System dynamics of red snapper populations in the Gulf of Mexico to support ecosystem considerations in the assessment and management process

Dinámica del sistema de las poblaciones de huachinango del Golfo en el Golfo de México para apoyar las consideraciones del ecosistema en el proceso de evaluación y gestión

Dynamique du système des populations de vivaneaux rouges dans le golfe du Mexique pour soutenir les considérations écosystémiques dans le processus d'évaluation et de gestion

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EXTENDED ABSTRACT

Over the past century, anthropogenic pressure on marine ecosystems has expanded dramatically. Currently, rates of ecosystem change are at record highs, prompting a pressing need for rapid and adaptive ocean management that considers a myriad of interacting factors. Numerous programs and initiatives aimed at supporting effective Ecosystem-Based Management of marine resources have been developed. However, socio-ecological factors are still rarely incorporated into the stock assessment and management process. This is largely because identifying how ecosystem factors interact with fish populations and affect their management remains challenging. It has long been recognized that fisheries stakeholders (i.e., resource users) develop detailed knowledge of the environments in which they fish through experience and generational learning (Murray et al. 2006; Anadón et al. 2009; García-Quijano and Pizzini 2015). When this knowledge is collected in a systematic fashion, it can be used to complement existing biological data, provide new insights, and can even be assembled in forms usable in quantitative stock assessments (Neis et al. 1999; Drouineau et al. 2021; Sagarese et al. 2021). In addition to helping fill data gaps, stakeholders can aid in characterizing linkages between social and ecological systems (Beaudreau and Levin 2014).

In this research we used participatory system dynamics modeling to gain an understanding of Gulf of Mexico (GOM) red snapper populations in the context of the larger social-ecological system in which they occur. GOM red snapper is currently undergoing a research track assessment, which is an extended stock assessment process where extensive changes in data, models, or stock structures can be considered. There is a lot of flexibility in the research track process for new information to be considered and incorporated, including important socio-ecological dynamics. Furthermore, the current assessment terms of reference (TOR) include describing any known evidence regarding ecosystem factors that may affect red snapper population dynamics. This TOR is commonly included in stock assessments in the region, but historically has been difficult to address. Participatory systems dynamics modeling is a powerful method used to conceptualize and understand the dynamic complexity of social-ecological systems (Videira et al. 2017). The participatory approach recognizes that stakeholders often have extensive knowledge and experience on the water and are well qualified to help identify some of the major factors affecting fish and fisheries.

Based on information collected from 27 charter-for-hire captains via in-depth, semi-structured phone conversations, we constructed conceptual models of the red snapper system in the GOM. We identified several factors that may affect red snapper population dynamics to the extent that they might be considered in the stock assessment process. These factors were broadly categorized into factors that affect red snapper mortality rates, and factors that affect catchability rates (Figure 1). On the mortality side, the most common driver in the red snapper fishery identified by captains throughout the GOM was depredation, or the removal of fish from fishing gear by non-target species (Mitchell et al. 2018). Captains generally believed that discards and high-grading are the main reason why depredation is such a problem, as these practices attract predators to fishing vessels and fishing grounds. All fish captured under the size limit or out of season are discarded, so captains mentioned that short open seasons and restrictive size limits can exacerbate the problem of discarding. Restrictive bag limits may also lead to recreational anglers throwing back fish above the minimum size limit in order to retain the largest individuals possible. In addition to potentially increasing levels of discarding and high-grading in the recreational fishery attracting predators, many captains also observed that sharks have become more abundant since fishing pressure on their populations decreased in the early 1990s. Many guides also mentioned that bottlenose dolphins have learned to follow boats, and adults are training their young to follow their boats for easy meals.

Conceptual models of the red snapper GOM fishery also included three drivers that could have an important impact on catchability of red snapper. These factors were hurricanes, substantial increases in recreational fishing effort due to COVID-19, and changes in fishing technology over time. Several captains mentioned that hurricanes can dislodge smaller artificial

structures, which are the main habitats anglers target for red snapper in some regions. When the number of structures with known locations declines after a hurricane, it can lead to a decrease in red snapper catchability as anglers have to move to structures further away or locate new structures. Hurricane wind speed presumably affects the extent to which artificial structures are dislodged, and therefore can be used to estimate how much catchability might be impacted in a given year. Storm energy in the north-central GOM, as measured by the accumulated cyclone energy (ACE) index, was particularly high in recent years (2018 and 2020) which could explain why numerous charter captains mentioned hurricanes as major drivers of the red snapper fishery. Red snapper catchability may be expected to decrease during years with high storm energy.

Captains also mentioned that the COVID-19 pandemic has significantly affected the red snapper fishery. These captains observed a substantial increase in the number of recreational anglers targeting red snapper since 2020 which has led to increased harvest and rapid declines in the local abundance of red snapper close to shore over the course of the red snapper season. Captions mentioned that this decline in nearshore abundance leads to a decrease in catchability as the season progresses, since anglers are required to travel further offshore to target red snapper. Trends in the number of saltwater recreational fishing licenses sold per year appear to confirm the observations of charter captains. In all states where data were available, the number of saltwater licenses sold increased from 2019 to 2020. Sales increased by 36% in Texas, 20% in Florida, 17% in Louisiana, and 2% in Alabama.

Finally, charter captains mentioned that red snapper catchability has greatly increased over time with advances in vessel and fishing technology. In regions where access to red snapper habitat (deep water) is further offshore (e.g., central Florida and Mississippi), captains noted that as reliable vessels with larger engines and higher maximum speeds have become readily available to recreational anglers and guides, it is now easier to access these offshore regions and thus target red snapper than it was in the past. Trends in outboard engine sales for all five GOM states (Alabama, Florida, Louisiana, Mississippi, and Texas) revealed patterns consistent with angler observations. For all GOM states, the number of boats sold per year with 50 hp or smaller engines has remained relatively constant from 2013 to 2020. The number of sales for boats with 50-150 hp engines has also remained fairly constant in Alabama, Louisiana, and Texas, but has increased slightly over time in Florida and Mississippi. Across all states, sales for boats with 150-300+ hp engines has increased fairly linearly over time, with the most dramatic increase being for Florida. The number of boats sold in Florida with 150-300+ hp engines has nearly tripled, from a minimum of 11,750 units sold in 2013 to a maximum of 32,098 units sold in 2020. Captains also mentioned that advancements

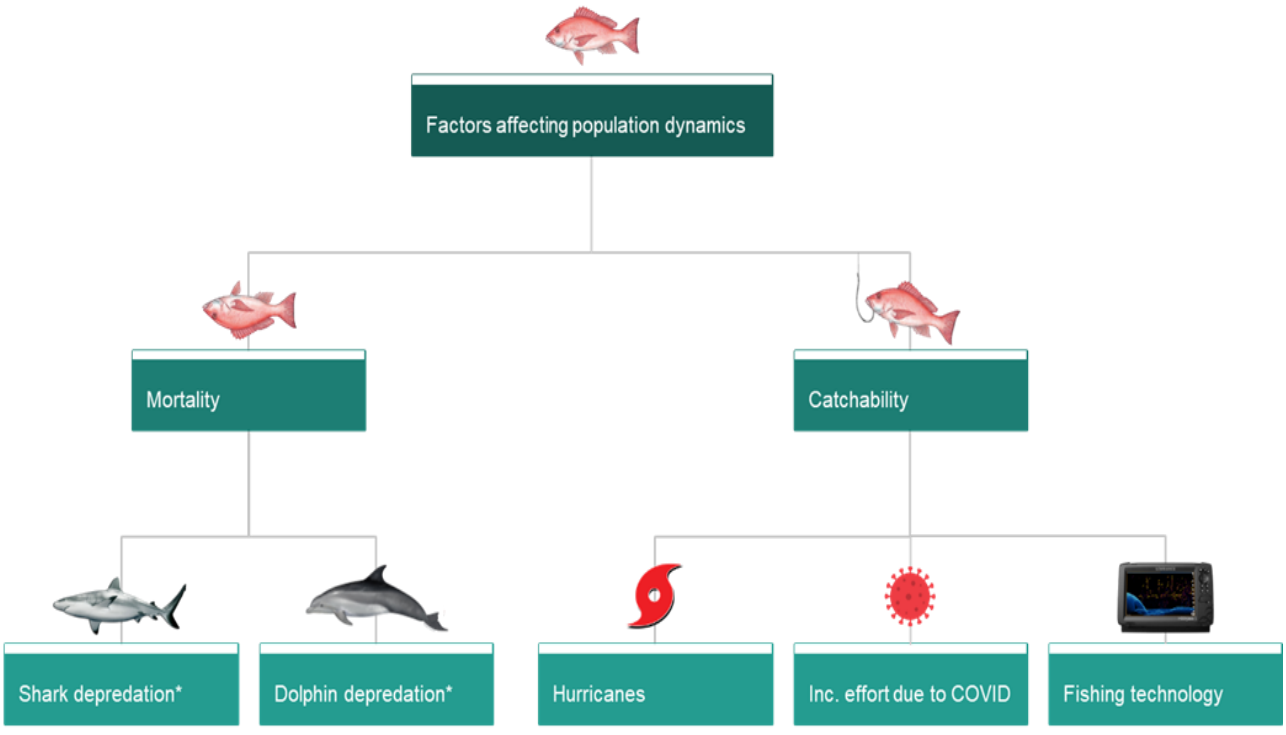

Figure 1. Flow chart illustrating the main drivers that were identified by charter for-hire captains as factors that may be affecting population dynamics of the red snapper fishery in the Gulf of Mexico.

in fish finder technology have allowed anglers to more easily locate fishing grounds (natural hard bottom or artificial structure). Once fishing grounds are located, advanced trolling motors with spot lock capabilities allow anglers to remain at lucrative fishing areas for extended periods of time. These observations suggest that red snapper catchability has likely increased over time and may continue to increase with future technological advancements.

In this study, participatory modeling allowed us to take the entire range of possible ecosystem factors interacting with red snapper and hone in the factors that are most likely impacting population dynamics. These are the factors that may need to be incorporated into stock assessment models. Participatory models also illustrated key socio-economic drivers and conflicts among fishing sectors that could have important implications for management. Our research highlights the numerous benefits of using a participatory modeling approach to aid in the transition towards Ecosystem-Based Fisheries Management.

KEYWORDS: Red snapper, Gulf of Mexico, ecosystem, management

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