

Spatiotemporal Catch Trends and Biological Fishery Indicators of the bull shark, *Carcharhinus leucas*, in the Mexican Atlantic

Tendencias de captura espaciotemporales e indicadores biológico-pesqueros del tiburón toro, *Carcharhinus leucas*, en el Atlántico mexicano

Tendances des captures spatiotemporales et indicateurs biologiques de la pêche du requin-taureau, *Carcharhinus leucas*, dans l'Atlantique mexicain

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EXTENDED ABSTRACT

Mexican artisanal fisheries contribute to the international sale and consumption of elasmobranch species. While general capture records are known, little to no species-specific data has been recorded over the course of the last fifty years and monitoring efforts only show a glimpse of shorter time periods. This lack of information impedes the use of conventional fisheries analyses, leaving room for innovative ways to use available data. To properly evaluate the effects of intense fishing on shark populations in the southern Gulf of Mexico, species specific studies must be carried out. Mexico in particular regulates its shark fishery by defining two size classes, tiburón (> 150 cm in length) and cazón (< 150 cm in length) and only identifies species in the realm of bycatch or general species composition charts in the annual National Fishery Chart (Carta Nacional Pesquera, in Spanish) without identifying the catch volumes for these species. Not every species has the same life- history parameters or ability to recover from intense fishing pressures, making it imperative to accumulate pertinent information so that proper steps can be taken to conserve and better manage economically important species (Dulvy et al. 2014).

Evaluating the spatiotemporal catch trends of the bull shark population in the southern Gulf of Mexico could result in better management and predictive models. Understanding the historic catch trends can determine the change in the catch composition over the years and allow researchers to evaluate the impact of new regulations and other historical events that might have affected changes in catch trends. Evaluating the available fishery indicators such as length at maturity and sex proportions have allowed for a holistic approach to stock status assessments and the sustainability of economically important species. A descriptive characterization considering the political, economic, and social agendas could offer explanations for certain catch trends and fluctuations in productivity.

Over the course of an extensive literature review, including official government records and gray literature, approximate proportions of bull shark catches were calculated across the six Mexican Atlantic states. For the present study, approximate catch percentages were calculated using historic catch composition studies in the six states bordering the Gulf of Mexico which include Tamaulipas, Veracruz, Tabasco, Campeche, Yucatan, and Quintana Roo. These percentages were then applied to the annual catch volumes for the combined size classes (tiburón and cazón) recorded and published by the National Commission of Aquaculture and Fisheries (CONAPESCA by its acronym in Spanish), yielding the approximate *C. leucas* catch volume for the six states across 50 years. This process was repeated for three defined regions (Region 1: Tamaulipas, Veracruz and Tabasco; Region 2: Campeche and Yucatan; Region 3: Quintana Roo) based on their physical habitat structures, fishing dynamics and ecology. A single proportion was calculated that assumed all six states as one single unit as a baseline and provide insight into general tendencies across the Mexican Atlantic.

Three time periods developed by Martínez-Candelas et al. (2020) were used to properly assess the historic changes specifically affecting the shark fishery in Mexico. The first period denoted “Local Commercialization” (pre-1979) focuses on smaller scale, local economies with limited transportation available due to the lack of connectivity between villages and towns. The second time period, the “Developed Industry” (1980-1998) is marked by the explosion of the sector with the assistance of government subsidies, infrastructural improvements, and ice plants which allowed for longer storage and transportation capabilities. The final and current period, the “Declining Industry” (1999-2020), refers to the observed decline in shark fishery productivity and reduction of government support for the industry. These time periods were used to divide the indicators and characterization using important historical events in Mexico’s fishery sector history, possibly affecting the stock status of sharks.

The complimentary components of the study include an analysis of historic fishery indicators and a punctual analysis using recent data collections. The historic indicators were placed in a table divided by region and time period and included studies from as early as 1986 and as recent as 2013. The indicators available were total lengths including the average and standard deviation, and population sample sizes for each study. The second half of the indicator comparison focused on a punctual statistical analysis comparing indicators collected by the ECOSUR fisheries labs in Villahermosa, Tabasco and Campeche, Campeche. This data set included total lengths, maturity stage, equipment used, sex, and in some cases, the weight of the individual. For the comparison analysis, basic normality distribution tests were conducted for total lengths and

then further compared with a Wilcoxon test to compare the length distribution between the two states. Sex proportions and stages of maturity were analyzed with independence tests since these two indicators are categorical and required a frequency comparison.

The characterization of the shark fishery as a whole in the Mexican Atlantic illustrates the changes in political and economic agendas that affected the shark fishery such as embargos placed on the yellowfin tuna fleet operating in Mexico, and economic crisis' that caused the declared bankruptcy of the bank that supported and subsidized fishing efforts. Blanket regulations that were implemented also affected the states in different ways, which was further compared in conjunction with the graphs created for the historic reconstruction to determine if these regulations and holistic sector changes were reflected in the approximate catch volume for *C. leucas*.

The observed approximate catch volumes range from as low as 8 tons calculated in Tabasco to as high as 200 tons registered in Yucatan. The fluctuation in catch volumes between the states across 50 years could be related to the different fishing dynamics associated to the states, including the type of gear used and the capacity to go further offshore due to the observed reduction in catch. The historic indicators showed little to no changes across 50 years, although it is worth noting that this available information is still important when looking at historic population structures and can be used in future studies focusing on biological parameters. The comparison between current indicators yielded differences in the distribution of lengths and stages of maturity for *C. leucas*. Campeche registered larger individuals on average (227.1 ± 32.1 cm), registers of gravid females and no neonates recorded. Compared to Tabasco on average, smaller individuals were registered (191.7 ± 72.2 cm) and the opposite was observed for maturity stages, where neonates were recorded and no gravid females. This may possibly be explained by the gear selectivity for the two states, where longlines were used in Tabasco and gillnets in Campeche. This indicator comparison was complimented by the characterization which takes into consideration large scale, impactful events that affected the shark fishery in the Mexican Atlantic.

This study was among the few species specific studies using a data deficient methodology. The historic reconstruction of approximate *C. leucas* catch volumes illustrates a small segment of the general observed decline in shark productivity in Mexico. The indicators show no changes in parameters generally used in conventional fishery analysis over the course of 50 years, but does display the variety of catch compositions related to lengths and maturities registered. The characterization compliments the results from the reconstruction and the indicator analysis since it describes the accomplishments and pitfalls of the Mexican shark fishery, affecting the resident shark populations. More species specific studies should be conducted to compliment management decisions and regulations being planned for future stock conservation.

KEYWORDS: *Sargassum*, citizen science, community science, monitoring, macroalgae

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