery

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1. Introduction

This working paper presents qualitative data from workshops with spiny lobster commercial fishers in Puerto Rico. Workshops were designed to gather fisher perspectives and knowledge to better understand the local social-ecological dynamics driving the fishery. This approach was adapted from previous Southeast Fisheries Science Center research for SEDAR 74 Gulf of Mexico red snapper (Gervasi et al. 2022; Gervasi et al. 2023).

This research addresses the SEDAR 91 Caribbean spiny lobster data workshop term of reference #1, to ***"review available data inputs and provide tables and figures including, but not limited to: a) commercial and recreational catches and/or discards; b) length/age composition data; c) life history and ecological information; d) indices of abundance; and e) data through at least 2022."*** The specific data provided includes: socioeconomic system dynamics; local ecological knowledge of environmental, physical, and biological drivers; perceptions of abundance and population dynamic changes; and impacts of regulatory actions. This research also serves to inform term of reference #2, to ***"provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment."*** This research is still in progress and findings summarized here are preliminary.

2. Methods

Fishers were consulted for this project via in-person workshops. Knowledgeable spiny lobster commercial fishers in Cabo Rojo, Ponce, Naguabo, and Vieques were identified via multiple "entry points" to ensure to the extent possible that a diversity of opinions were accessed. Contacts were recommended by Puerto Rico's Department of Natural and Environmental Resources (DNER), the Caribbean Fisheries Management Council, and NOAA Fisheries. From these contacts, we attempted to balance individuals who have been regularly involved in the management process as well as those who have not.

Workshops were conducted from July 30 – August 2, 2024 (Table 1). Fishers were asked a series of open-ended questions with the goal to address the following research questions:

- What are the main environmental and socioeconomic factors that influence the Puerto Rico spiny lobster fishery and spiny lobster populations?
- What were the main technological and regulatory impacts that affected the Puerto Rican spiny lobster fishery?
- How do changes in the ecosystem affect businesses and communities?

The workshop agenda and questions were adapted from previous participatory modeling approaches used by the Southeast Fisheries Science Center (McPherson et al., 2022). The workshops consisted of several components. We began with opening remarks outlining the objectives of the workshop, followed by participant introductions and a discussion of expectations. This was followed by an activity in which participants graphed and discussed their perceptions of changes in spiny lobster stock abundance and revenues over time. This activity served as a segue into a participatory conceptual modeling exercise, where participants identified physical, biological, social, and economic factors perceived to affect lobster abundance and the interconnections between these factors.

As part of the modeling process, fishers described their perceptions of environmental change over time, how they make decisions regarding fishing effort, size preferences, discard practices, gear and technology usage, changes in fishing techniques, market dynamics, and profits. Once the model was complete, participants highlighted the most important factors in the system, identified the biggest risks to the fishery, and expressed their values regarding preferred management approaches. The workshop concluded with another graphing activity to capture perceptions of changes in critical factors over time, including trends in catchability, seasonality, shifts in gear usage, and other factors that could impact selectivity and catchability.

Table 1. Summary of workshop dates, format, number of participants, and background of participants.

Workshop location	Dates	Format	Number of fishers	Gears used
Cabo Rojo	July 30, 2024	In-person	10	Mostly fishers who used traps and SCUBA
Ponce	July 31, 2024	In-person	15	Mostly fishers who used traps and SCUBA
Naguabo	August 1, 2024	In-person	17	Mostly fishers who used traps and SCUBA
Vieques	August 2, 2024	In-person	22	Mostly fishers who used traps and SCUBA

3. Results

3.1 Environmental Drivers

A variety of environmental factors were identified as influencing lobster dynamics (Table 2). Many of these factors were thought to influence the distribution or movement of lobster. Other factors influenced lobster abundance directly or indirectly. Environmental drivers also impacted other aspects of the fishery, such as the amount of effort that could be employed to target lobster or habitat impacts, which then indirectly were perceived to influence lobster dynamics. Workshop participants also differentiated between the wider Caribbean lobster stock and the local subpopulation that was the target of their fishing operations, and they described how particular environmental factors impacted the immigration or emigration of lobster with respect to the larger Caribbean-wide stock.

Table 2. The various environmental drivers mentioned in the workshops, areas in which these drivers were mentioned, and the particular impacts that were perceived.

Driver	Municipality	Impacts of driver
Ocean temperatures	Cabo Rojo, Naguabo, Ponce, Vieques	Ocean temperatures were thought to impact growth rates and reproduction rates of lobster; it was noted that higher temperatures are associated with reproduction at smaller sizes as well as more frequent molting. Temperatures are

		also thought to impact lobster distributions, with high ocean temperatures inshore pushing lobster into deeper waters.
Earthquakes	Cabo Rojo	Earthquakes were observed to change the bottom habitat and distribution of lobster.
Hurricanes	Cabo Rojo, Naguabo, Ponce, Vieques	Hurricanes contribute to heavy rainfall associated with increased nutrients from watersheds, and also damage coral reef habitat, both of which are perceived to impact lobster distributions. The exact impacts of hurricanes depend on the strength and how exactly they hit the fishing areas, but some hurricanes such as Maria were described as "cleaning the bottom" and after a short time, lobsters return to impacted areas in abundance. Hurricanes also influence the type of gear that is used because they contribute to high numbers of traps lost and these take investment and time to replace. Hurricanes passing nearby the islands cause extended periods of bad fishing weather and can reduce overall fishing effort.
River nutrients	Cabo Rojo	Nutrient discharge from rivers, particularly in large pulses after events such as hurricanes, were thought to influence the distribution of lobster. Specifically, lobsters move away from low salinity waters.
Cold fronts	Cabo Rojo, Naguabo, Vieques	Cold fronts were thought to drive immigration of lobster and movement between areas; cold fronts are associated with increased lobster abundance.
Climate change	Cabo Rojo, Naguabo, Ponce, Vieques	Climate change was perceived as a highly influential factor with indirect links to lobster dynamics via multiple drivers, such as increasing ocean temperatures, increasing severity of hurricanes, and coral bleaching.
Currents and tides	Vieques	Particular current patterns and tidal patterns, which are prominent during particular seasons or moon phases, are thought to drive immigration and movement of lobster.
Contamination	Naguabo, Ponce	Nearshore contamination, from rivers, or point sources such as factories, is thought to impact the inshore areas and cause lobster to move further offshore.

3.2 Biological Drivers

As with the case of environmental drivers, multiple biological drivers were identified by workshop participants (Table 3) that were thought to influence lobster abundance directly (e.g. through mortality) or indirectly (through movement or immigration).

Table 3. The various biological drivers mentioned in the workshops, areas in which these drivers were mentioned, and the particular impacts that were perceived.

Driver	Municipality	Impacts of driver
"slimy" red algae	Cabo Rojo, Ponce	Participants described the appearance of an unknown type of new red algae in recent years which was perceived to impacts lobster distributions; fewer lobsters are found in lobster caves where the algae are prevalent. The algae also reduces visibility for divers and impacts efficiency.
Habitat changes	Cabo Rojo, Naguabo, Vieques	Changes in the habitat, such as coral reef destruction from hurricanes, is perceived to affect the distribution of lobster. In Vieques there was heightened concern regarding habitat degradation, particularly as it relates to the historical uses of the island, irresponsible tourism activity, and coastal development. It was also noted that as the habitat condition degrades, there are fewer areas for lobster to live which increases their vulnerability to fishing.
Sargassum blooms	Naguabo, Ponce	Sargassum was recognized as an essential habitat for many species, but heavy nearshore blooms were thought to have negative impacts on the lobster stock. Sinking Sargassum was noted to smother lobster caves and render them inadequate for lobster habitat. Sargassum is also a nuisance for fishers as the thick blooms cause motor entanglements.
Depredation	Ponce, Vieques	In Ponce, several species were thought to contribute significantly to lobster mortality via depredation (groupers, nurse shark, octopus, and queen triggerfish). In Vieques, reef fish in general were associated with depredation; it was observed that in areas with more reef fish present there were fewer lobster.
Fish populations	Naguabo, Vieques	In Naguabo, lionfish were perceived to outcompete lobster by inhabiting their caves. In Vieques, reef fish populations in general were thought to impact the abundance and distribution of lobster as they compete for space and are also predators.
Artificial reefs	Cabo Rojo	The installation of artificial reefs makes lobster more accessible to fishers and increases catchability. (This was only mentioned in Cabo Rojo and it is not clear if the practice exists elsewhere in Puerto Rico).
Management of upstream populations	Vieques	Lobster populations of upstream islands (USVI) are important sources of recruitment and it was perceived that successful management of USVI populations and high abundance of lobster in those islands was a contributor to high recruitment in the Vieques area.

Of all of the drivers discussed, participants were asked to identify those factors that were thought to be particularly influential or concerning. Across all regions except Ponce, participants indicated that climate change was a particular concern. In Cabo Rojo, hurricanes and artificial structures (lobster shelters or "casitas") were also thought to be highly influential. In Ponce and Naguabo, coastal contamination was emphasized, and in Vieques, coastal development was also identified as a primary driver.

3.3 Socio-Economic Drivers

Puerto Rican workshop participants reported adjusting their catches based on market demand rather than resource abundance. They increase fishing during peak seasons and scale back or target other species during low demand periods.

Fresh lobster is preferred by both tourists and locals. Frozen lobster tends to become gelatinous and lose flavor, making it less desirable for restaurants. This creates pressure to sell quickly, as fishers cannot easily store excess lobster for later sale. In times of oversupply, prices may drop from $10/lb. to $6-8/lb. to move the product. Some participants noted that during low demand periods, fishers sell directly to households rather than restaurants. Additionally, during the conch closed season, fishers focus more on lobster, which fetches higher prices than fish. The reduction in fish traps is attributed to poaching rather than low lobster abundance.

Lobster demand in Puerto Rico is primarily driven by tourism and local consumer demand. In Vieques, participants noted that most of their local lobster production is purchased by a few wholesalers at moderate prices ($7-8 per pound), with only a small portion going to local restaurants. These wholesalers typically market the lobster on the main island, particularly in the San Juan metropolitan area and Naguabo.

Table 4 illustrates fluctuations in lobster demand throughout the year. From January to April, tourist demand for lobster is consistently high, aligning with the peak tourist season. Local demand is low in January and February due to preferences for traditional foods like turkey and piglets. However, it peaks in March and April due to Lent, which increases fish consumption. From May to July, tourist demand is moderate. Local demand rises in May due to Mother's Day and graduations, continues in June with Father's Day, and peaks in July with Independence Day and Puerto Rico's Constitution Day. From August to October, both tourist and local demand are low. Concerns about hurricanes, tropical storms, and power outages reduce spending on lobster. The reopening of schools also impacts local demand. In October, tourist demand remains low, though some tourists start visiting for the winter season. Local demand is low as Thanksgiving approaches, with preferences for traditional foods. From November to December, tourist demand increases as the winter season approaches. Local demand remains low in November due to Thanksgiving preferences but stays low in December as Christmas traditions favor piglets and turkey over seafood.

Participants reported that seafood demand in Puerto Rico is geographically dispersed. Wholesalers purchase locally caught fish and distribute it to restaurants and hotels in the metropolitan area of San Juan. When fishers sell to pescaderías (fish markets), fish cooperatives (villas pesqueras), and restaurants, sales are primarily for the local market. Wholesalers generally offer higher prices compared to local pescaderías.

Villas pesqueras are non-profit organizations that provide fishers with benefits such as access to docks, lockers, and other facilities in exchange for selling their catch at slightly below market price. However, participants noted that there is a growing trend of fishers diversifying their sales channels beyond these villas. This shift is driven by several factors: villas pesqueras often offer lower prices compared to other buyers, have membership fees, and restrict fishers from selling their catch elsewhere without authorization, which is typically granted only when the freezers are full. Matos-Caraballo from (DNER) highlighted that many villas pesqueras currently limit their own seafood purchases. For example, in Puerto Real, Municipality of Cabo Rojo, some villas only purchase on Mondays and Thursdays, but permit their members to sell to restaurants or along the roadside on other days.

Table 4. Seasonal Demand in the Commonwealth of Puerto Rico as reported by workshop participants.

Month	Lobster Demand from Tourists	Lobster Demand from Locals	Notes
January	High	Low	High tourist season; locals eat traditional foods such as turkey and piglets
February	High	Low	High tourist season; locals eat traditional foods, slight increase for St. Valentine
March	High	Improving sales due to Lent	High tourist season; Lent season increases seafood consumption
April	High	High sales due to Lent	High tourist season; Lent season increases seafood consumption
May	Moderate	Increased sales for Mother's Day and graduations	Shoulder tourist season; Mother's Day and graduations increase seafood consumption.
June	Moderate	Good sales, Father's Day	Shoulder tourist season; Father's Day celebrations, though not as significant as Mother's Day
July	Moderate	High sales for 4th and 25th of July	Low tourist season; 4th (Independence Day) and 25th (PR Official Constitution) of July increase seafood consumption.
August	Low	Low	Low tourist season; fear of hurricanes and tropical storms, fear power outages (LUMA) spoiling seafood in restaurant freezers, and school reopening reduce spending on seafood

September	Low	Low	Low tourist season; fear of hurricanes and tropical storms, fear power outages (LUMA) spoiling seafood (restaurants) and school reopening reduce spending on seafood
October	Low	Low	Low tourist season but some start visiting for winter; Thanksgiving reduces local demand of seafood because locals prefer piglets and turkey during this season
November	Moderate	Low	Low tourist season but some start visiting for winter; Thanksgiving reduces local demand of seafood because locals prefer piglets and turkey during this season
December	High	Low	Tourists visit during holiday season; Christmas reduces local demand of seafood because locals prefer piglets and turkey during this season

Factors Affecting Supply and Demand

Workshop participants identified several significant factors influencing the supply and demand of seafood, particularly lobster. Table 5 provides a concise overview of the primary issues discussed during the workshops.

Table 5. Key factors affecting lobster supply and demand in the Commonwealth of Puerto Rico as reported by workshop participants.

Issue	Municipality	Impact on Supply/ Demand	Description
Seasonal Migration	Cabo Rojo, Naguabo, Ponce	Supply	Lobster abundance increases from November to April due to natural migration patterns.
Conch Closure	Cabo Rojo, Naguabo, Ponce, Vieques	Supply	When the conch fishery is closed, fishers focus more on lobster fishing. Conch is often referred to as "gold" due to its consistent demand and higher market value.
Competition from Other Municipalities	Ponce	Supply	Competition from other municipalities affect local lobster markets. Lobsters from other areas are be sold at lower prices, impacting local fishers.
Artificial structures (casitas, zinc plates)	Cabo Rojo	Supply	Availability of artificial structures like casitas (artificial shelters) can increase lobster aggregation by providing habitats.

Coastal Development, Sewage, Contamination	Cabo Rojo, Ponce, Naguabo, Vieques	Supply	Construction and uncontrolled development lead to habitat destruction and contamination (Cabo Rojo, Vieques). Pollution from petrochemical plants and sewage (Ponce) Contamination from past military activities, such as unexploded bombs and chemical pollutants, can impact lobster habitats and health. In Vieques, the lagoon Nones is highly contaminated with bombs, which affects the coastal environment (Vieques). High cancer rates among fishers in Vieques. Contamination from rivers, factories, marinas pushes lobster offshore (Naguabo)
Aging fisher population	Naguabo	Supply	Fewer young people entering the profession reduces the number of active fishers.
Red algae (alga "moco rojo" in Cabo Rojo) Algae ("alga babosa" in Ponce) Sargasso (Naguabo, Ponce)	Cabo Rojo, Ponce, Naguabo	Supply	Algae lowers the visibility of divers and clogs lobster caves "Moco rojo" drives away conch. Sargasso clogs lobster caves (Naguabo,Ponce).
River/ freshwater outflows	Cabo Rojo	Supply	Lobsters shy away from low salinity environments.
Predators	Ponce, Naguabo, Vieques	Supply	Predators like nurse sharks, groupers, octopus and queen triggerfish impact lobster populations.(Ponce) Lionfish enters lobster cave and eats it (Naguabo) Sea turtles, queen triggerfishes and boxfishes (chapines) are predators of lobster (Vieques) Red hind (mero cabrilla) competes with lobster for space (Vieques)
Back to School	Cabo Rojo, Naguabo, Ponce, Vieques	Demand	The start of the school year reduces local demand for seafood as families focus on other expenses.

Seasonal Tourism	Cabo Rojo, Ponce	Demand	Higher demand for lobster during peak tourist seasons (December-April). Some restaurants close during off-seasons (September-November), reducing demand.
Holidays and Special Occasions	Cabo Rojo, Naguabo	Demand	Demand spikes during religious observances (e.g., Lent), special occasions (e.g., Mother's and Father's Day, graduations) and holidays (e.g., 4th and 25th of July).
Consumer Preferences	Cabo Rojo, Naguabo, Ponce, Vieques	Both	Consumers prefer fresh lobster since they don't freeze well, affecting marketing and pricing strategies.
LUMA Power Supply Issues	Cabo Rojo, Naguabo, Ponce, Vieques	Both	Frequent power outages and high electricity rates under LUMA have created storage issues, increased operational costs, and disrupted the supply chain.
Hurricane Impact	Cabo Rojo, Naguabo, Ponce, Vieques	Both	Hurricane Maria damaged lobster habitats, initially reducing populations but they have since recovered. Caused major disruptions and damage to local infrastructure. Initially reduced tourism but increased demand from rebuilding workers. Some residents displaced.
Rising Costs	Cabo Rojo, Naguabo, Ponce	Both	Increased costs of fuel, materials, and equipment affect both supply capabilities and pricing strategies. Increased cost of living was also mentioned.
Hurricane Season	Cabo Rojo, Naguabo, Ponce, Vieques	Both	Many restaurants close in September-October, significantly reducing demand.
Competition from Imports	Cabo Rojo, Naguabo, Ponce, Vieques	Both	Imported seafood affects local market dynamics and pricing for lobster.
Unlicensed/illegal/Recreational fishing and sales	Cabo Rojo, Naguabo, Ponce, Vieques	Both	Unlicensed fishers undercutting prices, depleting stocks, and taking advantage of known fishing spots. These issues affect both lobster and conch fisheries. Poaching of traps by recreational and commercial divers. Restaurants may buy illegal catch at lower prices, reducing demand for legally caught seafood.

Technological Advancements

Recognizing technological advancements in fisheries is important for stock assessments. Table 6 summarizes changes discussed during the workshops. Generally, these advancements originated from four main areas: a) enhancements in trap construction (materials and designs), b) modifications in vessel and engine sizes, c) improvements in fishing practices and equipment (e.g., trap pullers, scuba), and d) improvements in navigation and safety (e.g., GPS, fish and depth finders, cell phones, weather apps).

To thoroughly understand these changes over time, it is essential to incorporate additional sources of information, such as peer-reviewed and gray literature (e.g., Matos-Caraballo's and DNER commercial fishers' censuses), and to conduct further research. It is also important to acknowledge that placing these changes on a timeline can be challenging due to the presence of both early and late adopters. A broader analysis that includes these elements will help create a more detailed timeline of the ongoing transformations in the fisheries sector.

Table 6. Timeline of key technological advancements as recalled by workshop participants.

Approximate Date	Technology Adopted	Notes
1960-1980's	Improved Trap Materials	Transitioned from using wooden traps made out of mangroves and chicken wire to more durable and efficient materials like coated wire, which improved the longevity and effectiveness of the traps.
1960-70s	SCUBA	More folks transitioned from skin to SCUBA diving
1970s	Winches	The adoption of winches for lifting traps became more common, increasing efficiency and allowing for deeper fishing.
1980s	Vessel improvements	Introduction of longer fiberglass boats (18-20 ft) compared to traditional yolas (15-16 ft), allowing for more efficient fishing trips.
Late 1990s early 2000's	GPS, Fish and Depth finders	The use of GPS technology became widespread, helping fishers locate and return to productive fishing spots more accurately.
2000s	Hydraulic Winches	Hydraulic winches, operated via the boat's engine, replaced manual winches, further increasing efficiency and reducing physical strain.
2000s	Artificial Structures	Use of artificial structures like casitas to attract lobsters, although these are illegal and it is not clear how widespread this practice is; this was mentioned only in Cabo Rojo.

3.4 Impact of Regulatory Actions

Understanding fishers' perceptions of lobster fishery regulations is beneficial for accurate stock assessments. However, there was not enough in-depth discussion about the impacts of lobster regulations over time in the workshops to draw definitive conclusions about policy outcomes. To effectively track regulatory changes over time, it is important to integrate and update various information sources, including peer-reviewed literature, gray literature (e.g., Caribbean Fishery Management Council Plans and Amendments, Matos-Caraballo's and DNER commercial fishers' censuses, and historical timelines such as those by Rios and Agar from previous SEDARs).

The discussion on regulatory changes generally found support for regulations that set minimum size limits and harvest limits for lobsters, as these were seen as essential for sustainability. A participant from Naguabo mentioned that the prohibition of gaffs (bichero) was positive because it previously resulted in lobsters being damaged or killed if they escaped the hook. He also noted that the transition to using snares (lazos) has been seen as a positive change, despite being a bit slower, as it ensures the lobsters are captured alive and in good condition. Most participants felt the regulations were appropriate but highlighted a lack of enforcement.

4. Conclusions

We used participatory modeling methods to better understand the biological, social and economic components of the Puerto Rico lobster fishery. This work aimed to increase fishing community engagement, buy-in to the stock assessment process and integrate local knowledge and perspectives into the stock assessment process. This effort addresses several recommendations from the Caribbean Strategic Planning process workgroup "Socio-economic Data Needs and Implementation into US Caribbean Fisheries Stock Assessment" including: 1) using a systematic approach to guide the consideration of ecosystem and socio-economic factors in stock assessment and fisheries management, 2) using the SEDAR process as a pathway for incorporating socio-economic data into decision-making, 3) conducting conceptual modeling and collection of qualitative data in preparation for assessment, and 4) establishing mechanisms for data collection that addresses ecosystem-based fisheries management and engages stakeholders. Specifically, the local knowledge and stakeholder perspectives documented here can be used to better understand behavior of fishing fleets and markets, assist with interpretation of trends, and identify changes in selectivity, catchability or other parameters for which various assumptions must be defined and justified within the stock assessment model.

5. Acknowledgments

We would like to express our gratitude to the workshop participants for their valuable insights and contributions. Special thanks to our liaisons Daniel Matos-Caraballo, Luis Anibal Rivera, Wilson Santiago, Jesús Leon, and Mariangeline León for their assistance in organizing and facilitating these workshops. We also appreciate the support provided by municipalities of Cabo Rojo and Vieques and the Ponce and Los Hucares Villas Pesqueras in making this research possible.

The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the authors and do not necessarily reflect those of NOAA or the Department of Commerce.

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