CONTRIBUTION 3.9

Assessing the Spatio-Temporal Dynamics and Overfishing Implications for Guyana's Seabob Shrimp Industry

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Abstract

This paper focused on the dynamics of Guyana's *economic Seabob shrimp industry, using various mechanisms such as journals and articles to increase data efficiency, and then secondary data provided by the Ministry of Agriculture Fisheries Department to map and indicate Spatio-temporal patterns of Guyana's fishing dynamics over a 6 year period. Total Catch per annum was calculated utilizing the formula total landings of sea bob processed (peeled tail) weight in kilograms divided by total number of standardized days-at-sea yearly which indicated over fishing of the seabob shrimp. Each map's average locations were indicated by a crimson-to-dark red color shift, indicating heavy fishing on the coast of region 6 for the 6 year study with total size of these patches changed from year to year as the capture rate grew until years 2018 and 2019 which is due to Seabob shrimp aggregation behavior and environment, enabling for considerably simpler identification and capture procedures, resulting in a more focused fishing effort and a higher Total Catch per year which will eventually exhaust the resource.

KEYWORDS: Queen conch, abundance, towed video array, underwater drone, Turks & Caicos Islands

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1. INTRODUCTION

The Atlantic Seabob shrimp, *Xiphopenaeus kroyeri*, belongs to the decapod Penaeidae family and may be found from Virginia (USA) (75°43′W; 36°54′N) to Southern Brazil (32°39′S; 52°20′W) in the Western Atlantic (Costa et al. 2000). They're a fast-growing, short-lived species with a maximum carapace length (CL) of 32 mm and females are considerably bigger than males. Males have a life expectancy of 1.5 years, while females have a life expectancy of 2.0 to 2.5 years (Torrez, 2015; Castilho et al., 2015). Seabob shrimp are epibenthic with a predilection for mud or sand, and may be found in large quantity in both brackish and marine waters in depths of up to 70 meters, but most commonly in depths of 27 to 30 meters in shallow waters. (Holthuis 1980). These areas in which they are found are usually associated with significant sedimentation and nutrient inputs.

A *Xiphopenaeus spp*. taxonomic investigations revealed that there are two indistinguishable species of *Xiphopenaeus* in the area from Venezuela to Brazil according to Gusmo and colleagues, 2006. Studies in Brazil also showed that sediment type, salinity, and temperature are among the foremost important variables affecting the spatial and seasonal distribution of Seabob shrimp (Costa et al., 2007). Seabob shrimp is overexploited within the south and south-east of Brazil (Brasil, 2004), and as moderately exploited within the northeast (Vasconcellos et al., 2007). They exhibit relevant importance in benthic communities and food chains and as a result of the impacts generated by shrimp fishing, there is a big loss in biomass and biodiversity of the ocean floor (Souza et al., 2008; Lopes et al., 2013; Heckler et al., 2014; Pauly & Christensen, 1995; Pauly et al., 2002). There are major industrial fisheries for Seabob shrimp off the coast of Guyana and Suriname where it is believed that one stock is shared. The fisheries subsector of Guyana has three primary components, with further subdivisions. These are marine fishery which incorporates industrial trawl fishery, deep slope fishery, and small-scale artisanal fishery, an inland fishery that features a subsector of subsistence fishery, and decorative fish fishery with the last being aquaculture.

These three subsectors have accounted for Guyana's GDP accumulating over GYD11,434 million in 2017.Guyana's marine fishing activities are directed at exploiting its shrimp resources by using shrimp trawlers, and its ground-fish resources using wooden vessels and equipment by artisanal fishermen. This sector is of critical importance to the economy and social well-being of the country (Willems, 2015) (Castilho A.L, Gavio M.A, Costa R.C, Boschi E.E, Raymond T.B, Fransozo A, 2007). Atlantic Seabob shrimp is healthy and fully exploited. A replacement Harvest Control Rule came into force in 2020 to raise awareness and monitor the fishery.

In the context of declining fisheries and degradation of marine ecosystems globally, spatial management is increasingly promoted as a part of an ecosystem-based approach to marine resource management (Caddy JF, Carocci F, 1999), (Costa R.C, Castilho A.L, Freire F.A.M, 2005), (GreenStreet SPR, Hooand GJ, Fraser TWK, Allen VJ, 2009) This trend is seen by the growing application of marine spatial planning (MSP) approaches and seek to balance ecological, economic, and social objectives through comprehensive, integrated planning of multiple uses of the marine environment (Hall GB, Moore A, Knight P, Hankey N, 2009) (GreenStreet SPR, Hooand GJ, Fraser TWK, Allen VJ, 2009) (Jennings S, Alvsvag J, Ehrich S, Greenstreet SP, Jarre-Teichmann A, 1999). MSP has created greater demand for data on the spatial distribution of human uses of the marine environment. Data are sought to quantify impacts of the use of resource, understand areas

of conflict, and assess potential implications of proposed management measures (Costa R.C, Fransozo A, 2004), (Costa R.C, Castilho A.L, Freire F.A.M, 2005).

Fisheries constitute a pervasive use of the marine environment worldwide, yet have proven difficult to map because of limited availability, collection, and consistency of data, which results partly from the complex and changeable nature of fisheries over space and time (Costa R.C, Castilho A.L, Freire F.A.M, 2005) (Castilho A.L, Gavio M.A, Costa R.C, Boschi E.E, Raymond T.B, Fransozo A, 2007) (Andersen B, Christensen A-S, Sumalia UR, Marsden AD, 2006). Quantifying the relative intensity of fishing pressure, understanding fishery dynamics, and informing fisheries management strategies all depend on the distribution of fishing activity (Hall GB, Moore A, Knight P, Hankey N, 2009), (Stewart KR, Lewison RL, Dunn DC, Bjorkland RH, Kelez S, Halpin PN, 2010).

Understanding the distribution of fishing activity is significant to assess potential impacts of MSP on fisheries, identifying areas of economic importance to the fishing industry, and assessing possible loss of income or fishing effort displacement through a spread of methods including information submitted through fishers' logbooks, active recording of vessel sightings (Data mainly received from enforcement agencies), and automatic recording of vessel positions through vessel monitoring systems (VMS) (Willems, 2015) (Castilho A.L, Gavio M.A, Costa R.C, Boschi E.E, Raymond T.B, Fransozo A, 2007) (GreenStreet SPR, Hooand GJ, Fraser TWK, Allen VJ, 2009). The information collected are often combined with other spatial information using geographic information systems (GIS) then incorporated within the spatial analysis.

The goal of this paper was to research the dynamics of the Seabob shrimp industry for six years by utilizing qualitative data and software in providing information on the distribution of fishing activity on the coast of Guyana. The datasets are illustrative of those currently available at the Fisheries Department, to inform fisheries data and Seabob shrimp management planning within Guyana. This study focuses on analyzing log data, calculating CPUE, and displaying highly digitized maps to assess any changes supported the parameters utilized which can aid in future Seabob shrimp evaluations. The study also provides a qualitative assessment based on data records and interviews with personnel from the fisheries division and Seabob shrimp fishermen.

2. MATERIALS AND METHODS

The continental shelf of Guyana (54 -57 °W, 6 - 7 °N, Fig. 1), is situated between One (1) and Nine (9) North latitude, and between fifty-six (56) and sixty-two (62) west longitudes, it comprises of land area of approximately 214,969 square kilometers and is noted to be within the bounds of, Venezuela on the west, Brazil on the south and southwest and Suriname on the east (Mission.gov, 2021). The physical geography of the country is divided into four (4) main geographical zones: the low coastal plain, the Hilly sand clay region, the Interior savannahs, and the forest highlands (Schanzenbacher, 2021). The coastal area of the country occupies approximately 5% of the country land, the hilly sand clay regions occupy 14%, the Forest high land makes up 73% and lastly, the interior savanna makes up about 6% of land area (Guyana Lands and Surveys Commission, 2021). The coast of Guyana is described by wide sloping continental shelves, macrolides, and upwellings found along the edge of the shelf, and is profoundly influenced by the turbid freshwater discharge from the Amazon River (Heileman, 2008), which is carried to the coast of Guyana by the North Brazil Current and its extension, the Guiana Current (Hellweger & Gordon, 2002; Johns et al., 1998). The Guyana Shelf waters

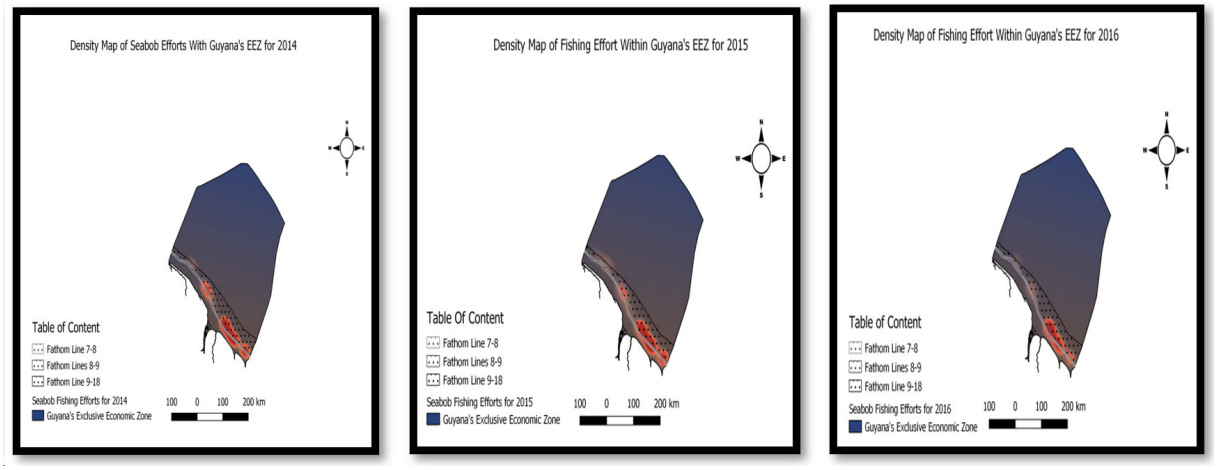
can be divvied into three (3) distinct zones that run parallel to the coast (Cadée G.C., 1975; Lowe-McConnell, 1962; Smith & Demaster, 1996). It is noted that, owing to the suspension of muddy deposits and freshwater inflow from both the Amazon and main local rivers, the brown nearshore waters contain high turbidity and low salinity. The combination of riverine nutrient input and decreased turbidity creates a productive zone with high chlorophyll concentrations between 20 and 50 km offshore, known as the green water zone. Irradiance increases further offshore from this zone, while nutrients become scarce for primary production, resulting in blue waters (Willems, 2015).

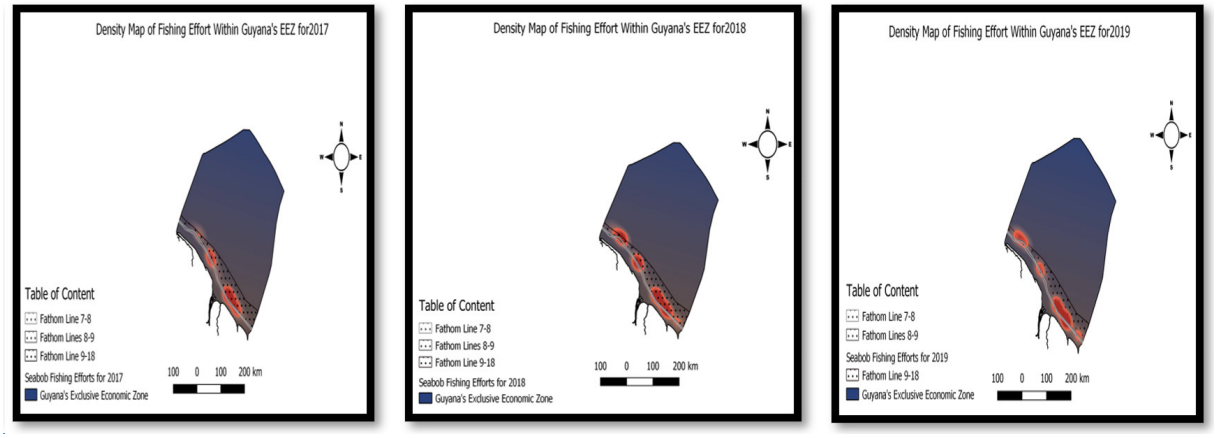
The process of creating maps for the study of Seabob shrimp fishing efforts began with data collection from one main route within the period of 2014-2019. VMS and yearly landings were obtained from the Ministry of Agriculture Fisheries Department via logbook data sets and stored in Excel sheets. These data sets consisted of geographic coordinates in decimal degrees (World Geodetic System 1984 format) accompanied by timestamps in UTC, vessel identification numbers, speed, heading, and yearly landings.

Briefly, the steps for obtaining the VMS data were as follows:

First, the vessels equipped with VMS send signals to the satellite from their position. Then, the satellite reboots the signal to a receiving station inland, these data are aggregated and transmitted to the database of the Ministry of Agriculture in the form of Excel Sheets. The data were saved as a CSV file for it to be read by QGIS Software. Then, dumped in a PostgreSQL database with PostGIS extension where the builder option was utilized to remove unnecessary data such as vessels with zero speed or speed above 3 (knots), which refers to non-mobile vessels, after evaluating the data quality the final step was to create the density maps. A spatial grid for data analyses in QGIS, emulating ICES squares on a smaller scale was utilized through the display option (Heat map) to present the yearly data sets. Exploratory analyses of the data were performed, in which the statistical distribution of the data and the existence of external trends in the spatial variation of the CPUE were evaluated. Then the CPUE was calculated using the formula calculated as total landings of sea bob processed (peeled tail) weight in kilograms divided by total number of standardized days-at-sea yearly.

3. RESULTS





Fishing Density Zones

Figure1. Spatio-temporal fishing density of Guyana Seabob trawlers from 2014 to 2019.

Density map of fishing effort within Guyana's EEZ for 2014 to 2019 (presented in *Figure 1*) illustrate the Seabob shrimp fishing zone (i.e., 7 and 18-fathom lines) beyond which Seabob shrimp vessels are not permitted to trawl by law. The applied color scale red/dark red represents the different trawling intensities and the areas "most fished". Seabob shrimp fishing takes place entirely within the Guyana EEZ (FAO area 31- Western Central Atlantic). Trawling for Seabob shrimp occurs over sedimentary plains of sand and mud on the continental shelf, within the permitted zone (8 to 18 fathom) (Cadée, G.C., 1975) as evidenced by the facts given in (*Figure 1*). Estimates of fishing effort for Seabob shrimp trawling on the coast of Guyana over the last six years have shown a patchy or aggregated distribution between latitudes 57°W to 58°W and longitudes 6°N to 7°N.. Seabob shrimp fishing operations indicated a substantial rise in the total yearly area trawled by boats between 2018 and 2019. Trawling density, indicated by bright red to dark red hues, was observed in 2015, 2016, 2018, and 2019, with similar patterns, although 2014 and 2017 varied. It should be noted that most trawling activities occurred within the 8-18 fathom and any records outside of the 8 to 18-fathom lines may suggest illegal fishing (Fisheries Department et al., 2015).

Table 1. Total Landing and annual CPUE for Seabob shrimp Industry in Guyana from 2014-2019

Years	Tonnage	Standardized days at sea	Yearly CPUE
2014	16,574	15,000	1,171 kg/sdas
2015	17,476	15,000	1,165 kg/sdas
2016	20,131	15,000	1,342 kg/sdas
2017	21,659	15,000	1,443 kg/sdas
2018	11,700	12,840	911 kg/sdas
2019	6,662	11,625	573 kg/sdas

(Source: Guyana Fisheries Department)

Fish Landings

Total catch data were collected during a six-year period (see *Table 1*). These years include 2014, with landings of 16,574 tones; 2015, with landings of 17,476 tones; 2016, with landings of 20,131 tones; 2017, with landings of 21,659 tones; 2018, with landings of 11,700 tones; and lastly 2019 with landings of 6,662 tones. For the years 2014-2019, annual CPUE statistics for

the whole fleet was computed. The Seabob shrimp fishing fleet first spent 15,000 standardized days-at-sea (sdas) in 2014, the maximum allowed total fishing effort of 15,000 sdas, catching about 16,574 tonnes of processed Seabob shrimp tails, resulting in an annual CPUE of 1,171 kg/sdas. This is significantly higher than the TRP of 630 kg/sdas, as well as the industry's alternative goal of 600 kg/sdas. Because data wasn't available for 2015, 2016, and 2017, the researcher used the maximum allowed total fishing efforts to compute the CPUE. The fishing fleet spent a maximum of 15,000 standardized days-at-sea (sdas) in 2015, with a haul of roughly 17,476 tonnes of processed Seabob shrimp tails, resulting in an annual CPUE of 1,165 kg/sdas. In 2016, a catch of approximately 20,131 tonnes of processed Seabob shrimp tail resulted in a yearly CPUE of 1,342 kg/sdas, in 2017, a catch of approximately 21,659 tonnes of processed Seabob shrimp tail resulted in a yearly CPUE of 1,443 kg/sdas (Jacobs, 2019),((Fisheries Department, 2020a). With a catch of about 11,700 tonnes of processed Seabob shrimp tails, the Seabob shrimp fishing fleet expended a total of 12,840 standardized days-at-sea (sdas) in 2018, considerably below the maximum authorized total fishing effort of 15,000 sdas, resulting in an annual CPUE of 911 kg/sdas. Finally, the Seabob shrimp fishing fleet spent a total of 11,625 standardized days-at-sea (sdas) in 2019, far less than the maximum allowed total fishing effort of 15,000 sdas, resulting in a catch of roughly 6,662 tonnes of processed Seabob shrimp tails and an annual CPUE of 573 kg/sdas. That's a lot lower than the TRPs we've seen.

4. DISCUSSION

This research focused on the dynamics of Guyana's economic Seabob shrimp industry, using various mechanisms such as journals and articles to increase data efficiency, and then secondary data provided by the Ministry of Agriculture Fisheries Department to map and indicate Spatio-temporal patterns of Guyana's fishing dynamics. Total Catch per annum was calculated using spatial patterns of fishing efforts dedicated toward Seabob shrimp trawling on an annual basis. Each map's average locations were indicated by a crimson-to-dark red color shift, indicating heavy fishing similar to studies done by (Costa R.C, Castilho A.L, Freire F.A.M, 2005) (Caddy JF, Carocci F, 1999) (Jennings S, 1999) (Stewart KR, Lewison RL, Dunn DC, Bjorkland RH, Kelez S, Halpin PN, 2010). The total size of these patches changed from year to year as the capture rate grew until years 2018 and 2019 where a decrease in catch rate and yearly CPUE was seen, this was as a result of continuous fishing around the coast of region six which has caused a reduction in population similar to studies done by (GreenStreet SPR, Hooand GJ, Fraser TWK, Allen VJ, 2009) (Costa R.C, Castilho A.L, Freire F.A.M, 2005) (Jennings S, 1999).

Over the last six years, a full picture of Seabob shrimp fishing activities revealed an increase in the total yearly area trawled (*Figure 1*) with greater spatial patterns in 2018 and 2019 (*Figure 1*) which shows increased trawling efforts with a decrease in landings and CPUE .These alterations might be viewed as a reflection of Seabob shrimp aggregation behavior and environment (Palomera et al., 2007) 1999 (Fréon & Misund), enabling for considerably simpler identification and capture procedures (Bertrand, Daz, & Lengaigne, 2008; Csirke, 1989; Fréon & Misund, 1999), resulting in a more focused fishing effort and a higher Total Catch per year. The use of indicators in the description of stock size by fisheries management authorities is primarily hampered, with the primary indication being catch-per-unit-effort (CPUE). (Bertrand et al., 2008; Csirke, 1989; Fréon & Misund, 1999; Hilborn & Walters, 1992; Fréon & Misund, 1999; Hilborn & Walters, 1992) the spatial distribution of the resource utilized and how the fleets fish these resources account for most of the variance. (Gaertner & Dreyfus-Leon, 2004; Petitgas, 1998). Using spatially explicit data to map fishing efforts is improving fish stock assessment and management (Caddy JF, Carocci F, 1999) (Willems, 2015).

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