EVALUATION OF THE TRENDS IN FISH LANDING DISTRIBUTION AND FISHING EFFORT IN SAINT LUCIA

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ABSTRACT

This study analyses trends in field sampling catch and effort data collected by the Saint Lucia Department of Fisheries from 1995-2021, with total and sample effort values calculated from 2000-2021. A cluster analysis of all species was conducted and standardised CPUE calculations using the generalised linear model were performed for six (6) commonly caught large oceanic pelagic species using trolling gear: dolphinfish (*Coryphaena hippurus*), yellowfin tuna (*Thunnus albacares*), skipjack tuna (*Katsuwonus pelamis*), blackfin tuna (*Thunnus atlanticus*), gulf sierra mackerel (*Scomberomorus concolor*), and blue marlin (*Makaira nigricans*). The analysis revealed an average annual landing of 1,215 tonnes from 2000 to 2021, with a peak of 1,545 tonnes in 2001. Fishing effort fluctuated slightly over the years, and Saint Lucian fishers employed 23 different gears and techniques. Cluster analysis identified four (4) main clusters of species caught over time, with trolling being the most commonly used gear across all clusters. Furthermore, CPUE calculations revealed that values varied by species, and the introduction of fish-aggregating devices may have enhanced large pelagic catches. Overall, it is imperative that data collection and analysis processes adapt to changes reflected in the data. Improved collection of biological data, such as length-based data, continued training of data collectors, and improved data monitoring processes, could aid in the analysis of sound data that would assist in making well-informed management decisions.

Keywords: fisheries management, landing distribution, large pelagic species, trolling gear, CPUE, FADs, Saint Lucia.

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1 INTRODUCTION

1.1 Background

Saint Lucia is located in the archipelago of islands in the Eastern Caribbean (see Figure 1) and has a land area of 617 km² and a population of approximately 182,000 (Food and Agriculture Organization, 2015).

Figure 1. Map of Saint Lucia (Saint Lucia International Finance Centre, 2008).

The climate varies slightly throughout the year, with an annual mean monthly temperature ranging between 26°C and 28°C. The nation's main income-generating sector is tourism followed by agriculture. The fishing sector has been a major form of employment and revenue in coastal communities (World Bank, 2019), with the pelagic fishery contributing $4,580,425.81 USD towards the gross domestic product (GDP) in 2021 (Department of Fisheries, 2022), while the coastal fishery surpassed $469,421.24 USD for the same period (Department of Fisheries, 2022). The sector has seen an increase in the number of people entering it over the last couple of years and as of 2021, the Department of Fisheries has registered 4,096 fishers, with 1,709 listed as active fishers (Department of Fisheries, 2022). Due to the island's varying bathymetry, Saint Lucia fisherfolk engage in both near-shore and off-shore fishing. The island's coastal waters are divided into two zones for coastal and offshore pelagic species (A and B), and three fishing zones for near-shore and bank species (C, D, and E) (see Figure 2).

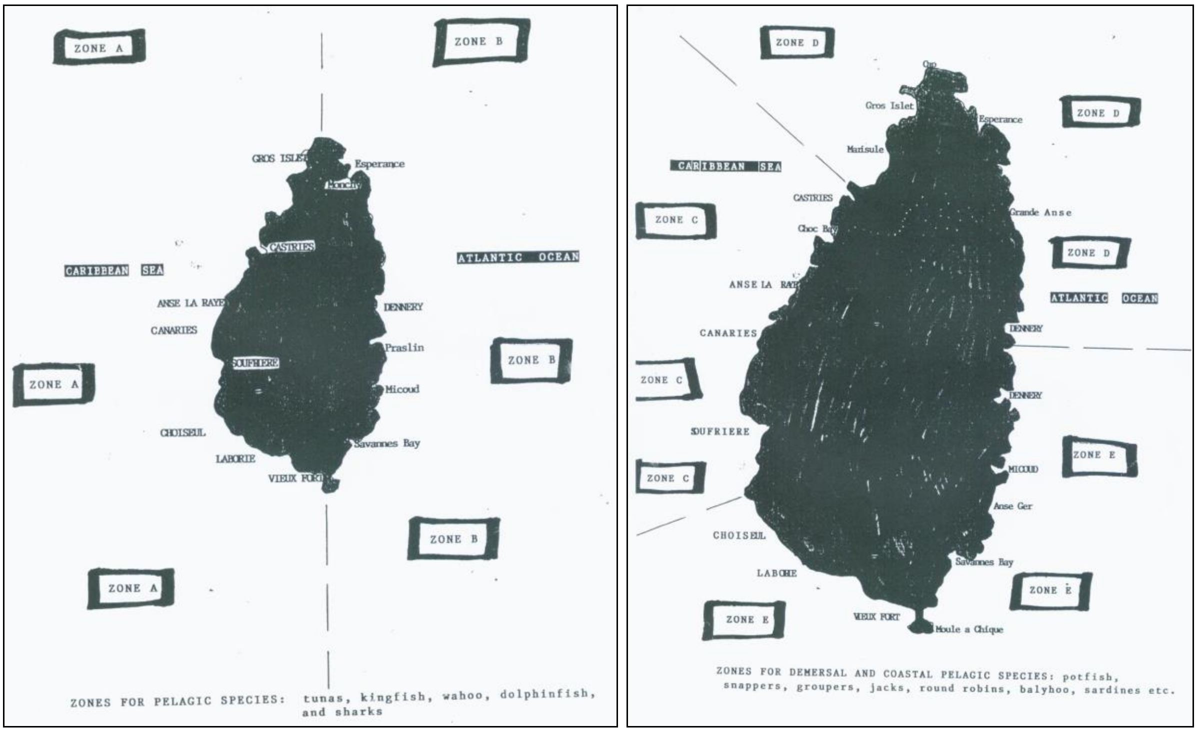

Figure 2. Fishing Zones in Saint Lucia (Department of Fisheries, 2015) for pelagic (left) and demersal (right) fisheries.

The offshore pelagic fishery is the more important fishery in Saint Lucia in terms of landings. The main species caught in this fishery are dolphinfish *(Coryphaena hippurus),* tuna (*Thunnini* spp.), and wahoo (*Acanthocybium solandri*). The fishers use baited lines, nets, and Fish Aggregating Devices (FADs) located around the island (see Appendix 8).

Furthermore, the coastal fishery consists of the capture of demersal species, such as the Caribbean spiny lobster and other small coastal pelagic fish. It is one of the most frequented fisheries used by older fishers and is the most highly priced species. Fishers employ a multitude of fishing practices in this fishery, such as the use of nets, lines, pots, and traps, and the use of scuba gear in the case of queen conch.

1.2 Fisheries Management in Saint Lucia

The Food and Agriculture Organization (FAO) has emphasised that fisheries and aquaculture play an important role in providing food for the world's population (FAO, 2022). Fisheries management is an integrated approach that involves regulating the removal, monitoring, and management of available resources (Food and Agriculture Organisation 2002). Thus, the

Department of Fisheries has worked to reduce fishing pressure by regulating resource users and protecting the marine environment, that is, the resource itself.

Both pelagic and coastal fisheries play an important role for the people of Saint Lucia. Therefore, the Department adheres to the provisions of The Fisheries Act, No. 10 of 1984 and the Fisheries Regulations, Statutory Instrument No. 9 of 1994, which forms the basis for fisheries development and management legislation, and the Saint Lucia Fisheries Act Cap 7.15, which is the principal legal instrument for the management of Saint Lucia's aquatic resources. Under this Act, certain species are subject to biological controls, such as weight limits and closed seasons, to ensure that the stock can regenerate. The Department also recognises that productive fishery depends on a healthy environment. For this reason, the Department has established marine protected areas and Fishing Priority Areas (FPA) around the island. These measures enable the conservation of marine ecosystems and ecologically valuable species found on the island (Chapter 7.15 Fisheries Act, 2023).

In addition, management measures are imposed on fishermen as this is equally important for the conservation process (Food and Agriculture Organization, 1995). Fishermen are required to present their fishing gear and safety equipment for inspection throughout the year. After successful inspection, new fishermen can be registered, and vessels licensed. The catch data that is collected from the fishers, which the Department uses to determine annual fishing effort, is also recorded. In addition, gear specifications are part of the management strategy imposed on fishermen, as only gear approved by the Department may be used in order to reduce the likelihood of undersized organisms and juvenile fish being caught (Chapter 7.15 Fisheries Act, 2023).

1.3 Limitations and Gaps

The Department has experienced recurrent problems with fishers complying with the regulations described. This is mainly because of inadequate enforcement capabilities within the Department due to financial and human capacity constraints. This has resulted in fishermen going unpunished for illegal activities, such as catching certain species during the closed season, fishing in restricted areas, and using illegal fishing equipment. Moreover, improper environmental practices, such as high sedimentation found in rivers due to deforestation, poor garbage disposal practices, and climate change, have further deteriorated the status of the marine environment. Consequently, this has had a negative impact on the state of certain fisheries in Saint Lucia, many of which have experienced annual declines (Department of Fisheries, 2022).

The Fisheries Act was amended in 2001, but many older fishermen continued to engage in the same practices as before the amendment. Without regular review and awareness of the management rules, there is a risk that fishermen and managers will negatively influence the fisheries sector.

1.4 Problem Statement and Rationale

For effective management of national fisheries, it is crucial that the relevant authorities know what is being caught. Effective fisheries management relies on the analysis of long-term data to provide information on patterns within a stock (Wagner, Midway, Vidal, Irwin, & Jackson, 2016). It is therefore important to look at trends at different landing sites around the island, as different species are associated with different sites; therefore, management solutions should also consider this. As previously mentioned, staffing and financial constraints hinder the department's ability to conduct analytical stock assessments for various fisheries. Therefore, management strategies are limited by the catch and effort data received from data collectors. These data need to be reviewed in a timely manner to determine if there are any changes in the stock that need attention. Currently, total landed catches are collected, but landing data are not analysed to determine species composition and distribution at individual sites. Therefore, it is necessary to conduct an analysis of the species composition at landing sites across the island. The results of this study could be used to implement targeted management strategies for individual species.

In addition, it is useful for assessing changes in fishing efforts. Changes in the availability and affordability of resources, such as an increase in fuel prices or shortage of raw materials used to make nets and fish traps, could significantly affect the fishing sector. Both cases were observed during the COVID-19 pandemic. In addition, most fishers engage in a multispecies fishery, but some are known to be either pelagic or near-shore fishers, and as such, would exert different levels of effort depending on their preferred fishery. Therefore, it is equally important to measure the trend in catch per unit effort (CPUE) per landing site.

1.5 Study Implications

The Resource Management Unit (RMU) in the Department of Fisheries is responsible for monitoring the status of fishery stocks and marine ecosystems using a variety of scientific approaches. However, due to limited resources, the unit is unable to conduct regular analytical stock assessments, and therefore relies on the results of assessments conducted by external consultants or on complaints from fishermen when they have difficulties in finding certain species. By conducting this study, the Department of Fisheries, and by extension, the Ministry of Agriculture, would gain a better visual understanding of the species composition and distribution in each community using the maps and other graphical representations, such as charts, that have been produced. This would allow officials to identify areas that may be at risk, which in turn would enable the implementation of more proactive management measures.

Officers will also be able to identify trends in gear use over time and the associated efficiency within a fishery. This will assist department officials in gaining a better understanding of the level of effort in the various fisheries in Saint Lucia, which in turn would assist the department in facilitating informed measures to assist fishers in the form of fuel subsidies and the revision of gear specifications such as mesh and hook sizes.

1.6 Project Goals

1.6.1 To analyse the trends and patterns in the coastal and off-shore fisheries at the ten (10) primary landing sites in Saint Lucia

- To describe the spatial and temporal trends in landings and effort using data from the ten (10) major landings sites in Saint Lucia for a period of 2000-2021
- To identify landing sites and gears that are similar in species composition to inform fisheries management
- To calculate and standardize the catch per unit effort (CPUE) as a measure of stock status for six (6) key species

1.6.2 Assess the current management measures for the coastal and offshore fisheries in Saint Lucia

- To assess the current management measures that have been implemented in Saint Lucia’s fisheries sector and the impact that they could have had on landings over the years
- Prepare recommendations for sustainable management of demersal and pelagic fisheries in Saint Lucia

2 LITERATURE REVIEW

2.1 Estimating Fishing Effort

The assessment of fishing effort is a crucial factor in determining the pressure that a fishery can exert on the environment. Fishing effort, determined by analysing resource inputs (e.g. number of fishing gear, vessel size, and fuel consumption), is a key indicator of fishing activity in an area. Therefore, fishing efforts can change with improved technologies, changes in the composition of the sector, and changes in the environment (McCluskey & Lewison, 2008). This information is necessary to estimate fishing efficiency, which would assist in effectively managing the fishery sector in a country (McCluskey & Lewison, 2008). Fishing effort can be described as both nominal and effective fishing effort. The latter describes information related to catch rate, while nominal effort refers to resources that contribute to fishing operations, such as vessel and engine size, and fuel consumption. Information on both types can be collected by fisheries data collectors using various techniques, such as surveys and interviews, questionnaires, and logbook data.

However, the use of logbooks is quite resource-intensive, and in areas where artisanal fisheries predominate, such as the Caribbean, this may prove difficult. In this respect, interviewing fishers has proven to be a more successful method for data collection (Brander, 1975). However, this method leads to some information gaps, as data collection may not always capture the correct parameters, mainly because of inadequate training of data collectors and low cooperation of fishers in submitting the information. Nevertheless, the measurement of fishing effort is crucial for the assessment of fish stocks, especially when the capacity to conduct stock assessments is limited. Notwithstanding these limitations, McCluskey and Lewison (2008) have demonstrated that minimal data are sufficient to provide a basic analysis of the fisheries sector in a country, as shown by experiments conducted with data from California, Spain, and Scotland (McCluskey & Lewison, 2008). This approach seems quite promising for the Caribbean, as the data currently collected, although not extensive, could be useful for assessing the impact of fishing on an area.

In addition, the assessment of fishing effort allows fisheries managers to target fishing gear, which in turn could influence regulatory reform. The world's marine resources have been under considerable pressure for years, as the global consumption of aquatic resources has increased. As demand increases, fishing technologies will improve, as fishers focus on improving their efficiency. As far as offshore fisheries in the Caribbean are concerned, these changes included the introduction of Fish Aggregating Devices (FADs), which helped promote the aggregation of large pelagic species. However, without adequate monitoring and data collection procedures, it is difficult to determine the impact of gear change on a fishery; therefore, landings and effort data are the most important tools for assessing this change. This is especially true in the Caribbean for larger pelagic stocks, as most of them are highly migratory and therefore difficult to assess on a regular basis. Therefore, a regional approach to data collection analysis would allow for better management of shared resources.

2.2 Stock assessment models

Stock assessment models have proven extremely useful for stock assessments when countries have limited data. A common tool is the catch per unit effort (CPUE) approach, which is based on catch and effort data obtained from fishermen. The CPUE approach is believed to provide a fairly accurate representation of a fishery stock, as it assumes that there is a proportional relationship between the size of the stock and the calculated value (Venables & Dichmont, 2004). However, this is not the case, as population dynamics influence stock size in most cases and, although plausible, it would be inaccurate to assume that a decline in fish caught means a decline in the population. Nevertheless, this method has proven to be more useful over time through standardisation (Maunder & Punt, 2004). One method used for standardisation is the use of a generalised linear model (GLM). The GLM focuses on the statistical distribution of the response variable (e.g. catches) and how this value is a linear combination of a set of explanatory variables related to the expected value of the response variable (Maunder & Punt, 2004). Therefore, the GLM provides fairly accurate data once appropriate values are entered.

3 METHODOLOGY

3.1 Data

3.1.1 Data Collection

The data used in this study consists of landing data collected by the Department of Fisheries for the period 1995-2021. The landing data were collected by data collectors using a stratified sampling approach, that is, information was collected from every other returning vessel on the day of sampling. Data collectors gather vessel information, effort data such as the number of gears on the vessel and time out at sea, and catch data, which includes the weight and cost of the fish per pound. This information is usually obtained from the captain of the vessel and is recorded in a notebook which is later transferred to the data collection sheets generated by the Department of Fisheries (see Appendix 1).

The sampling process is performed by ten (10) data collectors that are stationed at the ten (10) primary landing sites that are island wide. Data collectors work fifteen (15) randomly selected days each month, including weekends, and from this, the monthly totals are estimated. As previously mentioned, the data collectors collect information from every other vessel that returns to the port but record the total number of vessels actively fishing that day. The data collectors use scales to record the weight of the landings, and if scales are not available, the collectors are trained to make visual estimates (World Bank, 2019). Weight estimates are usually based on the whole or gutted weight, with the former being the more common form of measurement. Data collectors are provided with regular training in identifying fish species, and most, if not all, are able to identify fish down to the species level. The type of gear used during the fishing trip is also collected; however, since many of the fishers are considered mixed-species fisheries, similar species may be caught using multiple gears, and fishers switch between gears during trips; thus, landings of one species are not limited to one gear type. The data collectors take note of the general zones in which boats operate. Each zone is associated with either offshore or coastal fisheries.

Once a month, data booklets are collected from the data collectors, and a new booklet is issued by the Data Manager or the appointed fisheries officer. The fisheries officer responsible for collection does an initial verification with the data collector to ensure that their entries are accurate. Afterwards, the officer performs a secondary check on the data, and any errors and omissions are highlighted and corrected before the final dataset is submitted. The catch and effort data recorded by the data collectors is stored in the Trip Interview Program (TIP). This program was adopted for use in the Caribbean region with support from the Organization of the Eastern Caribbean States (OECS) Fisheries Unit and CARICOM Fisheries Resource Assessment and Management Programme (CFRAMP) (Murray et al., 1996). The Licensing and Registration System (LRS) is also utilized for capturing and storing vessel and fisher data.

3.1.2 Data Preparation

The raw data was extracted from the TIP database of the Department of Fisheries in Saint Lucia and was stored using the extension *".dbf"*. The data were cleaned, and the datasets were renamed and regrouped into tables that were appropriate for data analysis. The files were then transformed into *".rda"* files to make it easier for data manipulation. The main data tables created using the selected time period were (see Appendix 2):

- Sampled catch data
- Fishing days and fishing vessels per landing site
- Landing sites ID
- Landing sites GPS locations
- Type of fishery
- Type of gear
- Species
- Gear use and area fished
- Estimated Trip data

3.2 Fish landing sites

Over the years, landing sites have been improved to include infrastructure, such as jetties and lockers. These landing sites are also associated with data collectors and active fisher cooperatives. Landing sites with these amenities were classified as the primary landing sites. Currently, there are ten (10) primary landing sites on the island where catch and effort data are collected (Figure 3).

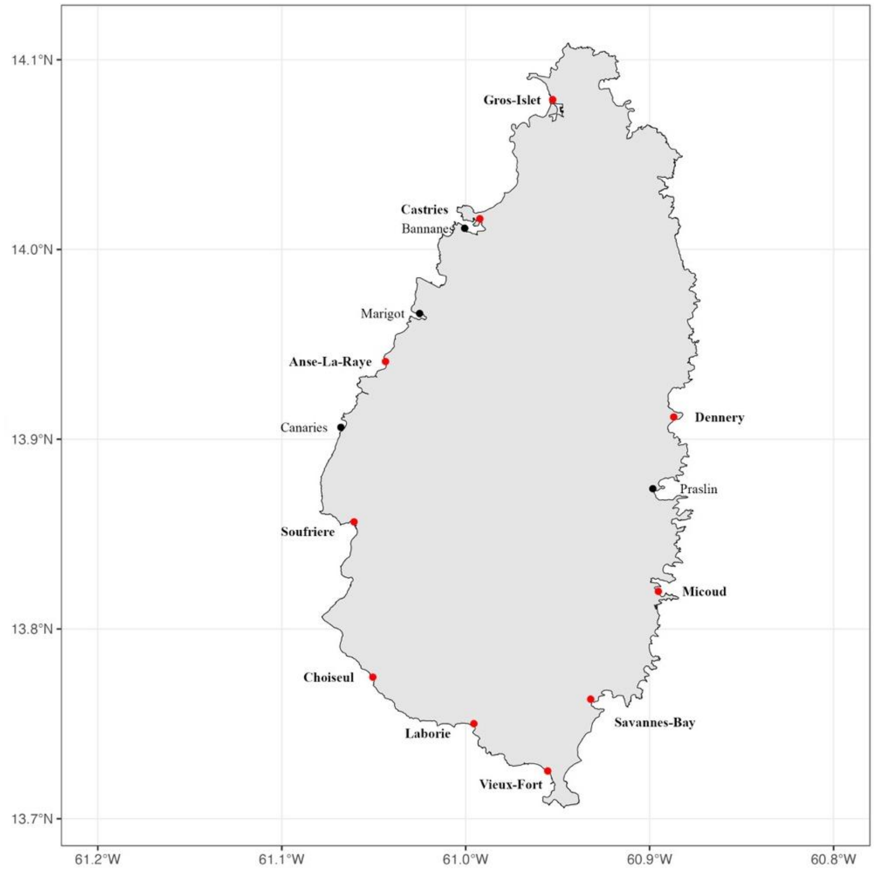

Figure 3. Communities where primary landing sites are located (red dots show primary landing sites and black dots represent some secondary sites).

However, in the dataset used for the project, there is information from some secondary landing sites (Table 1), which are categorised as sites with minimal infrastructure, and tertiary landing sites which would be mainly beaches (World Bank, 2019). Presently, the Data Management Unit within the Department of Fisheries links certain secondary and tertiary landing sites with a primary landing site based on similarities such as location or the dominant fishery in the area. The raising factor that is calculated and used for each primary landing site would then be used to estimate the total landings for the associated secondary and tertiary landing sites for the month. These sites are then listed as 'OTHER' in the department's system, and values from this category are also used to calculate the yearly landings.

It should be noted that for the purpose of this study, landing and effort data from the secondary and tertiary sites were not included in the analysis because of missing accompanying data. Therefore, raised values and the '*R*' factor were not calculated for these sites.

Table 1. List of landing sites in Saint Lucia

Landing Site	Location Code	Location on Map	Status
Gros Islet Landing Site	GRIS	North	Primary Landing site
Castries Landing Site	CASF	North	Primary Landing site
Bannanes Landing Site	CAST	North	Secondary Landing site
Anse-La-Raye Landing Site	ALRA	West	Primary Landing site
Canaries Landing Site	CANA	West	Secondary Landing site
Soufriere Landing Site	SOUF	West	Primary Landing site
Choiseul Landing Site	CHOI	West	Primary Landing site
Riviere-Doree	RIDO	South-West	Tertiary Landing site
Laborie Landing Site	LABO	South-West	Primary Landing site
Vieux-Fort Landing Site	VIFO	South	Primary Landing site
Savannes-Bay Landing Site	SABA	South-East	Primary Landing site
Micoud Landing Site	MICO	East	Primary Landing site
Dennery Landing Site	DENN	East	Primary Landing site

3.3 Effort

Currently, both sampled and total effort data are used to calculate the total fishing effort in Saint Lucia.

3.3.1 Sampled effort

Sampled effort is based on the information collected by the data collectors. Data collectors collect information on the sampled vessels, which is the total number of vessels sampled on the day. The sampled days, which are the total number of days that the data collector worked for the month, are also used in the sample effort calculation.

3.3.2 Total effort

Total effort was calculated using data from 2000-2021. In 2000, the Department of Fisheries implemented a new data collection system that included the collection of effort data such as the total number of vessels out at sea for the month at each primary landing site. In this regard, calculations were only performed from 2000 onwards; hence, the total catch and effort were only calculated for that period.

The total boat activity and fishing days were calculated by month and year for each landing site. The total boat activity is captured during the monthly submission by the data collector and is the total number of vessels engaged in fishing activities for the month. However, the total monthly fishing days at the primary landing sites were calculated using the following formula (Edwin, 2011):

a. *Total Fishing Days = Total # of days in a month – (Total # of Sundays in month + # "0" zero boat out days + holidays)*
b. *Total Fishing Days = Total # of days in a month – (Total # zero boat out days + holidays)*
   ***Calculation (a) applies to all sites except VIFO and DENN. Calculation (b) applies to VIFO and DENN*

The mean trips per day, which is equivalent to the mean number of boats fishing per day, is estimated as:

Mean trips per day = Sum of total vessels landed on sampled days/ number of sampling days

The total monthly effort, which is measured as the number of trips, is calculated as:

*Total Monthly Effort = Mean trips per day * Total Fishing Days*

A raising factor is then generated for each primary landing site to calculate the total monthly and, thus, yearly raised catch:

Raising Factor = Number of trips (for the month)/ Sampled trips

3.4 Catch

Landings refer to the fish that were landed at the different landing sites. Because of the sampling process in place, the sampled weight collected must be converted to obtain the total landings for each landing site and, subsequently, each year. The sampled catch weight was summarised by species, gear type, landing site, month, and year. The total catch was estimated by applying the raising factor, as follows:

*Total Catch = Sum of sampled weight * Raising factor*

3.5 Spatial and Temporal trends

Species were grouped by landing site and year, and changes over the years were examined using these two main categories. Descriptive analyses were used to study the patterns and evolution of fishing efforts and catch data by landing site over the years. Gear use and trip type were also plotted to show changes in fishing practices during the study period.

3.6 Cluster Analysis

Cluster analysis is used to identify similarities and patterns within groups in the multivariate data (McKenna Jr., 2003). The main outcome of this analysis is the creation of a dendrogram showing the patterns and similarities associated with the different subgroups.

The total landed catch weight by month, landing site, and gear type for each species were used for cluster analysis to obtain hierarchical clusters of species assemblage, to determine which species are similar with respect to the geographical region they are caught in and the gear type targeting the fishery and the time of the year the fishery occurs. In addition, the groups created using cluster analysis were used to determine which fishing gear was most used for the different species. A similar procedure was used for the effort data.

The five (5) most common species caught by each gear type were used, resulting in a total of 51 species (Appendix 5, Table 5). All 23 gear types were considered for the analysis; however, harpoon (HARP) was excluded from the final analysis. The data were standardised by range so that all variables were on a similar scale. Clustering was conducted using the pvclust routine in R (Suzuki, 2019). The routine uses bootstrapping to generate probability values (p-values) for the identified clusters. The p-value ranges from zero (0) to one (1) and is used to assess the strength of similarity within the cluster, and hence, the likelihood of obtaining the same cluster. For this study, the approximate unbiased (AU) p-value was used because it provides a more reliable approximation (Suzuki, 2019).

3.7 Catch per Unit Effort

Due to its significance, the pelagic fishery was chosen as the target fishery for the calculation of catch per unit effort (CPUE). Analysis of catch trends and cluster analysis revealed that the troll fishery resulted in the largest landings of large pelagic species at different sites, with dolphinfish, gulf sierra mackerel, yellowfin tuna, skipjack tuna, blackfin tuna, and blue marlin landing occurring in the largest quantities. Therefore, CPUE calculations for the trolling gear were performed for the six (6) main species. In addition, the calculations were limited to three

(3) landing sites (Dennery, Micoud, and Vieux-Fort landing sites), as these sites consistently recorded the largest pelagic landings on the island during the study period and were the three sites most likely to land the same species.

3.7.1 Nominal CPUE Analysis

The non-standardised CPUE or catch rate was calculated using the raised landing data for the years 2000-2021. For the selected species, the nominal CPUE was calculated using the sum of the catches divided by the number of trips.

3.7.2 Generalized Linear Model

The Generalized Linear Model (GLM) with a Gaussian link was used to obtain a standardised estimate of CPUE. This form of regression modelling was used to illustrate the influence of predictor factors on the catch rate within a fishery, such as the possible impact of the timing of the fishery or the location of a landing site on the catch. In this study, year, month, and landing sites were used as explanatory variables in the model. The analysis was conducted for each of the six (6) key species: dolphinfish, yellowfin tuna, skipjack tuna, blackfin tuna, gulf sierra mackerel, and blue marlin. For each species, data were filtered for the main gear used in the fishery, which is the trolling gear. The model can be expressed as:

$$ln\ (CPUE + c) = Intercept + Y + M + L + + \varepsilon,\ \varepsilon \sim N\ (0, \sigma^2)$$

where c is a constant, *Y* is the year effect, *M* is the month effect, *L* is the landing site effect, and ε is the error which assumes a normal distribution with a mean of 0. A constant *c* was added to nominal CPUE to overcome the problem of zero catch.

Further, each dataset was filtered by the key landing site to examine the effect of year and month on the catch at three (3) of the most important landing sites for the selected species, using separate models for each landing site.

The residuals of all the models were checked to ensure that the assumptions of a Gaussian distribution were satisfied. A deviance was also calculated for each model as a measure of variability explained by the model. All the data analysis was done using the R statistical software (R Core Team, 2015)

4 RESULTS

4.1 Landings

4.1.1 Total Landings

The total raised landings of sites sampled over the entire time series showed some fluctuations; however, the overall trend was stable (Figure 4). There was an average of 1,215.00 tonnes landed each year for the period 2000 to 2021. The year with the highest landings was 2001, reporting 1,545.32 tonnes, while the lowest landings of 996.56 tonnes occurred in 2000 (see Appendix 6: Table 6).

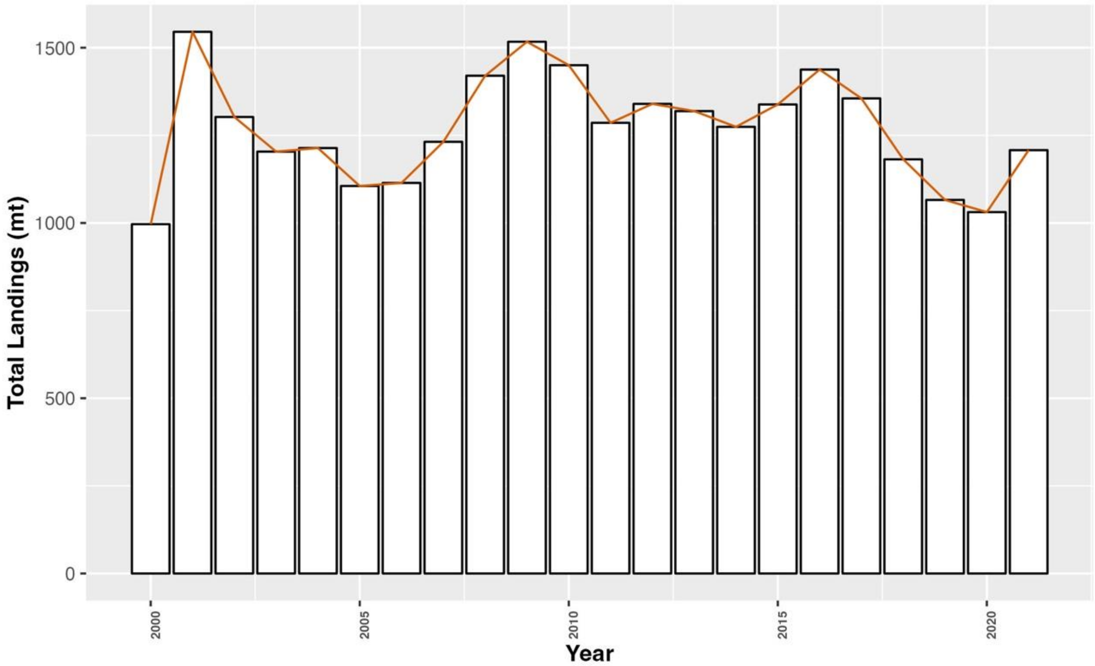

Figure 4. Graph showing the total raised landings recorded in Saint Lucia for the period 2000-2021.

Landings were relatively constant at the various primary landing sites, with noticeable yearly fluctuations recorded at Castries, Gros-Islet, Laborie, Anse-La-Raye, and Soufriere (Figure 5), with the Anse-La-Raye records showing the greatest fluctuations for the period. Areas such as Dennery, Vieux-Fort, and Micoud consistently recorded slight increases in annual landings. Conversely, sites such as Castries had a lower catch recorded and greater fluctuations in landings throughout the period. Furthermore, analysis has shown a decrease in landings at several sites over the years, such as Gros-Islet, Choiseul, Laborie, Soufriere, and Savannes-Bay. However, missing data from Savannes-Bay, owing to a nearly 15-year gap in data collection, may prevent an accurate representation of the overall trend in landings. This lack of data collection from 2001 to 2016 is a result of the change in the status of the landing site, from a sampled site in 2001 to an unsampled site until recently, when data were collected from fishers.

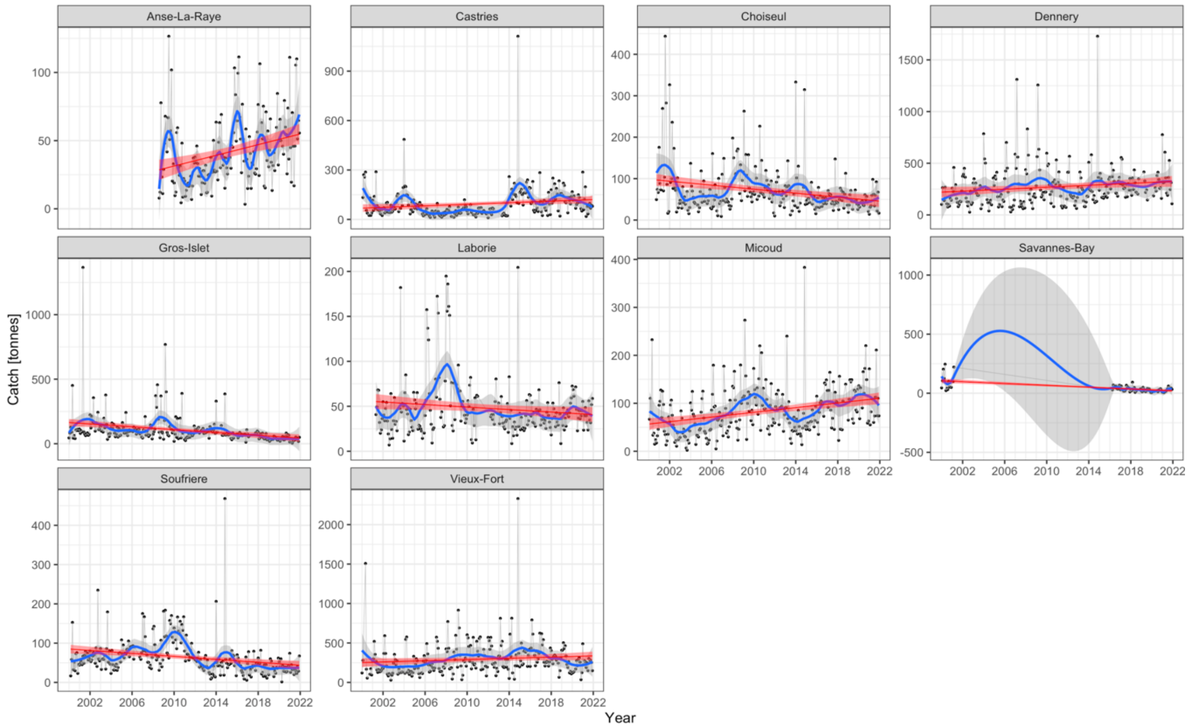

Figure 5. Trends in monthly landing distribution by landing site showing a smooth trend line plotted using the generalised additive modelling and a red line showing a linear trend.

4.1.2 Landings by Species

Dolphinfish (*Coryphaena hippurus*), tuna (*Thunnini* spp.), and marlin (*Istiophoridae* spp.) are some of the most important pelagic species caught by Saint Lucian fishers. The sampled landings of these species remained consistently higher than those of the other species (Figure 6). Tuna species make up the largest proportion of catch by fishers, with the highest recorded landing of 499.44 tonnes being recorded in 2010 and the lowest in 2018. Landings of dolphinfish and queen conch have also decreased in recent years. There has been an overall increase in the landing of billfish, and in the case of the parrotfish fishery, there appears to be an overall decline in the total landings after 2013.

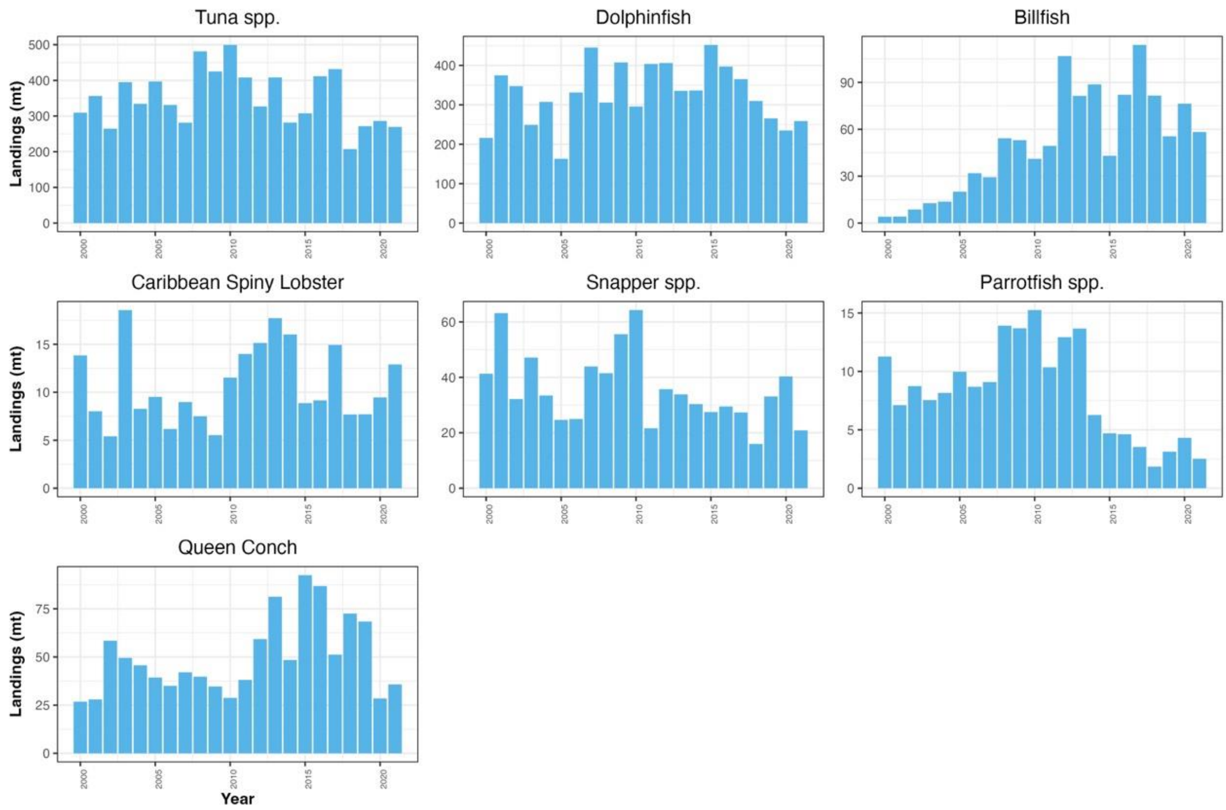

Figure 6. Graph showing landings for selected commercially important species (scale on the y-axis differs by species).

4.1.3 Seasonality of Landings

Landings appear to be the highest at the beginning of the year and steadily decrease for most sites throughout the year. However, the landings on Gros-Islet showed a relatively constant landing throughout the years. In addition, fishermen at the Vieux-Fort landing site reported the highest average landings per month (Figure 7).

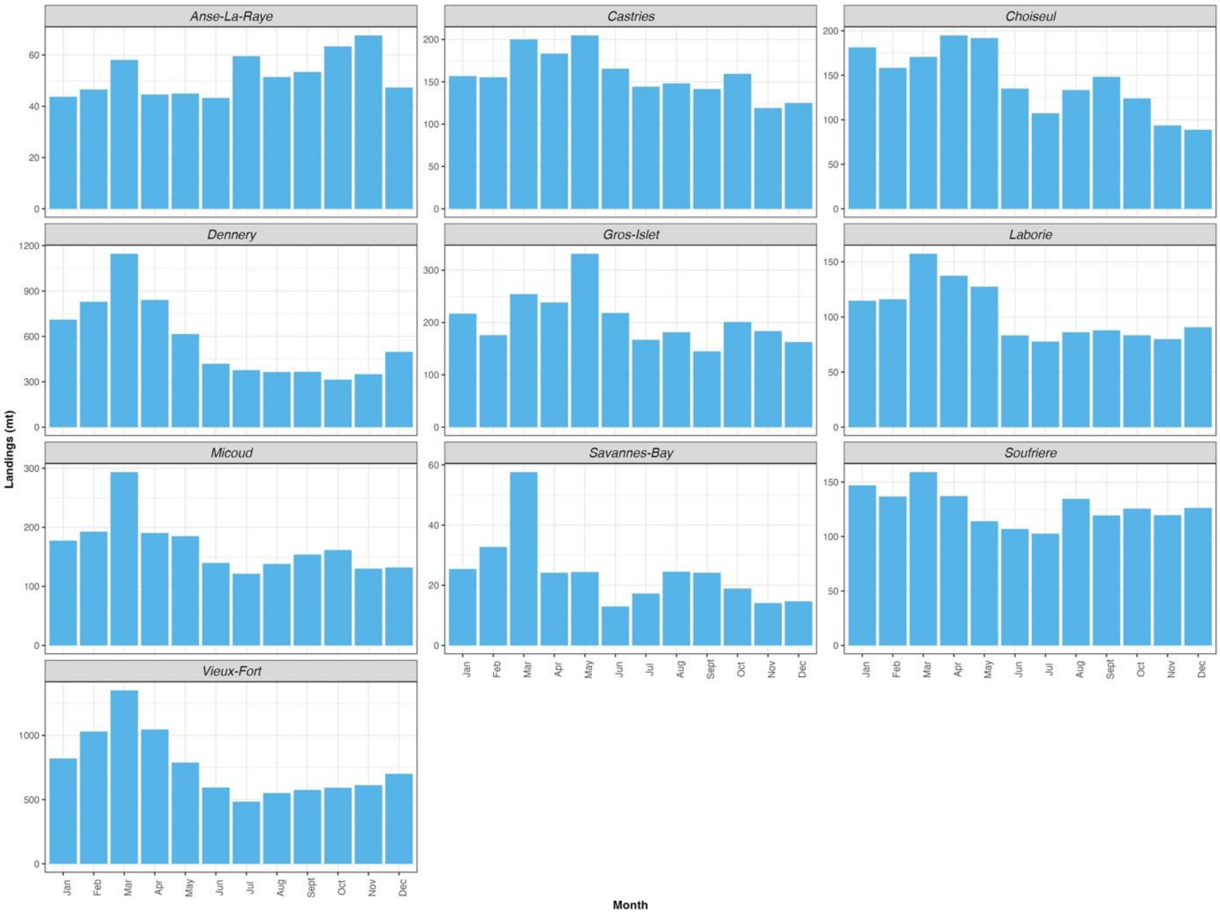

Figure 7. Barplot showing monthly landing variation at different landing sites (scale on the y-axis differs by landing site).

Landings for some of the more commercially important large ocean pelagics seem to follow a similar seasonality throughout the year. The tuna and dolphinfish fisheries seemed to be more successful at the beginning of the year, mostly between January and May, with the peak months being January for the tuna fishery and March for the dolphinfish fishery (Figure 8). During the low season or the period when a lower number of pelagics are caught, there is an increase in the landings of the reef and bank fish. In terms of the lobster fishery, it takes place mostly between August and December, with almost no fishing taking place for lobster from May through July. However, the queen conch fishery does not show any major seasonality in terms of landings.

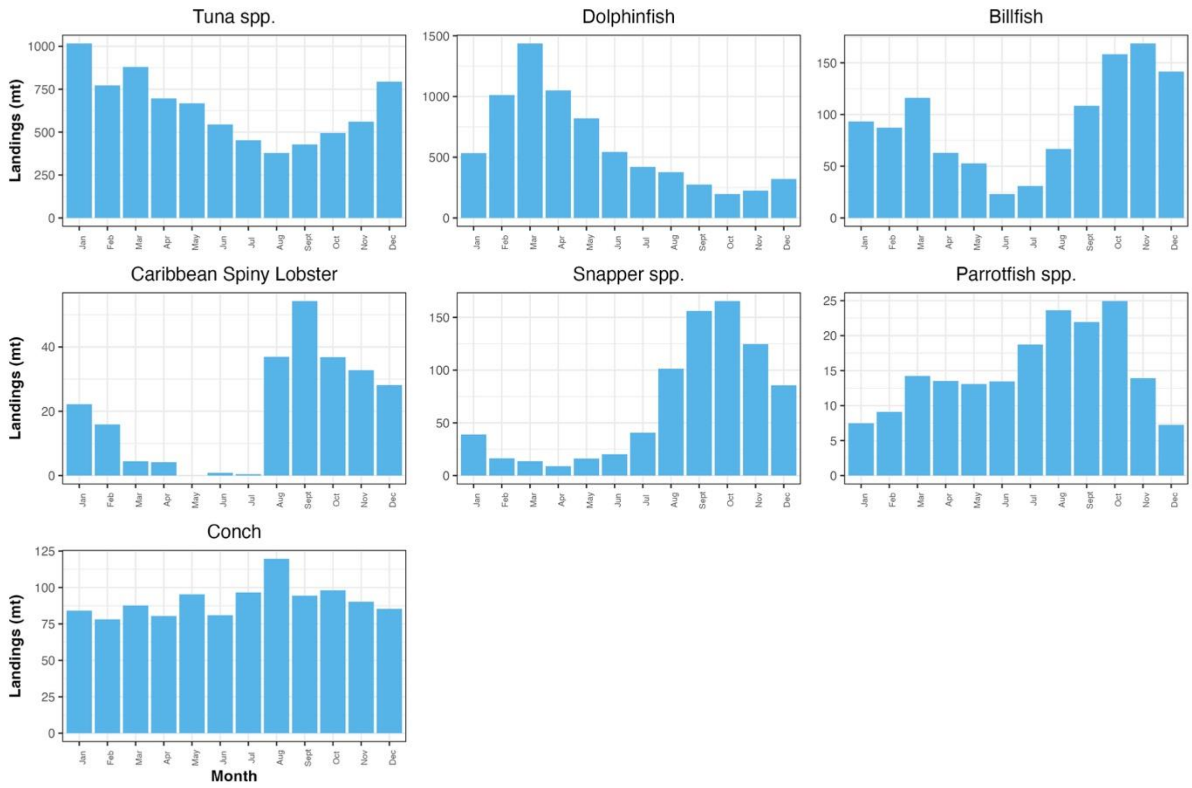

Figure 8. Seasonality of some commercially important species (scale on the y-axis differs by species).

4.2 Trends in Gear Use

Saint Lucian fishers have landed fish using 23 types of gears and fishing techniques over the years, including bottom line, beach seine, cast net, free-diving, dip net, fish pots, gillnet, catching by hand, harpoon, handline, hookah, lobster pot, palangre, pole and line, pots, rod and reel, scuba diving gear, speargun, surface long line, scoop net, trawl, trolling and vertical line (Figure 9). The use of trolling and pots has remained high over the years, with trolling gears being the most popular gear type. However, pot use dropped significantly after 2007 and has yet to surpass records prior to 2007. On the other hand, the use of trolling gear seems to have increased during the same period, with a spike in the number of trips where trolling gear was used, recorded from 2015 to 2017. The use of trolling gear has been decreasing in recent years, but it remains the most popular gear used by fishers. Gillnets appear to be the third most common gear used over the years.

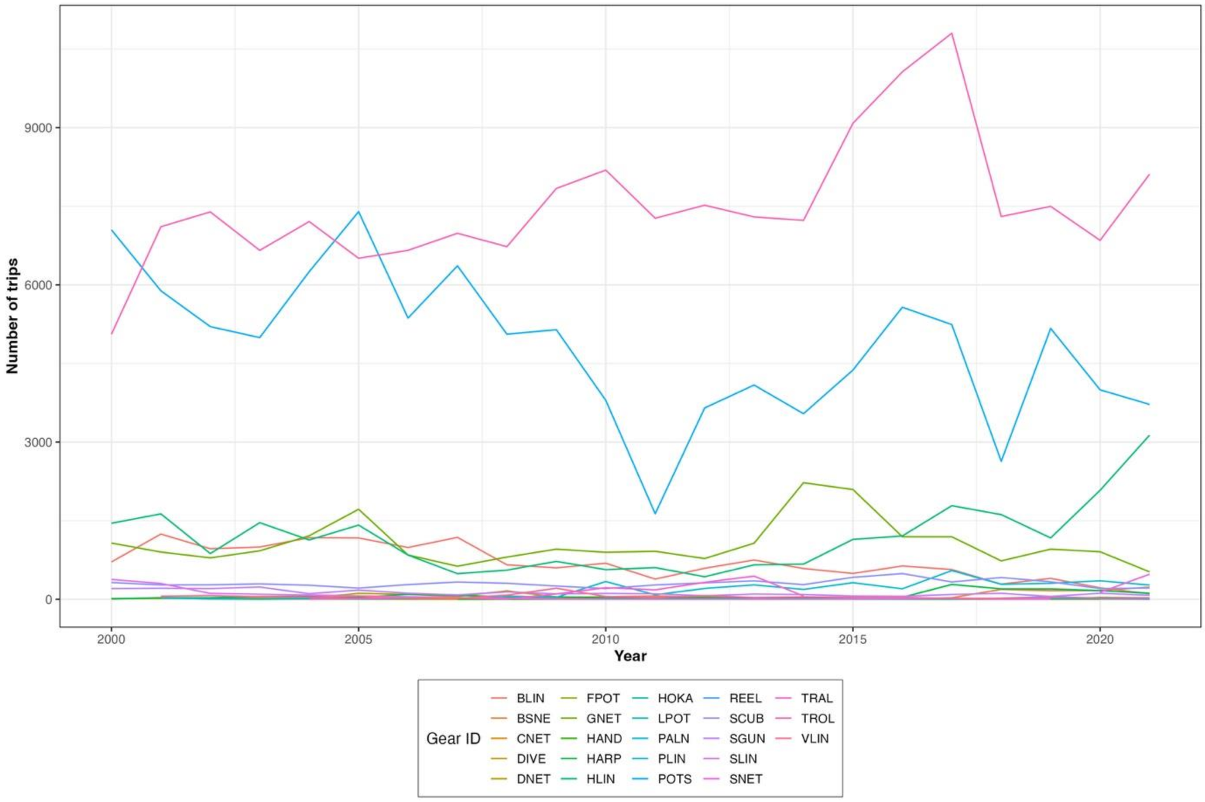

Figure 9. Graph showing change in gear use from 2000-2021.

In terms of landings, trolling is consistently the gear with the highest landings over the period, namely in dolphinfish, tuna, and billfish fisheries. Gillnet (GNET) fisheries showed the second-highest landings over the period. The pot fishery has somewhat lower, albeit consistent, landings than trolling, which is expected since the pots are designed to catch smaller fish. Gear types such as handlines (HLIN), scuba (SCUB), and speargun (SGUN) are also frequently used (Figure 10).

Figure 10. Bar graph showing total estimated landings by gear used 2000-2021 (scale on the y-axis differs by gear type).

During the study period, the trolling gear appeared to be the most popular gear used at the five (5) landing sites. The Dennery, Micoud, and Vieux-Fort landing sites all recorded consistently high levels of trolling over the years. In Anse-La Raye, Castries, and Gros-Islet, there seems to be a wide variation of gear utilised by fishers; however, in Castries and Gros-Islet, the variety of gear used has been decreasing over time. The use of scuba gear has increased slightly over the years at the Gros-Islet landing site, whereas the use of handlines has decreased. Pots are the most popular gear type used at the Laborie landing site, and this gear type is also popular at the Choiseul and Savannes-Bay landing sites (Figure 11).

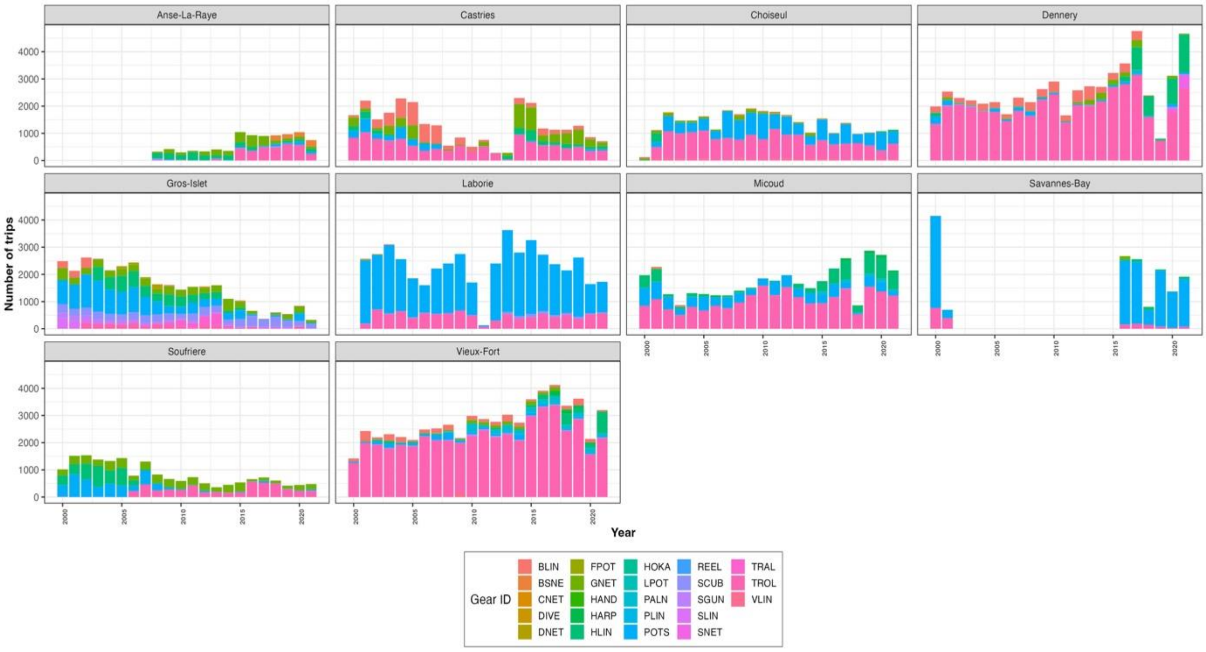

Figure 11. Bargraph showing frequency of gear used at the primary landing sites 2000-2021.

Fishers have exhibited a preference for trolling over the years, as more trip types have been recorded as trolling trips (Figure 12). The use of scuba gear seemed to be most common at the Gros-Islet and Laborie landing sites, with the frequency of use being higher at the Gros-Islet site. Moreover, bottom longlines are most commonly used by fishers at the Castries, Dennery, and Vieux-Fort landing sites, but their use has decreased over the years.

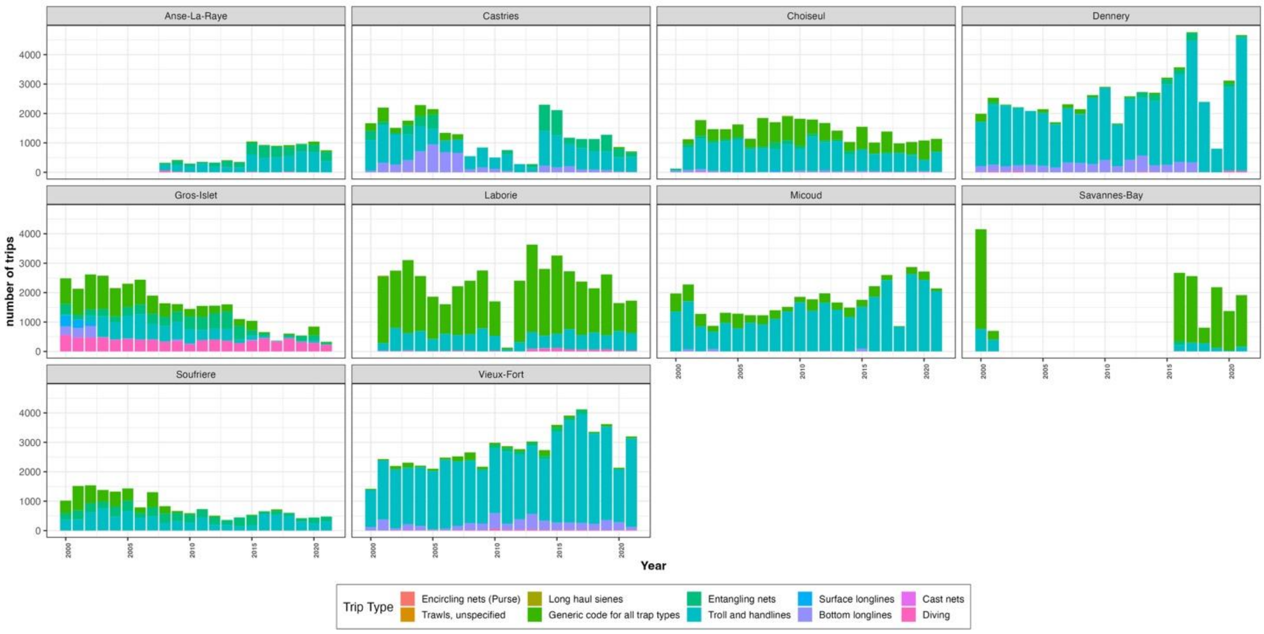

Figure 12. Bar graph showing change in trip type at the different landing sites 2000-2021

4.3 Effort Trends

4.3.1 Total Effort

The total estimated fishing effort by fishers from 2000-2021 and effort levels seem to have fluctuated slightly over the years (Figure 13). From 2010-2015, the number of fishing trips was lower than that recorded before 2010. A similar trend was observed after 2017, when the number of trips declined until an increase was recorded in 2021.

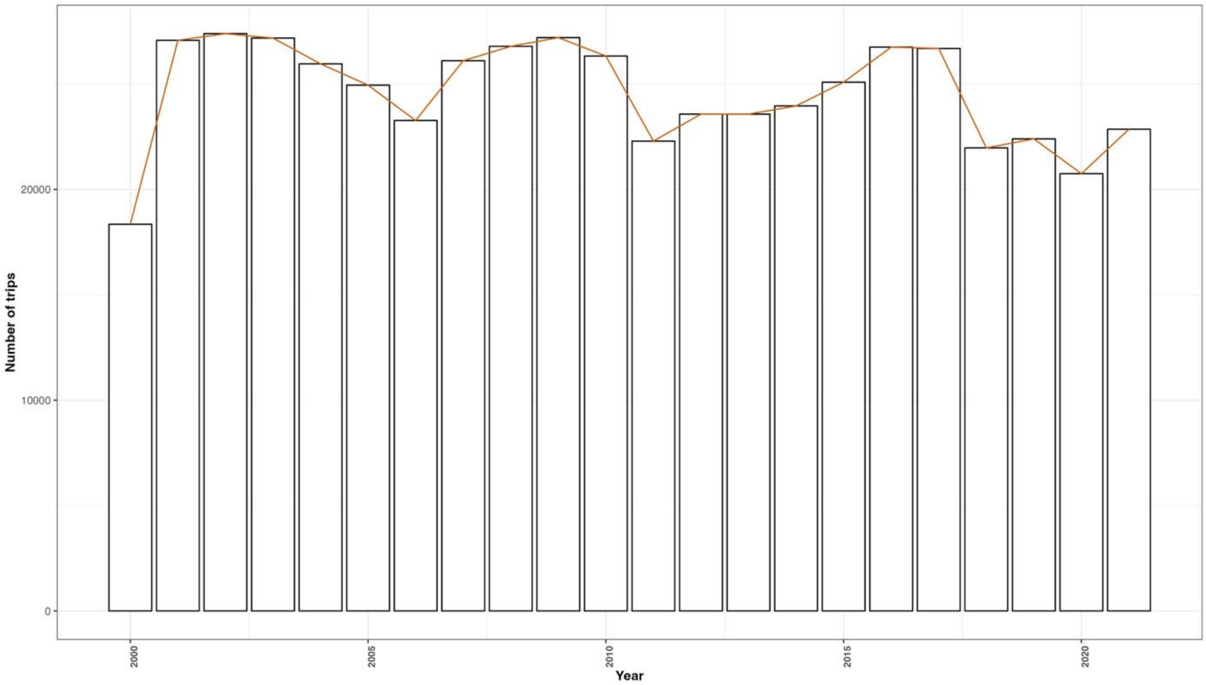

Figure 13. Barchart showing the total estimated effort using the total number of trips, recorded 2000-2021.

4.3.2 Effort by Landing Site

The areas with the highest recorded landings of large ocean pelagics, namely Dennery and Vieux-Fort, had the highest and most consistent number of fishing trips over the years (Figure 14). Landing sites of lesser importance showed somewhat larger variability and conflicting trends in the number of trips over time. Landing sites such as Castries, Choiseul, Gros-Islet, and Soufriere exhibited significant declines in the recorded number of trips. Yearly fluctuations occurred more frequently and to a greater extent at the Soufriere landing site than at the Choiseul and Gross Islet landing sites. On the other hand, Anse-La-Raye had a higher number of fishing trips from 2013 compared to prior years.

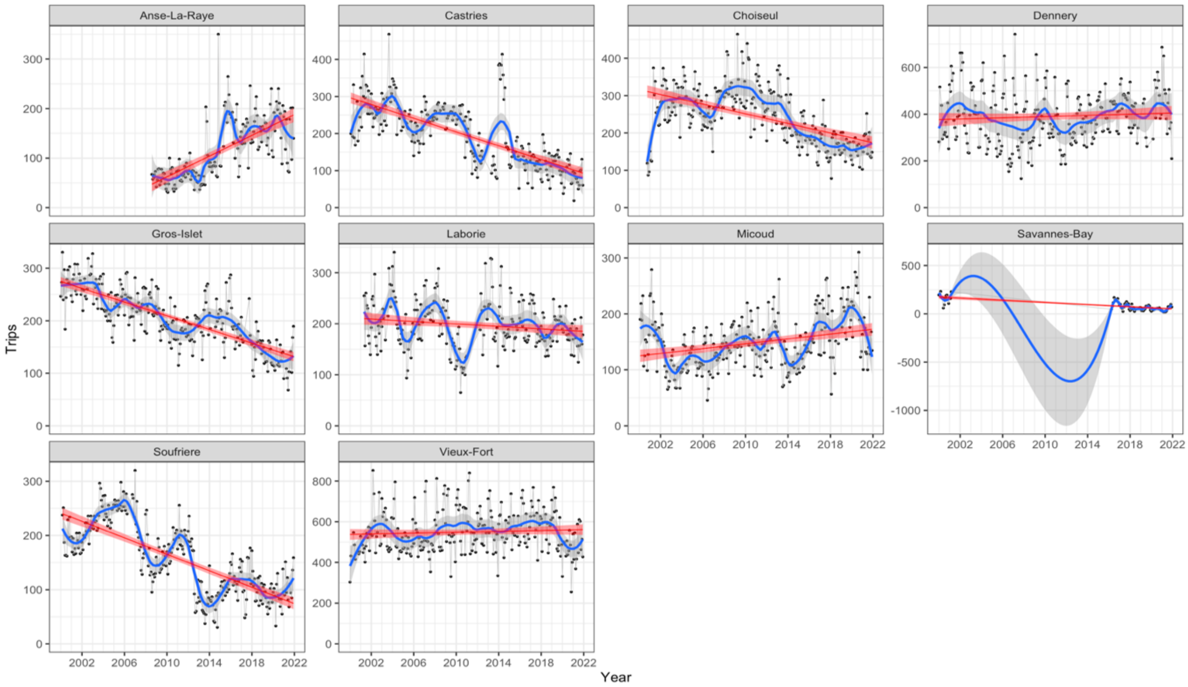

Figure 14. Total monthly fishing effort recorded at the primary landing sites 2000-2021 showing a smooth trend line plotted using generalised additive modelling, and red line showing linear trend.

4.3.3 Total fishing vessels at sea

Landing sites such as Castries, Choiseul, Gros-Islet, and Soufriere all showed decreasing numbers of vessels engaged in fishing during this period. In contrast, sites such as Dennery and Vieux-Fort recorded high fluctuations in the number of fishing vessels recorded at each site (Figure 15).

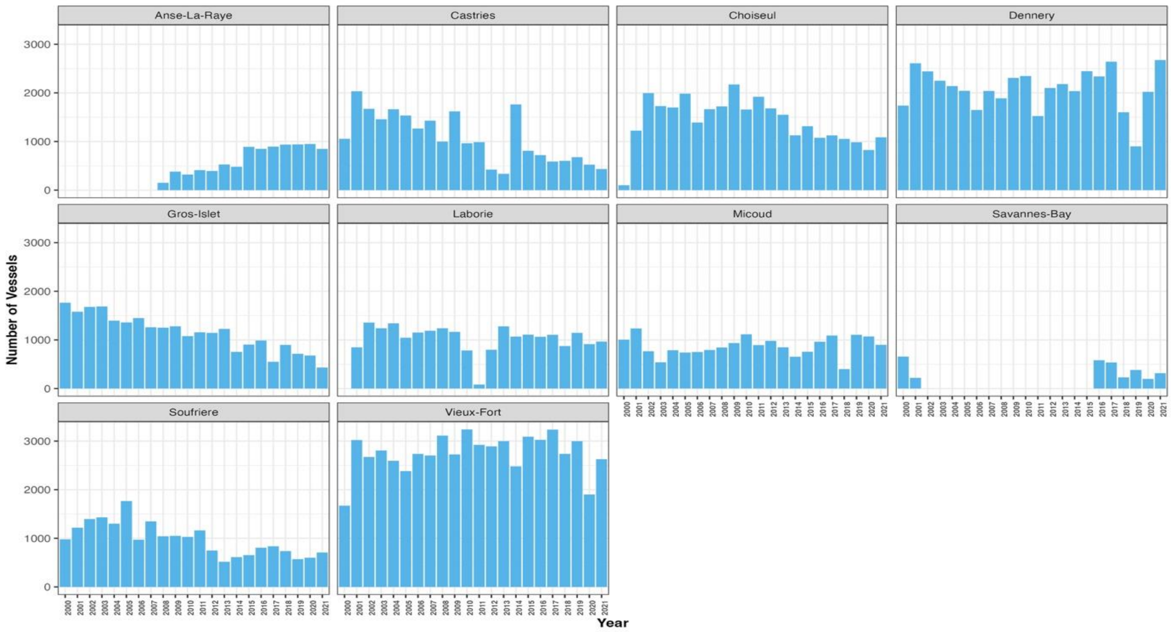

Figure 15. Change in total fishing vessels at the primary landing sites 2000-2021.

4.4 Cluster Analysis

In the dataset used for cluster analysis, 90 percent (90%) of the total catch comprised twenty-three (23) species, whereas 51 species comprised 97% of the catch. The output of a hierarchical cluster analysis was a dendrogram showing the patterns and similarities associated with the different identified subgroups. The length of the lines indicates the similarity between the clusters, which decreases the levels created within the dendrogram. Four (4) main species groups were identified from the dendrogram in Figure 16 at a dissimilarity level of approximately 25. The first cluster consisted of dolphinfish (CORYHI), gulf sierra mackerel (SCOMSO), yellowfin tuna (SCOMAB), skipjack tuna (SCOMPE), blackfin tuna (SCOMAT), and blue marlin (ISTINI) with a probability of 74, since all species are large ocean pelagics. Although all species were found in the same group, CORYHI and SCOMSO were the most similar in terms of the type of gear used to catch them and quantity at landing. Therefore, they were clustered with a probability of 100. The second cluster exhibited a probability of 100, suggesting that squirrelfish (HOLOAD) and coney (SERRFU) were always caught together in similar quantities using similar gear types. Clusters 3 and 4 contained mainly reef and bank fish, such as parrotfish and snappers, which are usually caught using nets, fish pots, and lines.

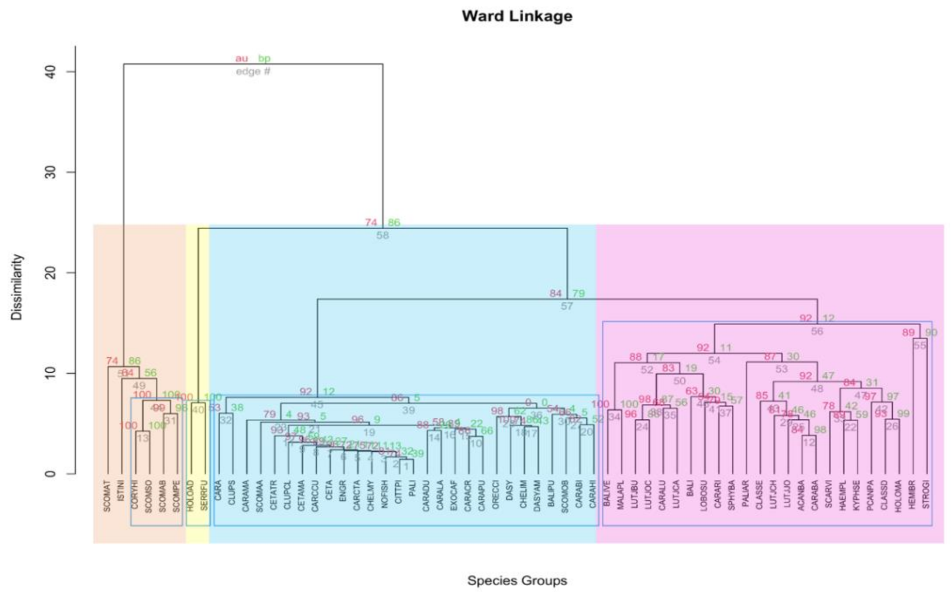

Figure 16. Dendrogram showing the four species assemblages formed from cluster analysis. Clusters are colour coded with cluster 1 represented in brown, cluster 2 in yellow, cluster 3 in blue and cluster 4 in pink.

Cluster 1 recorded the highest landings by weight for the period, since the species that are found within this are mainly large ocean pelagics (Figure 17). The second largest clusters by weight were clusters 3 and 4, both of which contained reef fish, including jacks and scads. Cluster 2, which contained two types of reef fish, squirrelfish, and coney, had the lowest landings by weight.

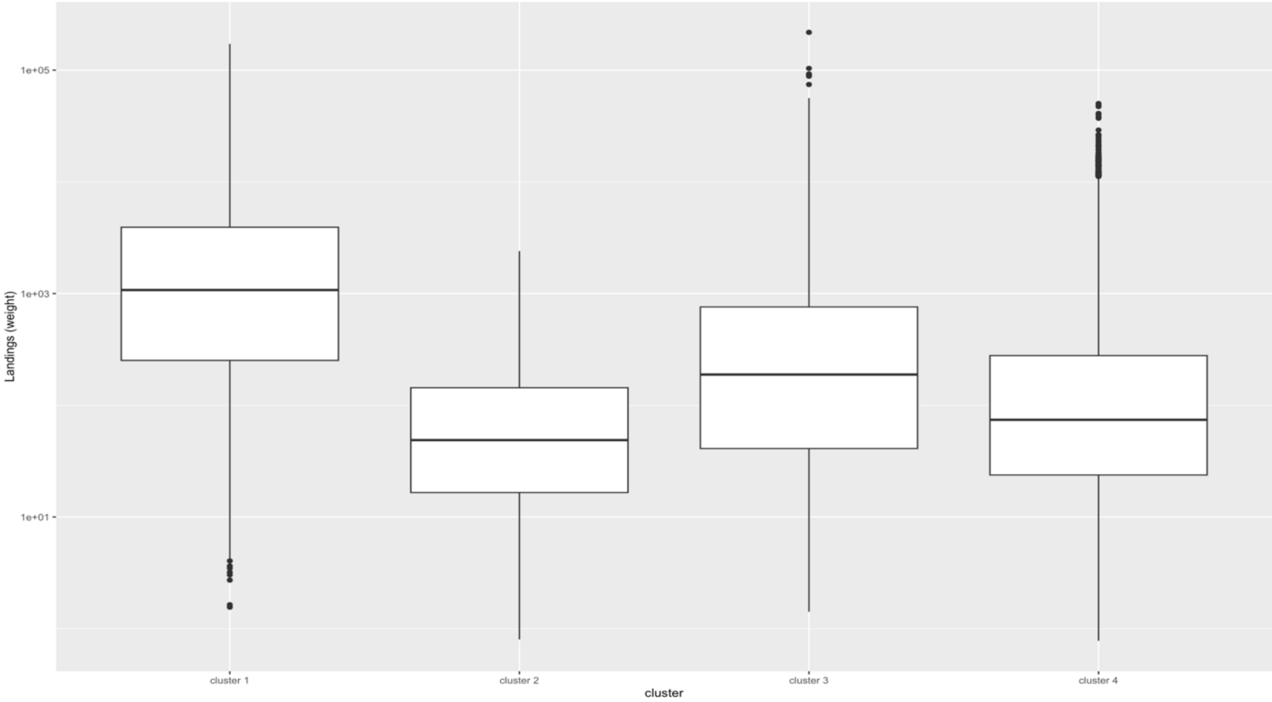

Figure 17. Boxplots showing species clusters formed from the cluster analysis.

It can be deduced that trolling gear captures all the main species, making it the most popular gear utilised during this period (Figure 18). Species in cluster 4 were caught using twenty (20) of the 23 gears during this period, whereas those caught in cluster 1 were caught using only thirteen (13) gear types. In cluster 1, trolling was the most popular gear used to catch ocean pelagic species, while species in clusters 3 and 4 were caught using the largest collection of gears.

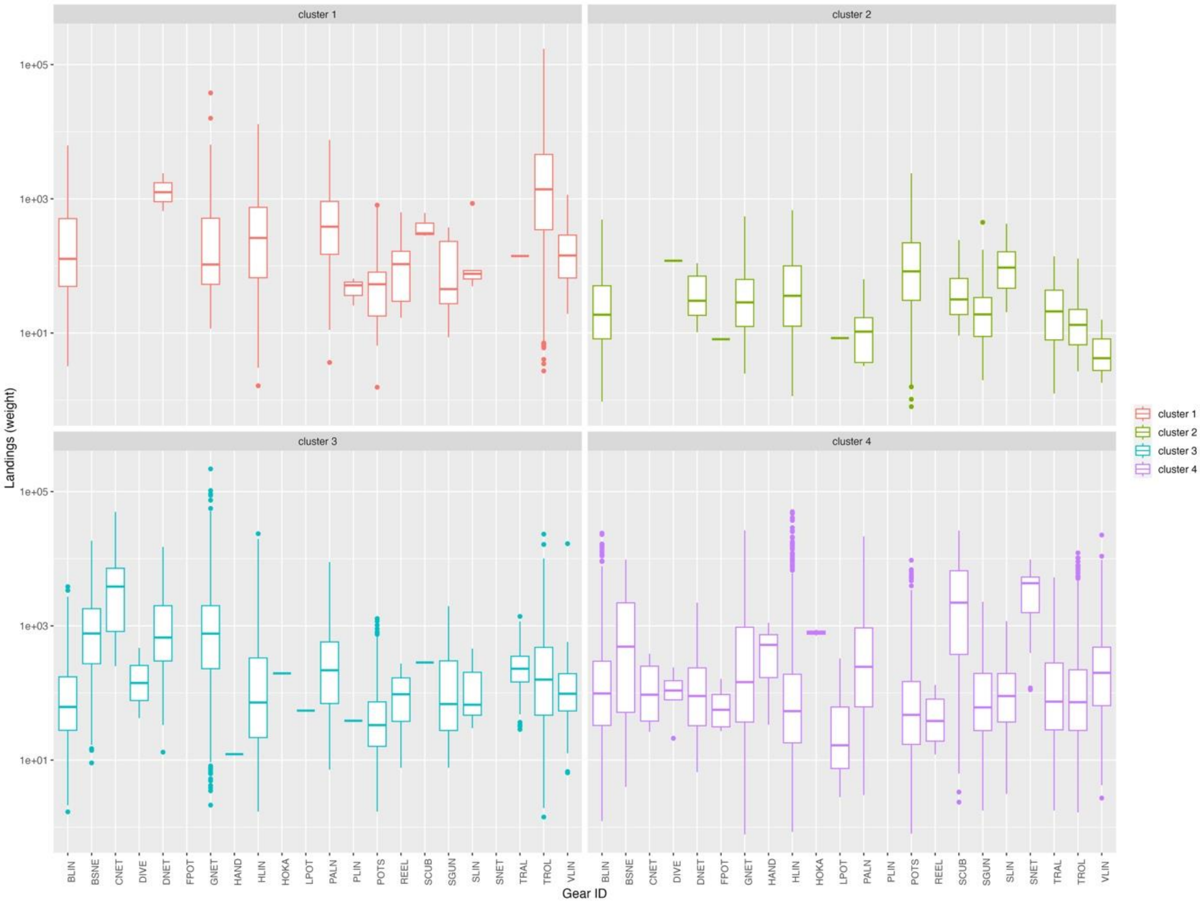

Figure 18 Dendrogram showing cluster selection by gear type

All clusters of species were found at all landing sites around the island (Figure 19); however, cluster 1 produced the highest recorded landings by weight at all sites. The Anse-La-Raye (ALRA) landing site recorded a wider weight distribution for cluster 3 species. Cluster 4 appeared to be the largest grouping by weight for Soufriere (SOUF), followed by Cluster 3. Both clusters contain small demersals that are caught using nets, lines, and pots and as such, the average expected weight is significantly lower than that of cluster 1 which contains large ocean pelagic species.

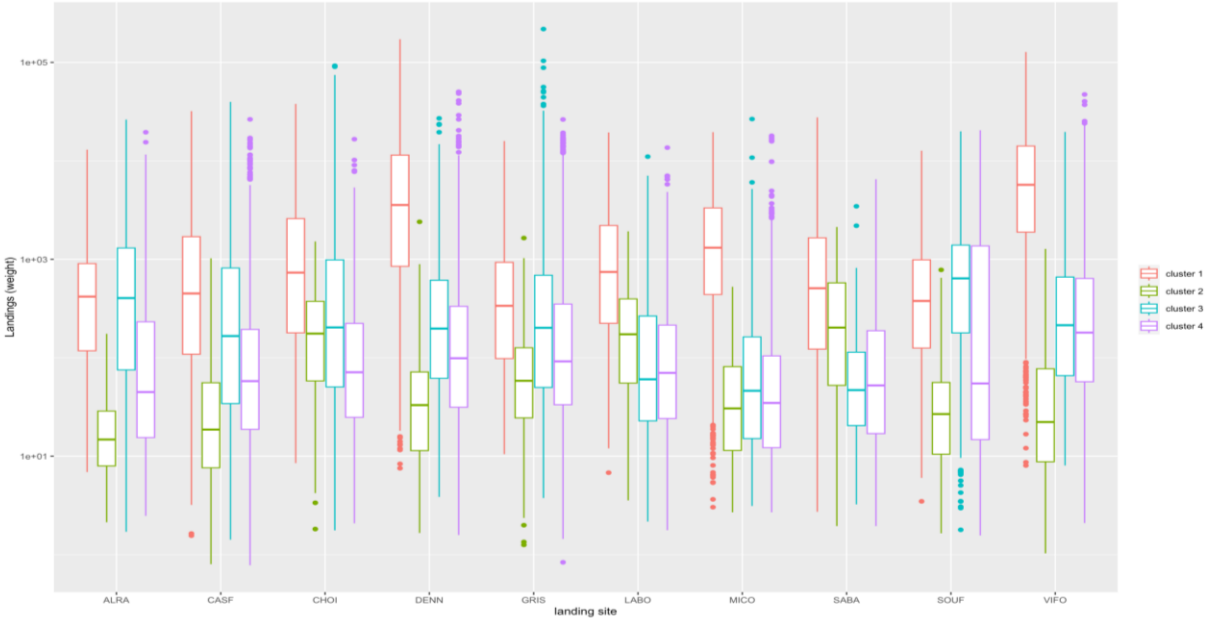

Figure 19. Boxplots showing cluster assemblages by landing site.

4.5 Gear assemblage

Cluster analysis was used to assess which gears were similar according to catch composition. Two groups were observed at a dissimilarity level of approximately 18. The first cluster consisted of trolling (TROL), whereas the remaining gears were grouped together with a probability of 100. The remaining gears were further separated into pots (POTS) and scuba diving gears (SCUB), which were classified as groups by themselves. The remaining gears were then grouped with a probability of 83 at an approximate dissimilarity level of 13. The remaining gear was further broken down based on quantity because many of the gear types in this group are used less frequently than others (see Figure 20).

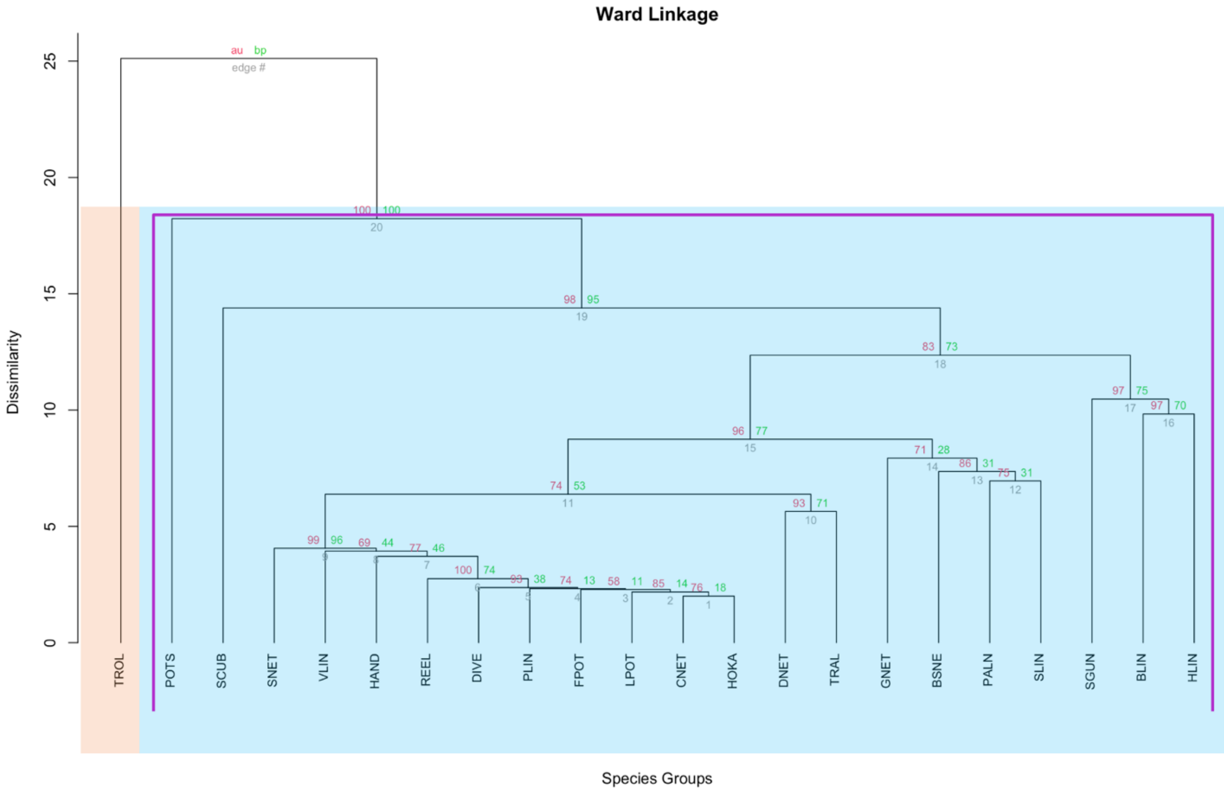

Figure 20. Dendrogram showing the two gear clusters formed from the cluster analysis with cluster 1 represented in brown and cluster 2 in blue.

4.6 Landing site assemblage

An analysis was also done to find regions that were similar according to the composition of the catch landed. Two clusters were observed at a dissimilarity level of approximately 16. The first cluster comprises Micoud (MICO), Dennery (DENN), and Vieux-Fort (VIFO) and is clustered with a probability of 100. These sites are associated with larger catches of large ocean pelagics, and the DENN and VIFO landing sites were further clustered with a probability of 100, making them the most similar sites within that cluster based on the catch and gear compositions. The second cluster was formed, with the remaining landing sites formed at a probability of 100 (see Figure 21).

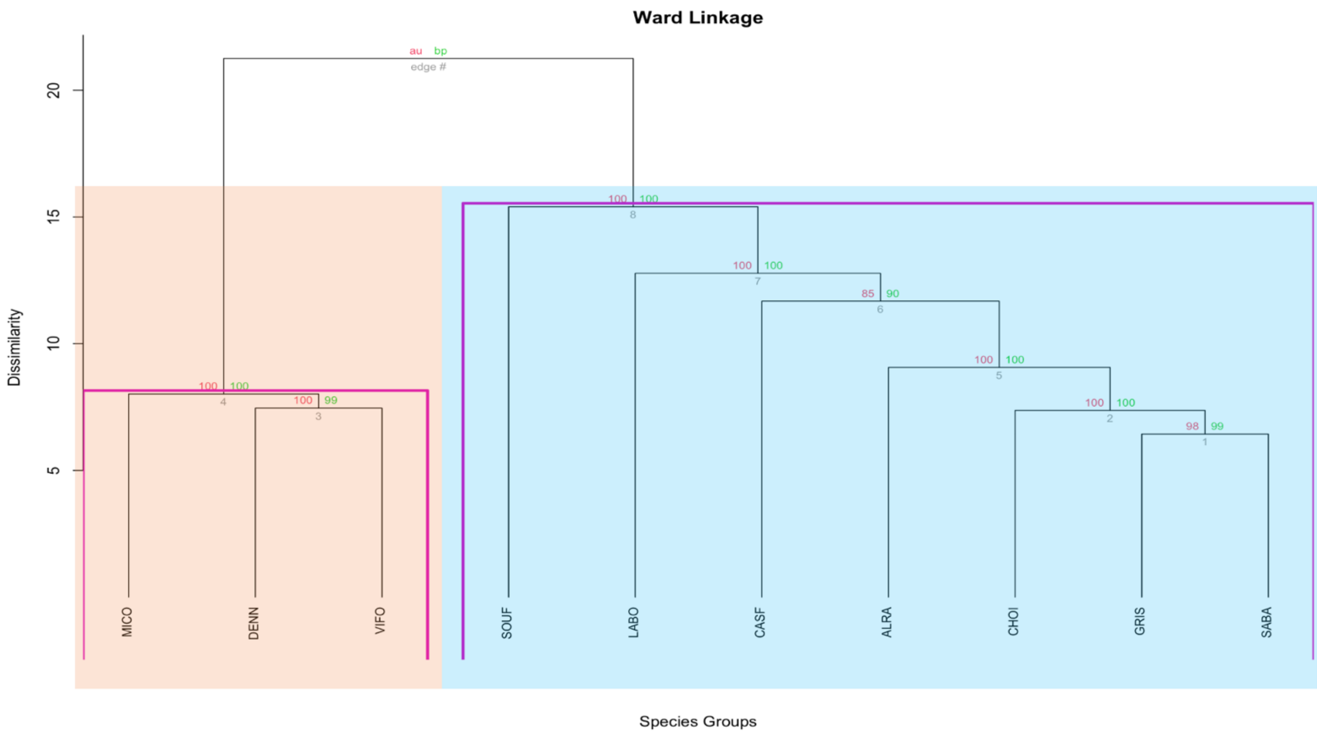

Figure 21. Dendrogram showing the two landing clusters formed based on catch commonality at each site with cluster 1 represented in brown and cluster 2 in blue.

4.7 Catch per Unit Effort Calculations

4.7.1 Dolphinfish

Over time, it was observed that the overall CPUE for dolphinfish fluctuated considerably (Figure 22). CPUE was lowest in the first five (5) years of the time series with the standardised CPUE of Dolphinfish, showing a somewhat lower catch rate in the period 2000-2004, and a generally higher albeit quite variable catch rate during 2005-2015. In the decade that followed, high fluctuations were observed, with three (3) peaks observed in 2007, 2011, and 2015. In the last five (5) years, a more stable trend has been observed.

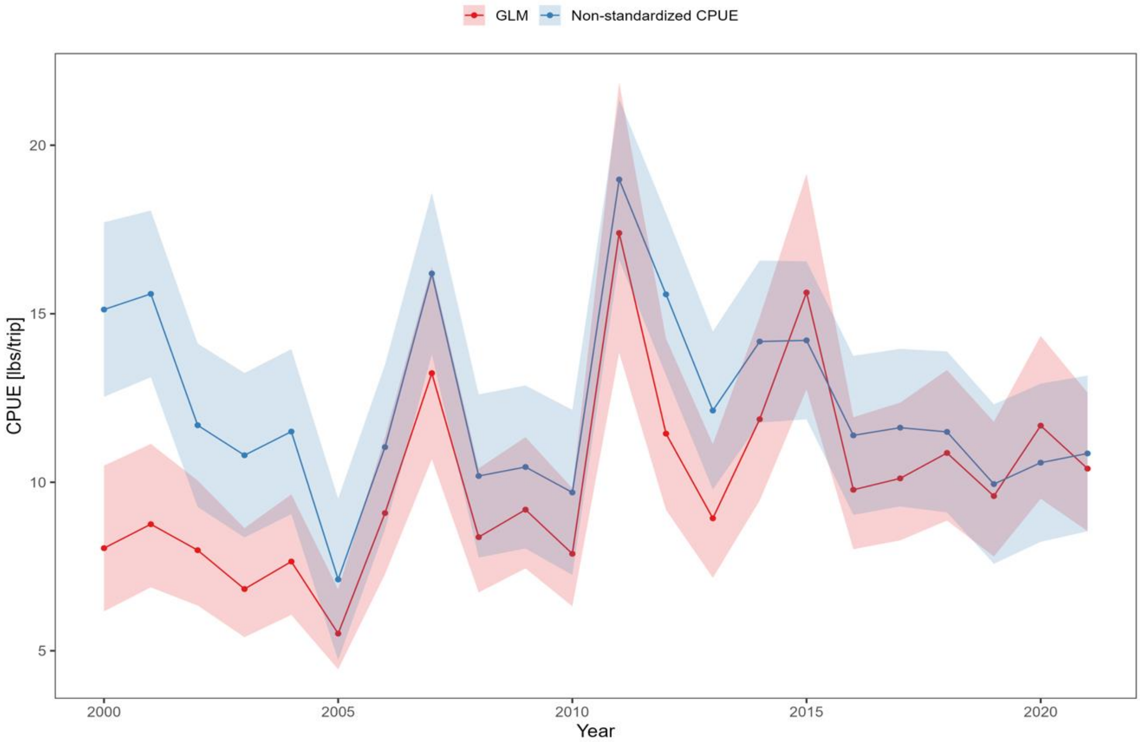

Figure 22. CPUE trends for the Dolphinfish fishery 2000-2021. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

At the Dennery landing site (Figure 23), there were some noticeable fluctuations in the CPUE for dolphinfish. From 2000 to 2004, CPUE was considerably lower than that in the second half of the first decade. There was a significant decline in the CPUE in 2010, followed by a sharp increase in 2011. CPUE continued to decline until 2013. In 2018, fishermen recorded a sharp increase in CPUE, followed by a sharp decline.

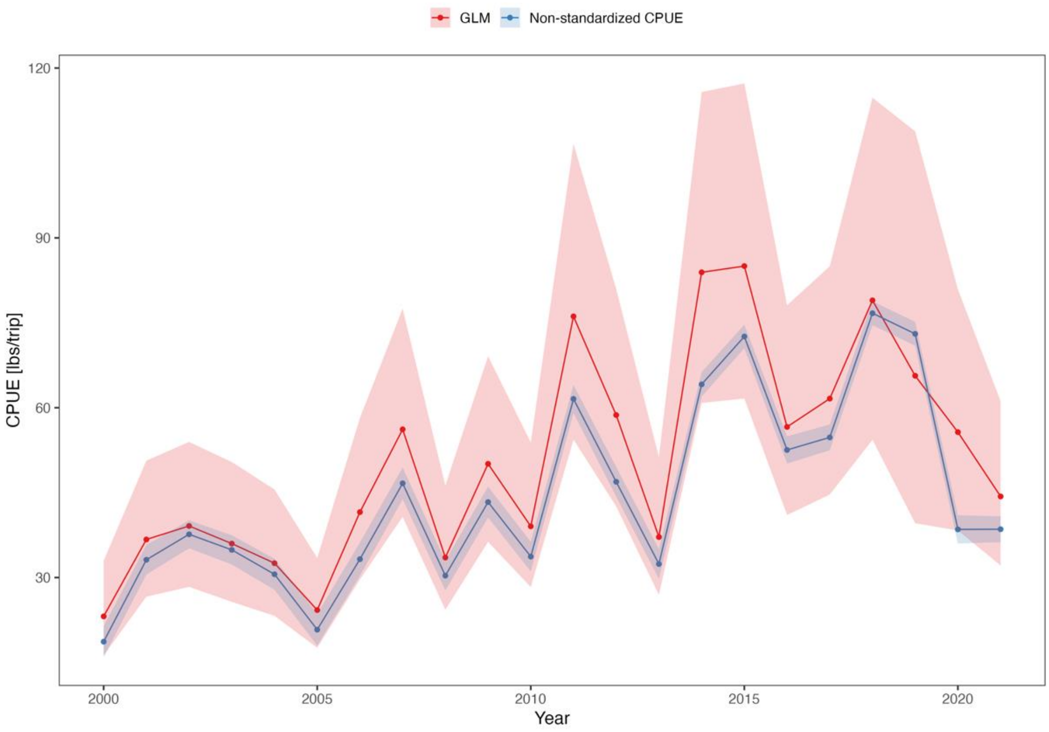

Figure 23. CPUE trends recorded for dolphinfish fishery at the Dennery landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

The CPUE values were lower in the first decade than in the second decade. Following a significant decrease in 2010, the CPUE increased, followed by a steady decline until 2013, with an increase recorded afterwards. After 2015, the CPUE continued to decline until a slight increase was recorded by 2020 (Figure 24).

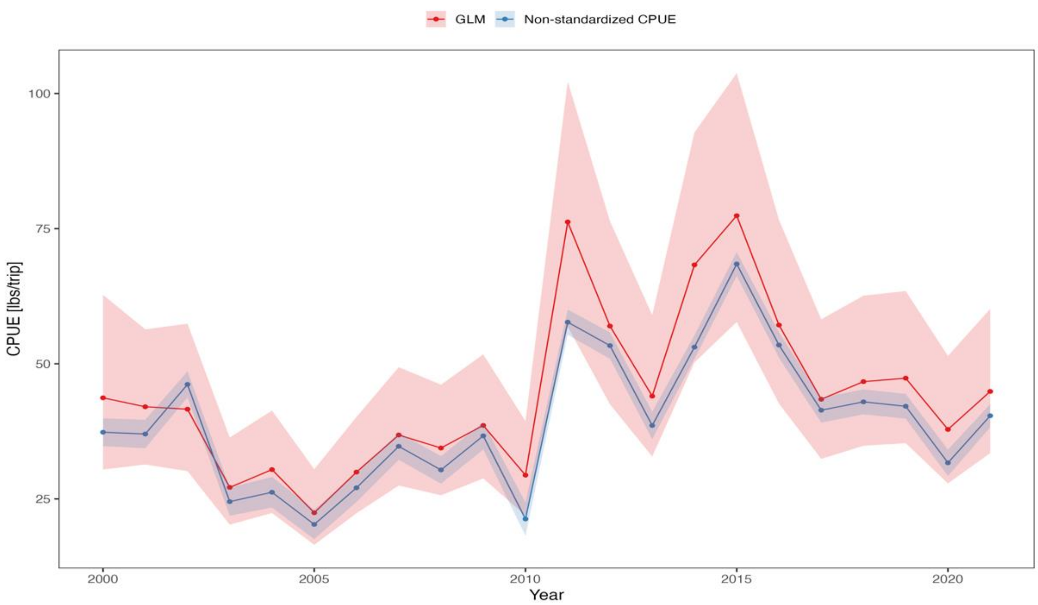

Figure 24. CPUE trend recorded for dolphinfish fishery at Vieux-Fort landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

Similar to the other two sites, there was a decline in CPUE recorded in 2010, followed by an increase in CPUE in 2011, after which CPUE declined with fluctuations (Figure 25).

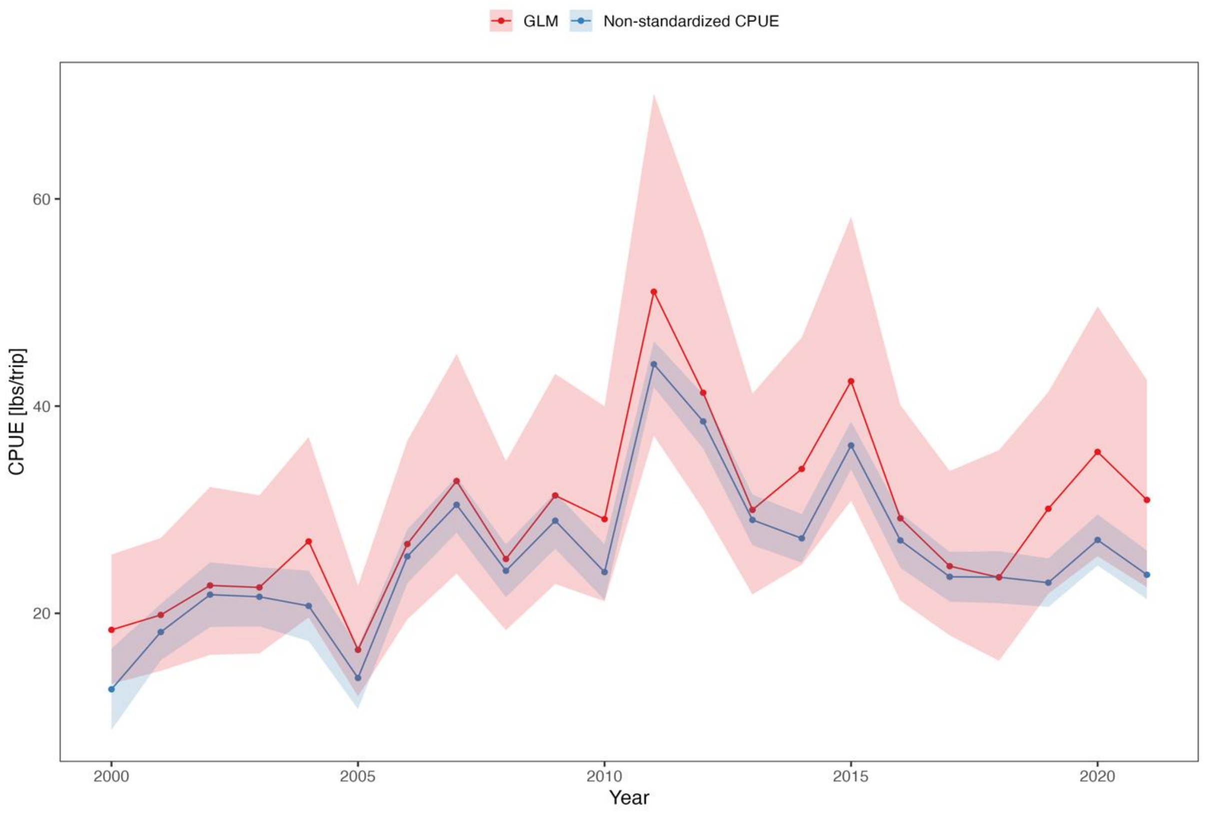

Figure 25. CPUE trends recorded for dolphinfish fishery at the Micoud landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

4.7.2 Tuna

4.7.2.1 Yellowfin Tuna

The CPUE for yellowfin tuna changed regularly during the study period, with fishers experiencing alternating years of high and low CPUE. Furthermore, following a decrease in 2018, the CPUE appears to have increased within the fishery, with a decrease being recorded again in 2021 (Figure 26).

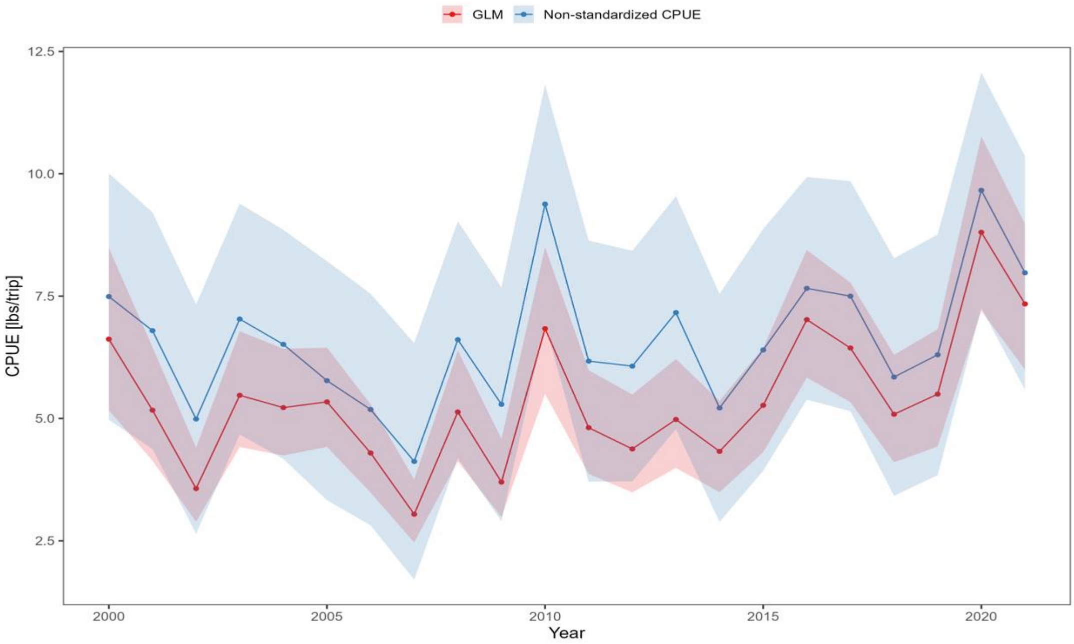

Figure 26. CPUE trends recorded for yellowfin tuna fishery 2000-2021. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

Overall, the CPUE at the Dennery landing site was stable with fluctuations. In addition, after 2017, the CPUE began to decrease until it peaked in 2020, reaching the highest recorded level for the period (Figure 27).

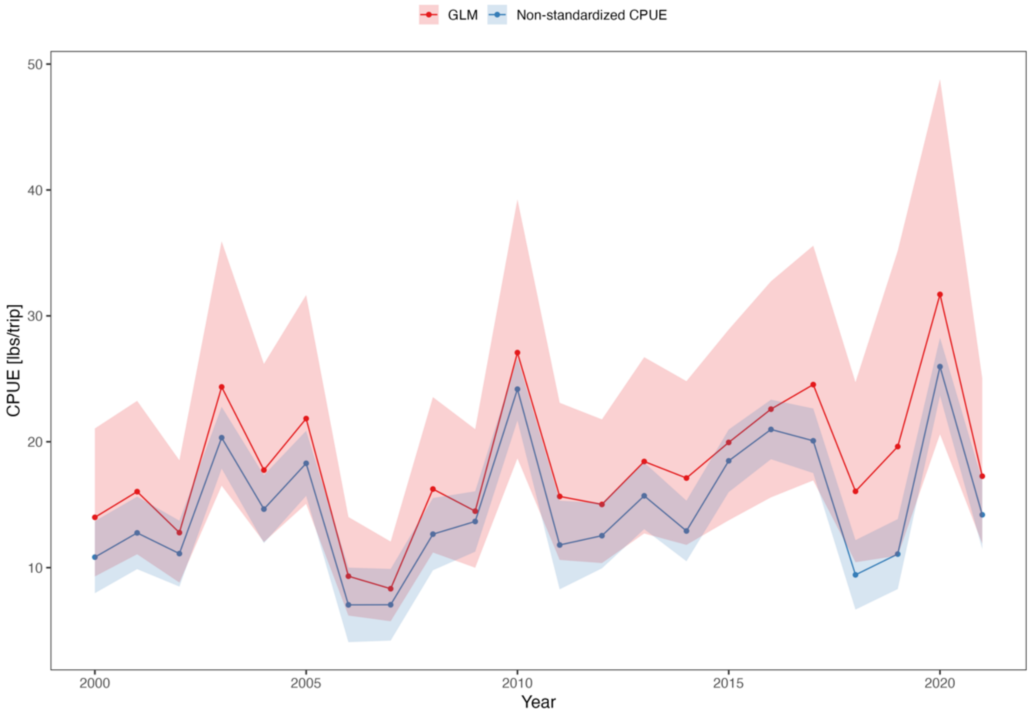

Figure 27. CPUE trends recorded for yellowfin tuna fishery at the Dennery landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

Fishers from the Vieux-Fort landing site experienced a decrease in the CPUE from 2000 to 2002. Fluctuations were recorded in the years following, with noticeable dips in 2009, 2012, 2014, and 2019. Interestingly, CPUE increased sharply in 2020, but plummeted in the following year (Figure 28).

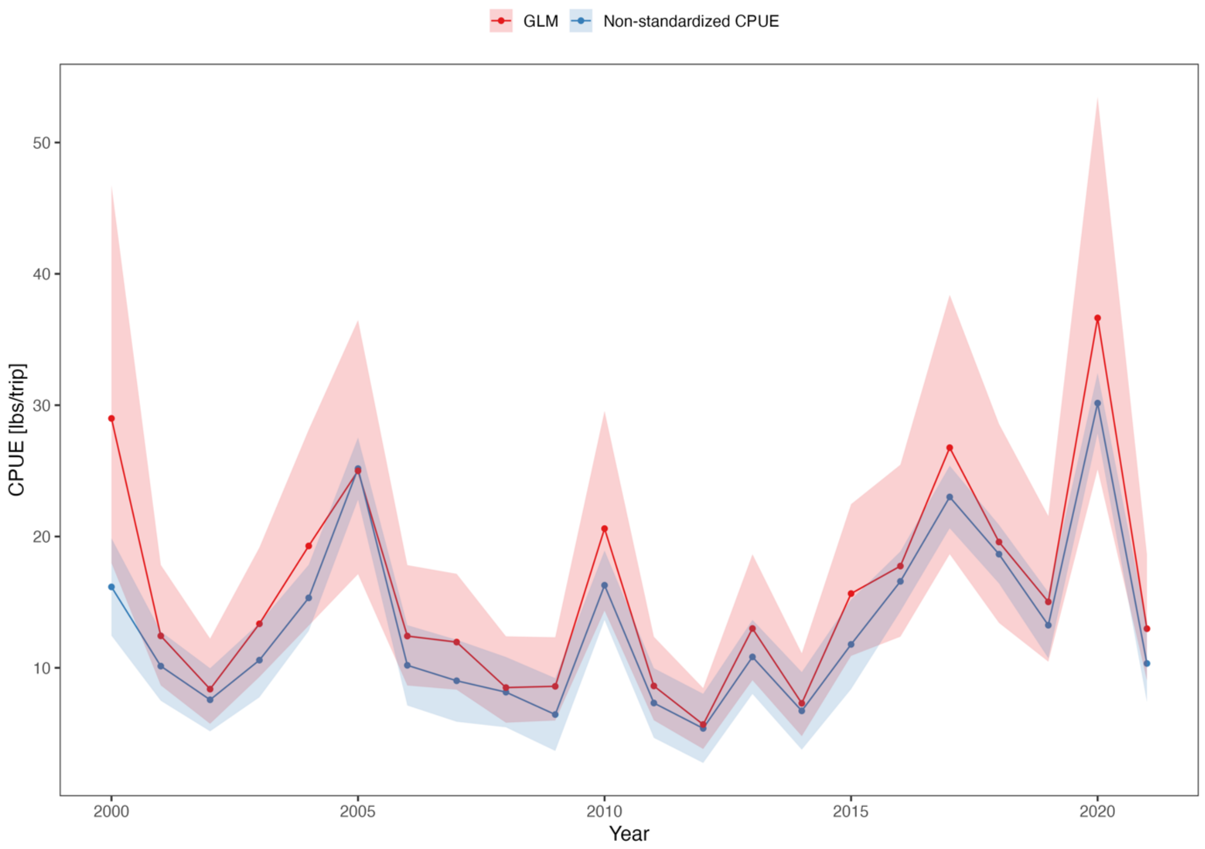

Figure 28. CPUE trends recorded for yellowfin tuna fishery at Vieux-Fort landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

However, the CPUE was lower in the first decade than in the last decade. Similar to Dennery and Vieux-Fort, the CPUE at the Micoud landing site displayed a noticeable dip in 2011 and 2012, and a higher value in 2015. The last five (5) years show an overall increase (Figure 29).

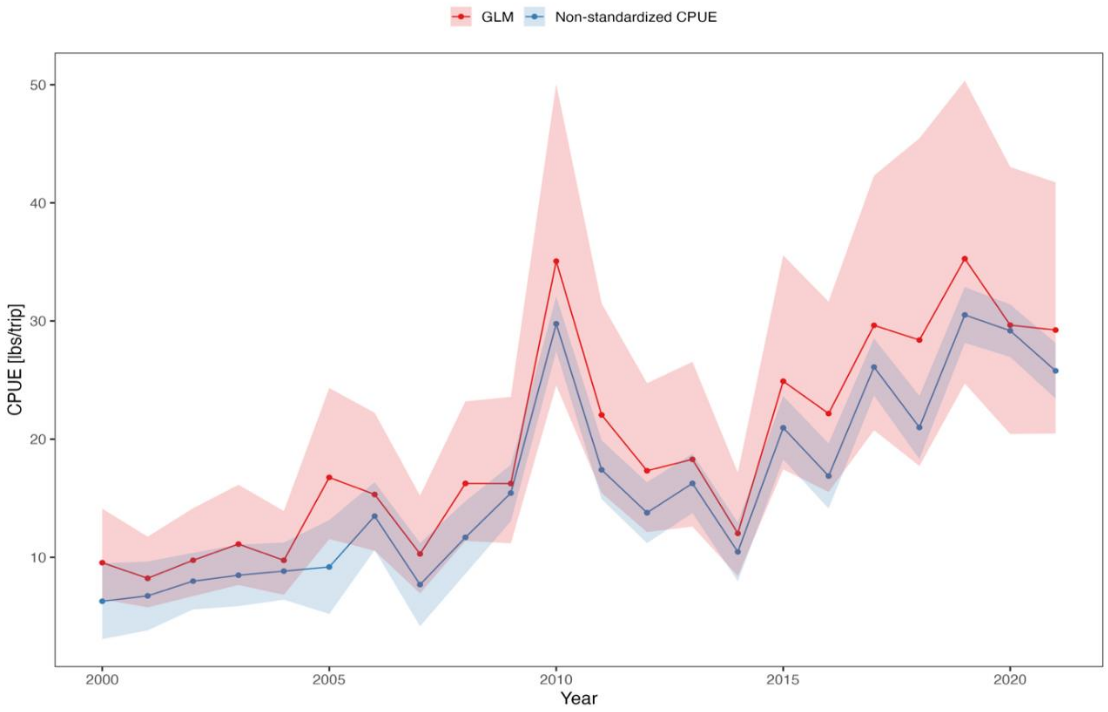

Figure 29. CPUE trends recorded for yellowfin tuna fishery at the Micoud landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

4.7.2.2 Skipjack Tuna

Overall, the CPUE for skipjack tuna was higher from 2000 to 2013 than in the following years, when a continuous decline was recorded (Figure 30).

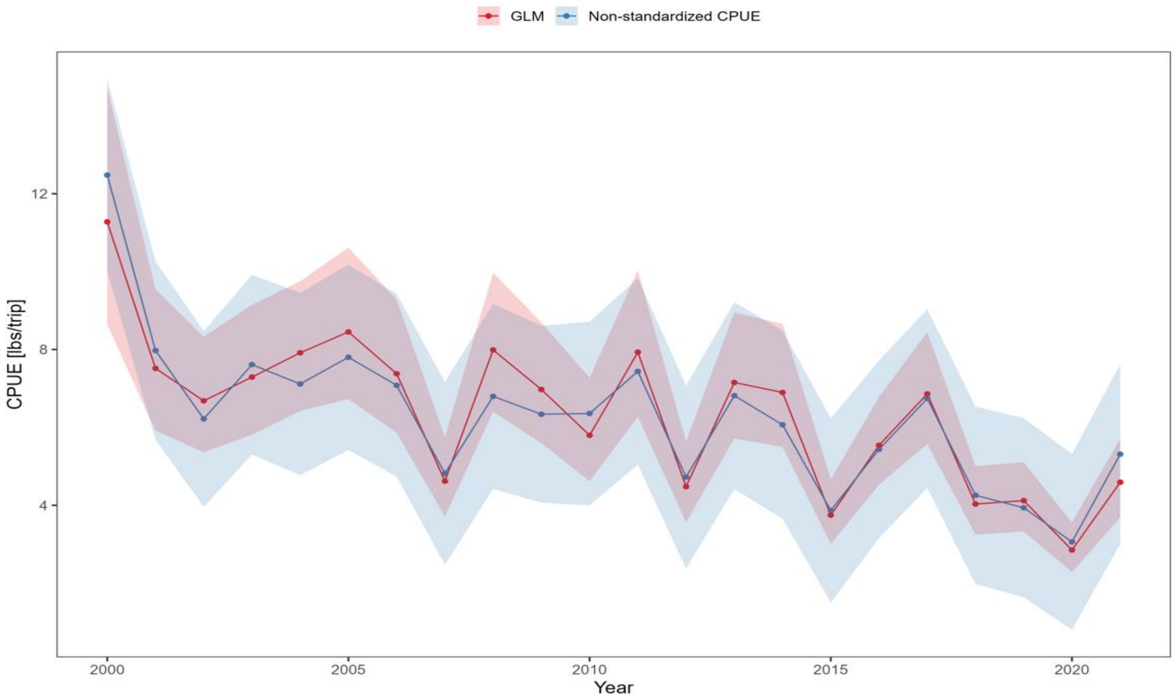

Figure 30. CPUE trends recorded for skipjack tuna fishery 2000-2021. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

Fishers at the Dennery landing site recorded continuous fluctuations in their CPUE, with lower values recorded in the second half of the study period than in the first. The catch rates in recent years were approximately half of those at the beginning of the time series (Figure 31).

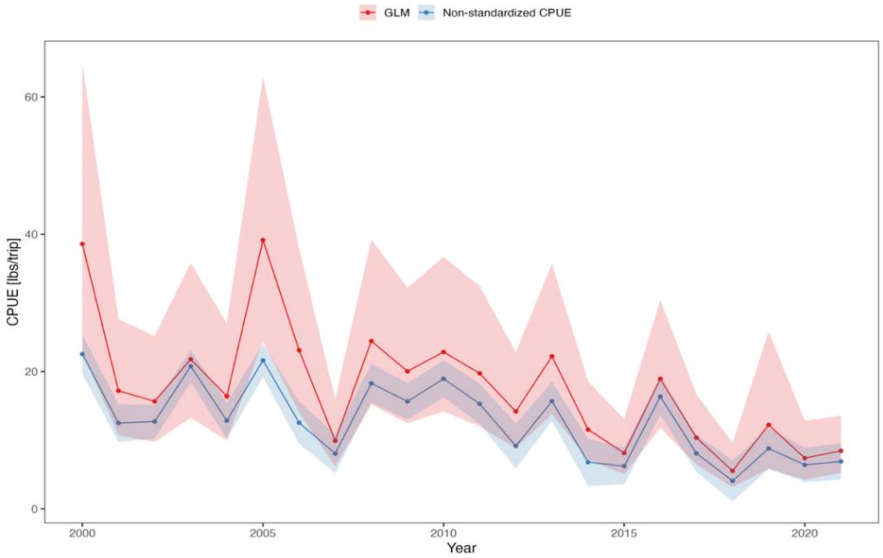

Figure 31. CPUE trends recorded for Skipjack tuna fishery at the Dennery landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

At the Vieux-Fort landing site, there was a steep decline in the CPUE from 2000 to 2002. CPUE values fluctuated over the years, with high values recorded in 2005. Following this, the CPUE remained stable with some fluctuations until 2017, with a slight overall decline in recent years (Figure 32).

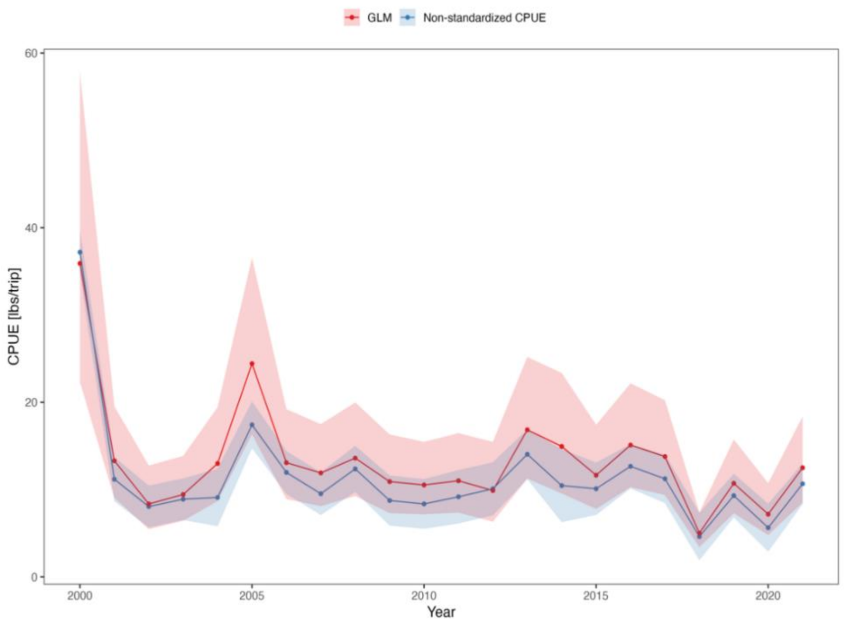

Figure 32. CPUE trends recorded for skipjack tuna at the Vieux-Fort landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

Fishers at the Micoud landing site recorded a declining trend in CPUE over the years, with a slight increase in 2021 (Figure 33).

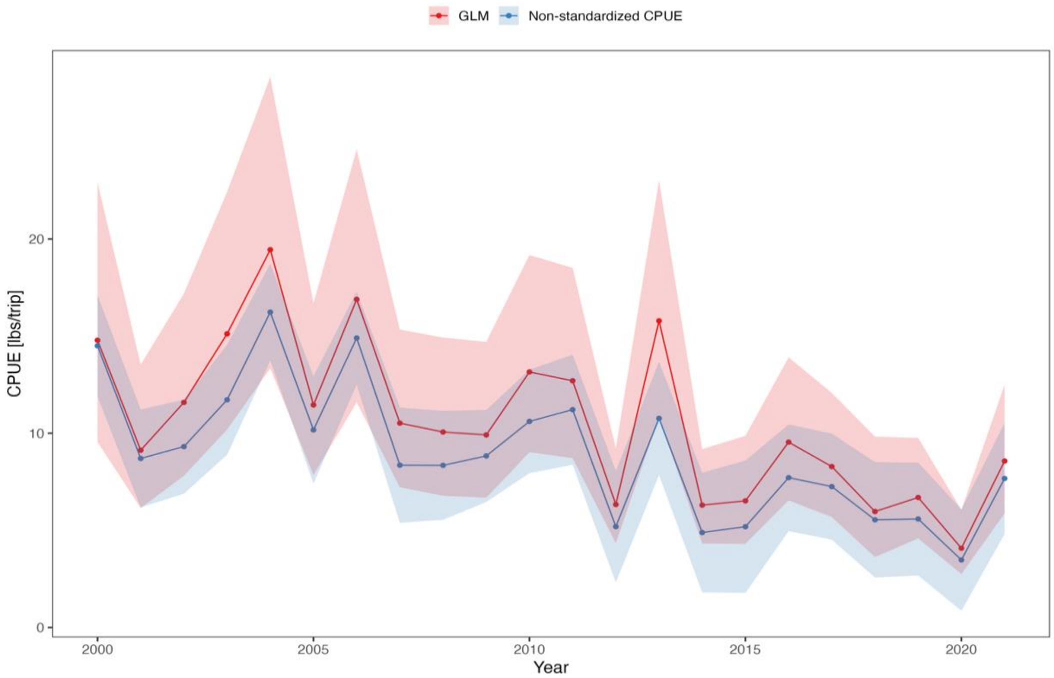

Figure 33. CPUE trends recorded for skipjack tuna at Micoud landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

4.7.2.3 Blackfin Tuna

The blackfin tuna fishery recorded a steady increase in the CPUE from 2000 to 2009. Subsequently, a continuous decrease was recorded until 2015. The last five years shows a fluctuating but stable trend overall (Figure 34), with catch rates similar to those observed at the beginning of the time series.

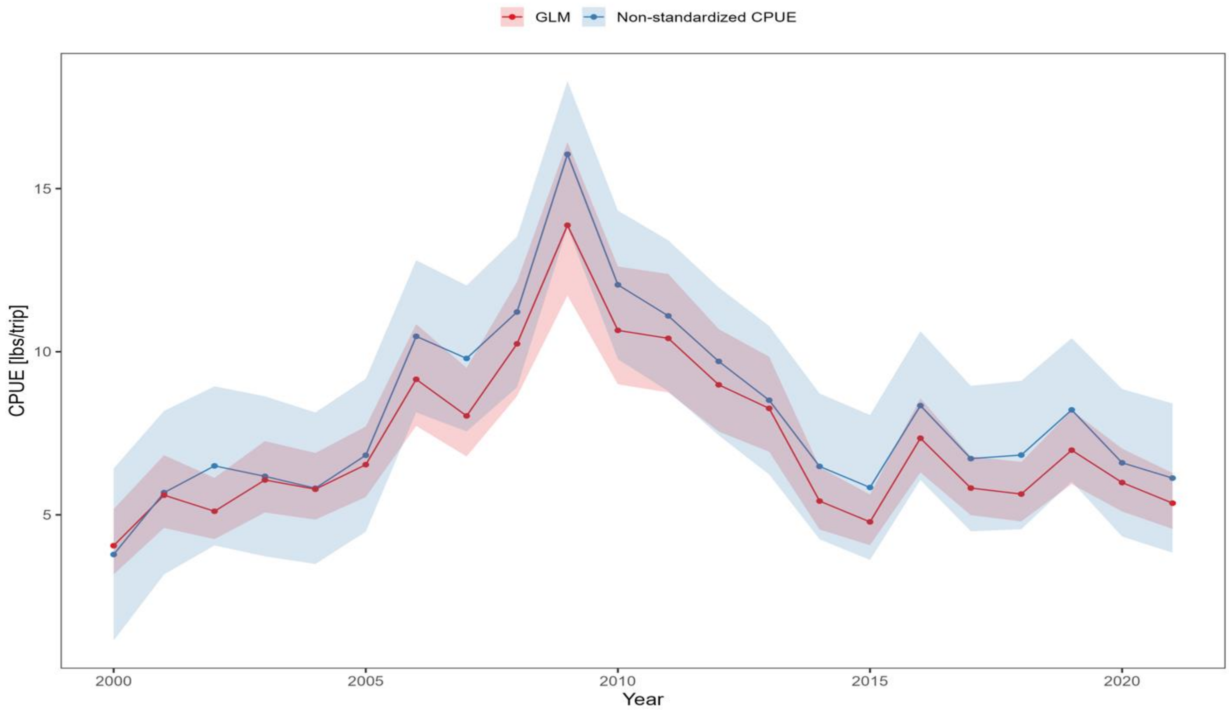

Figure 34. CPUE trends recorded for blackfin tuna 2000-2021. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

At the Dennery landing site, there were minimal differences between the first and second decades of study. CPUE looks stable overall with a spike in values recorded in 2009 (Figure 35).

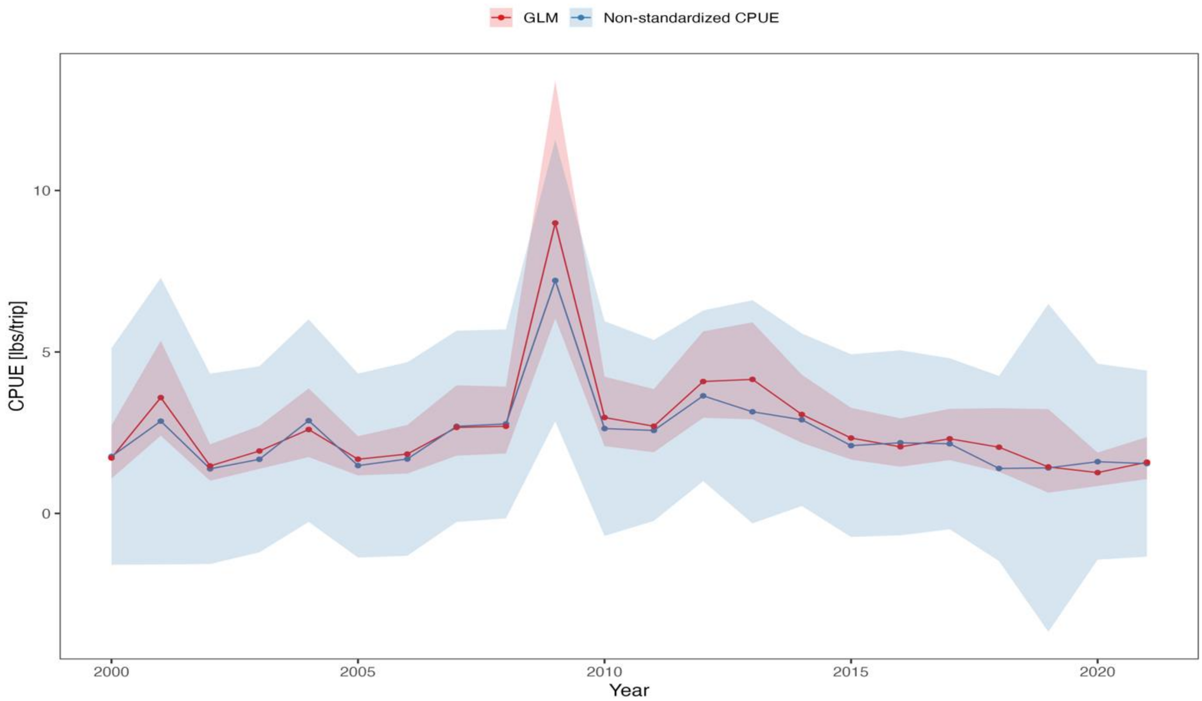

Figure 35. CPUE trends recorded for Blackfin tuna at the Dennery landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

Fishers at the Vieux-Fort landing site recorded large annual variations in CPUE trends. From 2001 to 2007, the fishery showed marked fluctuations in CPUE values, with an overall increasing trend. Following this, the CPUE increased significantly and remained relatively constant from 2008 to 2012, before the CPUE plummeted until 2018. Subsequently, the CPUE values increased until 2020, with a decrease in 2021 (Figure 36).

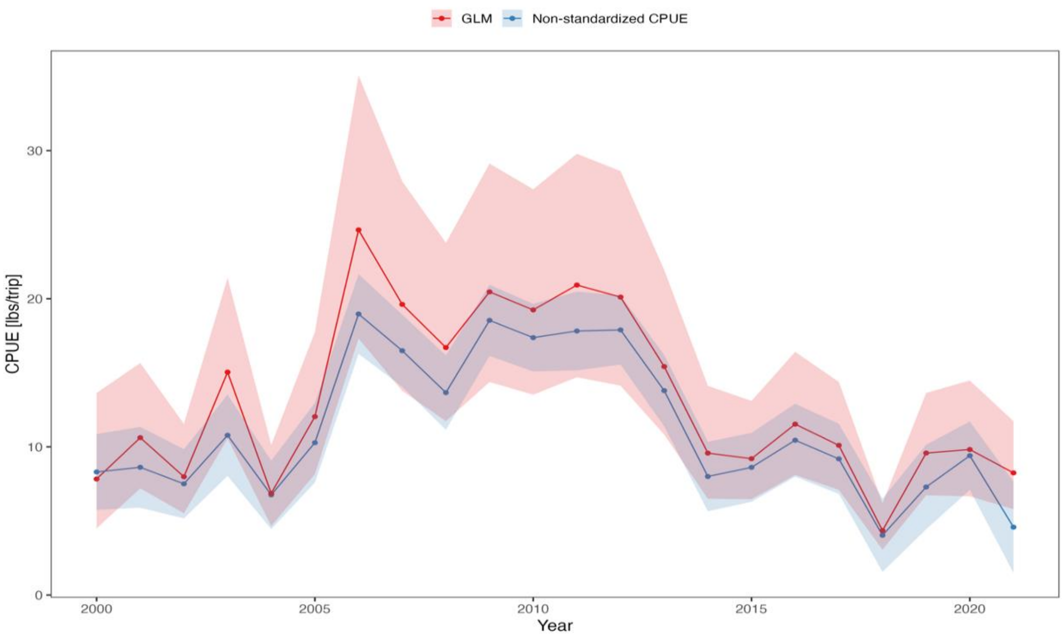

Figure 36. CPUE trends recorded for Blackfin tuna at the Vieux-Fort landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

CPUE at the Micoud landing site increased regularly during the first half of the study period (2000-2009) while showing a peak in 2009. The rest of the time series after 2010 appears to be rather stable. In addition, following 2014, CPUE values appeared to have decreased in 2018 and 2021, with a marked peak between the four years (Figure 37).

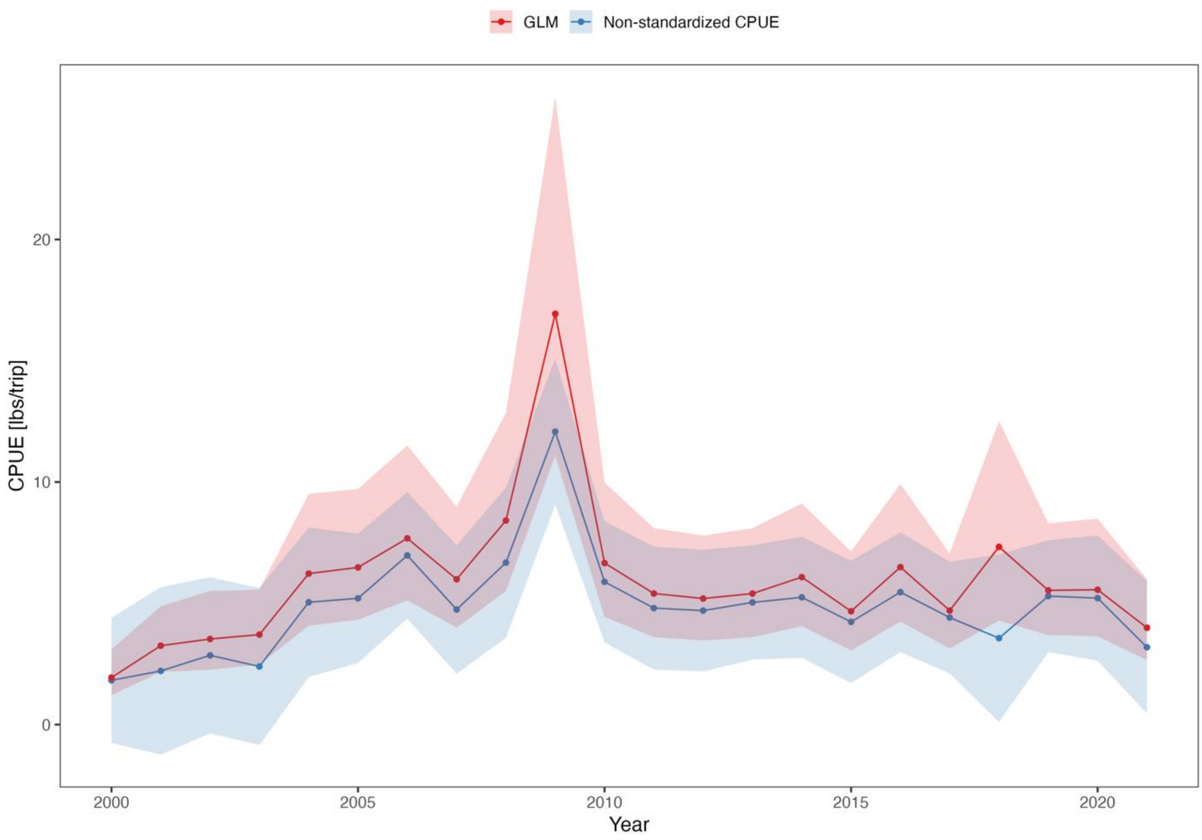

Figure 37. CPUE trends for blackfin tuna at the Micoud landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

4.7.3 Blue Marlin

Blue marlin recorded a steady increase in CPUE during the study period. The variability decreased between years, with the CPUE fluctuating slightly from 2008 to 2021. Despite these high levels, there was a sharp decrease in the CPUE in 2015, which was anomalously low. Although catch rates have been declining in recent years, the CPUE in 2021 is still more than twice that observed at the beginning of the time series (Figure 38).

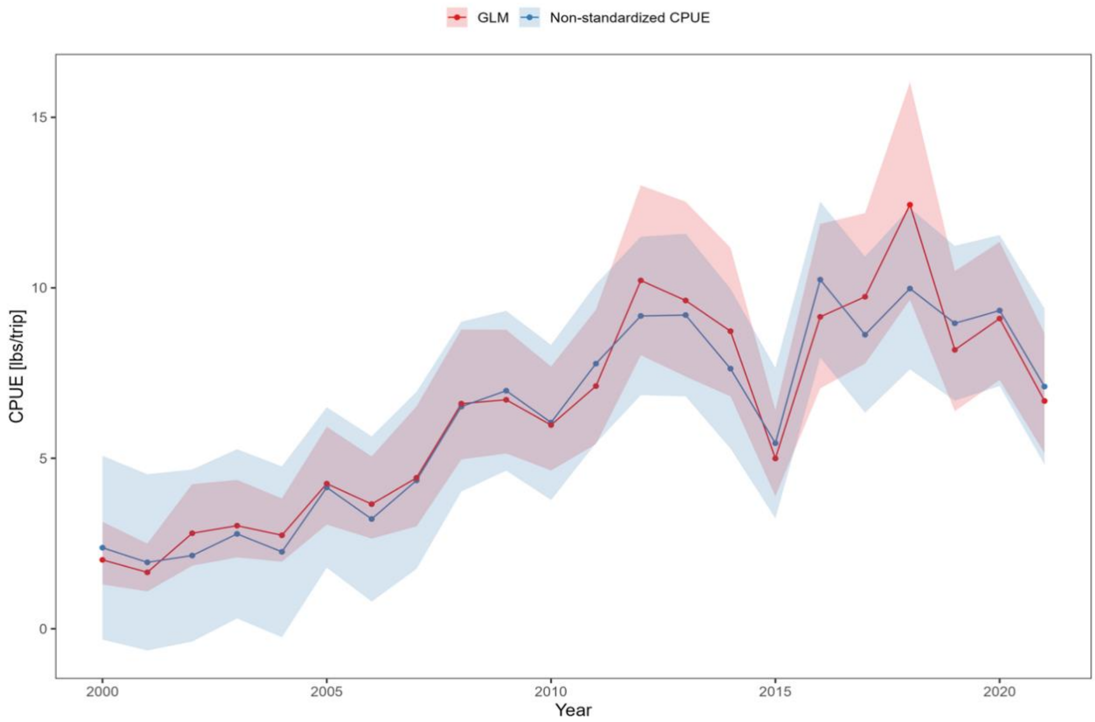

Figure 38. CPUE trends for Blue Marlin 2000-2021. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

From 2000 to 2007, fishermen at the Dennery landing site recorded smaller fluctuations in CPUE values; however, CPUE was lower during that period compared to the period from 2008 to 2021. Nonetheless, between 2017-2019, fishers recorded a large variation in CPUE values (Figure 39).

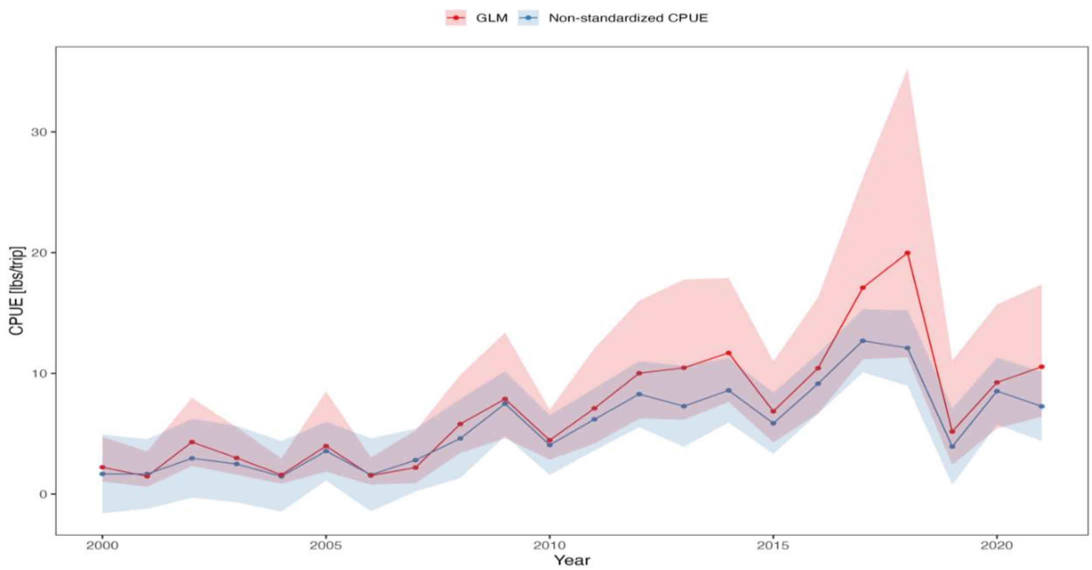

Figure 39. CPUE trends recorded for blue marlin at the Dennery landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

In 2012, fishers recorded the highest CPUE for the blue marlin fishery in Vieux-Fort. High variance levels recorded in 2000 were also observed in the following years. The CPUE values increased slightly from 2010 to 2012, followed by a sharp decrease until 2015. The CPUE values remained fairly consistent over the last six (6) years (Figure 40).

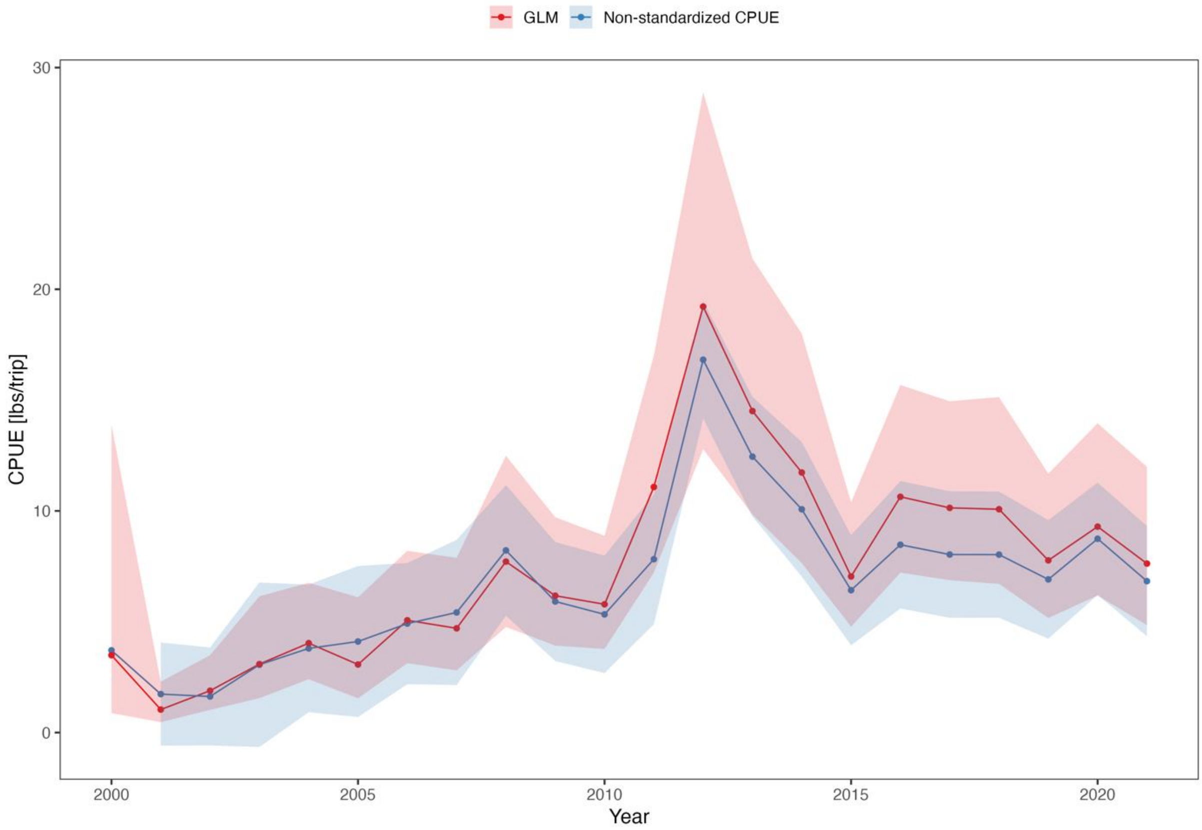

Figure 40. CPUE trends recorded for blue marlin at the Vieux-Fort landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

Unlike the other two sites, the fishers at the Micoud landing site recorded varying CPUE for the blue marlin, with the standardised and non-standardised values varying significantly, indicating a poor model fit to the data (Figure 41). CPUE values increased from 2000 to 2010, but then decreased until 2013. An increase was observed in the years following the year 2015. Overall, a peak in CPUE was recorded in 2018, whereas the last few years showed a declining trend.

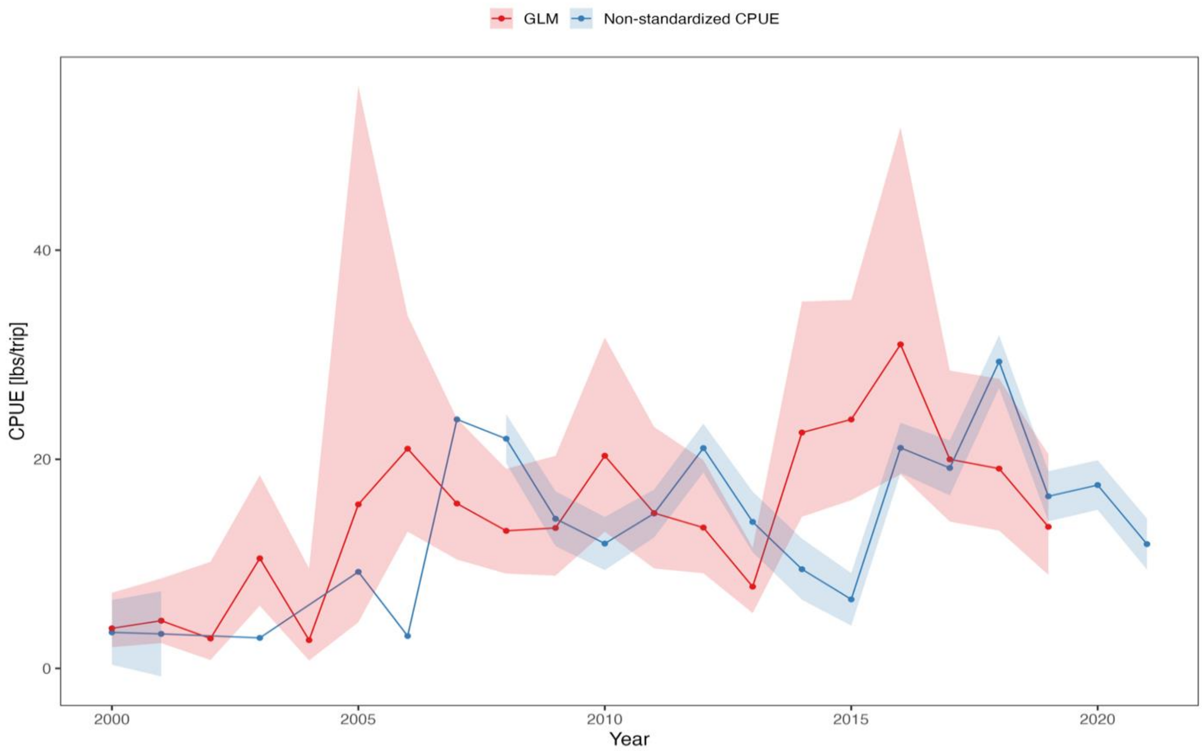

Figure 41. CPUE trends for blue marlin at the Micoud landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

4.7.4 Gulf Sierra Mackerel

The CPUE for Gulf sierra mackerel decreased steadily after 2010 (Figure 42).

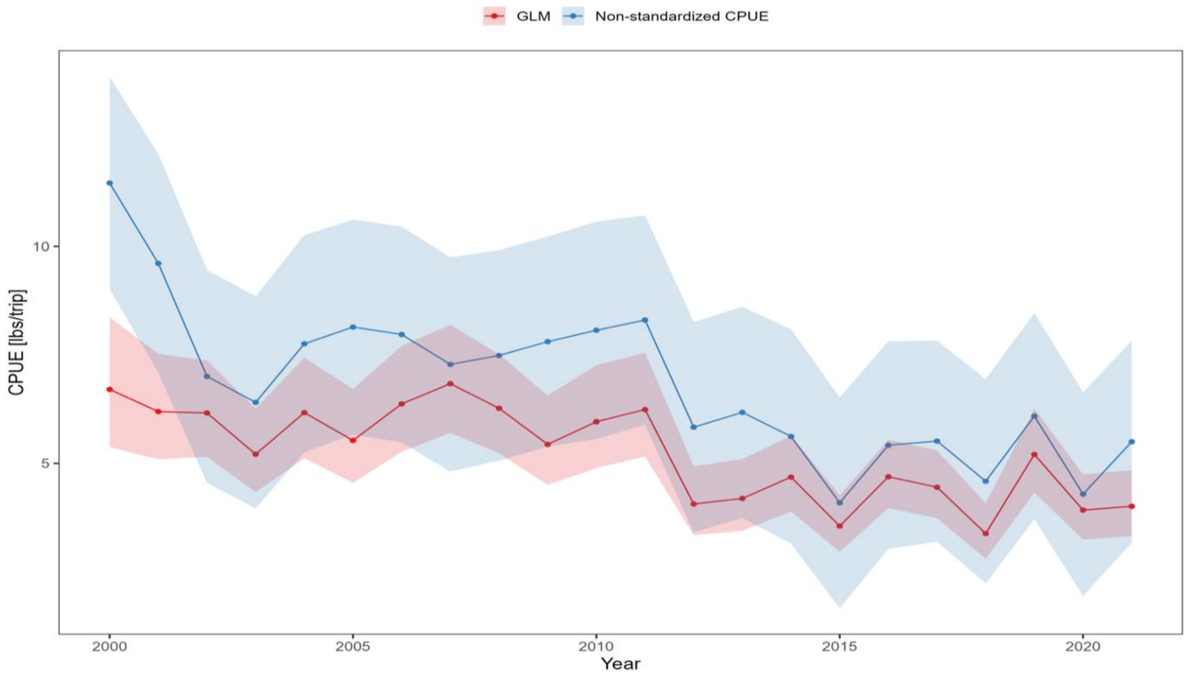

Figure 42. CPUE trends recorded for Gulf Sierra Mackerel 2000-2021. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

At the Dennery landing site, a steady increase was observed in CPUE values from 2000 to 2006 (Figure 43). After 2006, CPUE decreased gradually. Following this, CPUE records fluctuated frequently, with a noticeable spike in 2019, but an overall declining trend throughout the time series.

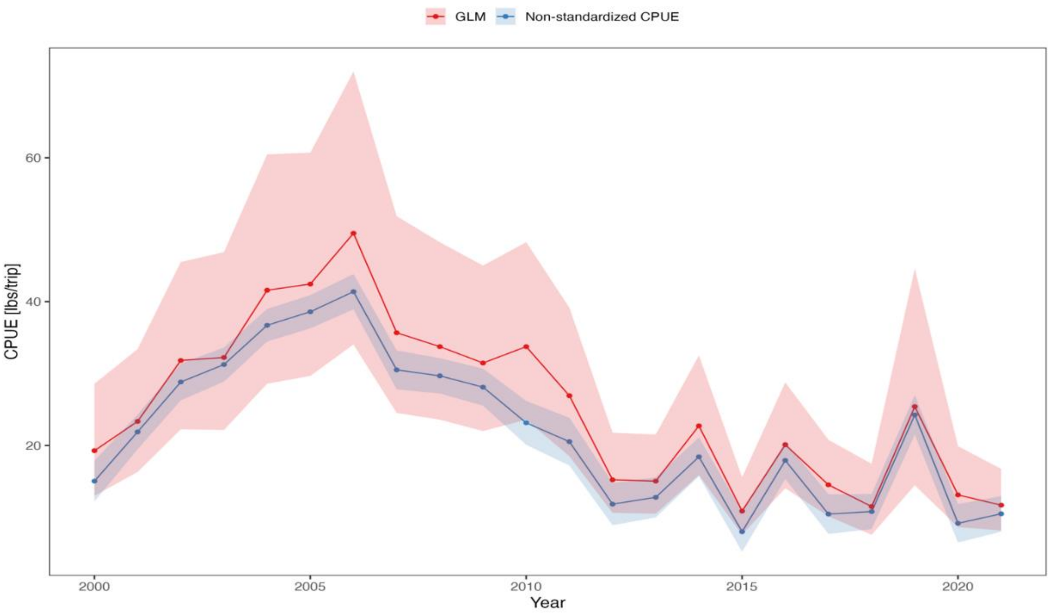

Figure 43. CPUE trends recorded for Gulf sierra mackerel at the Dennery landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

At the Vieux-Fort landing site, the CPUE decreased steadily during the study period, with spikes recorded in 2004, 2009, and 2011 (Figure 44).

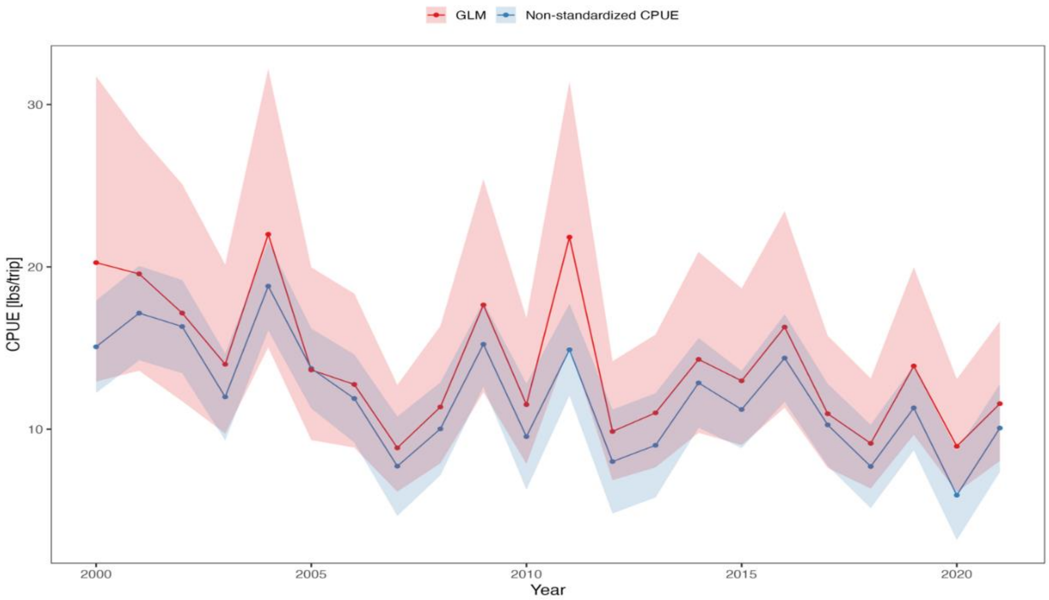

Figure 44. CPUE trends for Gulf sierra mackerel at the Vieux-Fort landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

At the Micoud landing site, there was an increase in the CPUE from 2000 to 2001. However, this was followed by years of seasonal changes in CPUE (Figure 45). However, from 2011, the CPUE levels continued to decline over the years, with a sudden peak recorded in 2017, after which the CPUE values dropped slightly.

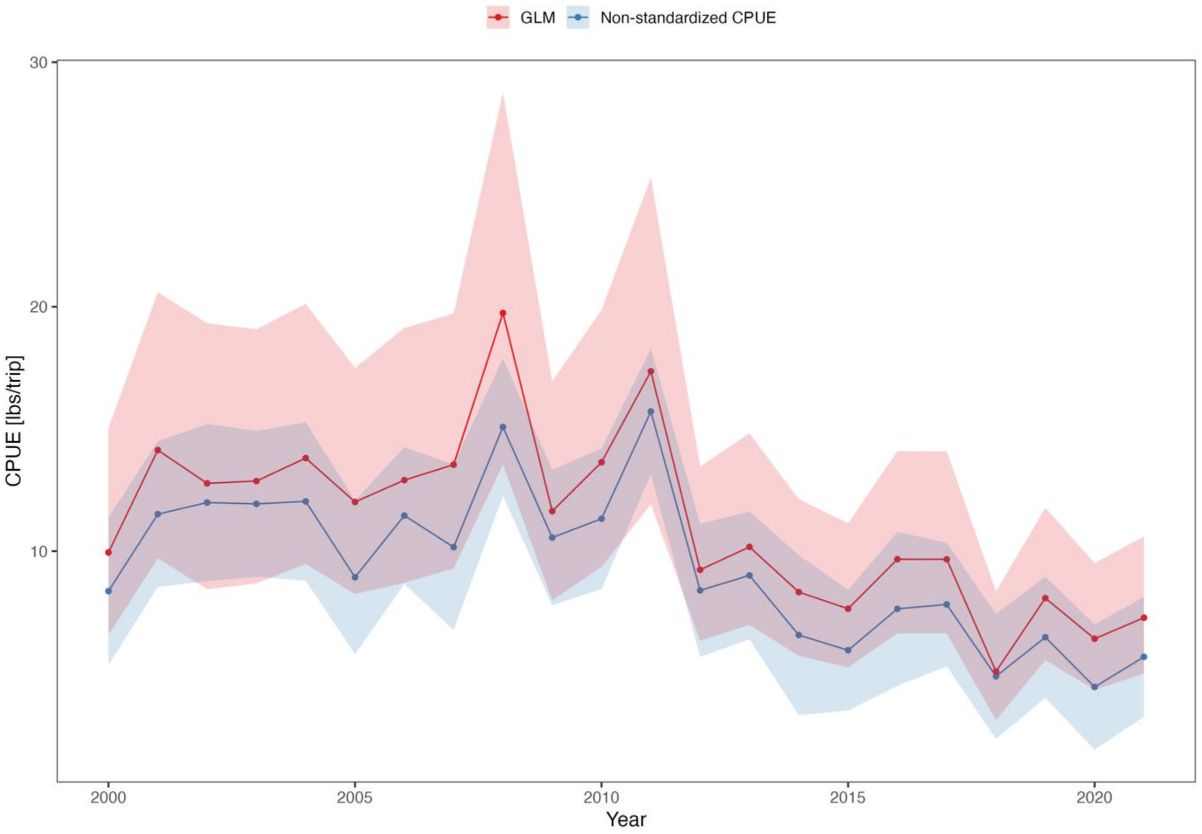

Figure 45. CPUE trends for the Gulf sierra mackerel at the Micoud landing site. The nominal CPUE is shown in blue and the standardised CPUE from the GLM in red.

5 DISCUSSION

5.1 Landings

Overall, there are no persistent trends in total landings. However, in areas such as Castries, Gros-Islet, Anse-La-Raye and Soufriere, landings seem to fluctuate regularly. In Dennery, Vieux-Fort, and Micoud, the annual landings were consistent throughout the years. This could be because landings in these areas consist mainly of large pelagic species such as tuna, dolphinfish, and marlin, all of which could be caught at the fish aggregating devices (FADs). However, in areas such as Castries, Gros-Islet, Anse-La-Raye, and Soufriere, landings seem to fluctuate regularly. This could be because fishers catch a greater variety of species at this landing site.

Island-wide landings appear to be highest at the beginning of the year and then steadily decline at certain points during the year. This fluctuation could be related to the different weather periods, namely the dry and rainy seasons, that occur throughout the year which in turn is reflected in the seasonal/monthly effort. The rainy season, or months when the island experiences more rainfall and hurricanes, coincides with the decline in landings from June to November. In contrast, landings on Gros-Islet remain relatively constant throughout the year. This could be related to one of the main fisheries conducted at this landing site, namely the queen conch fishery. Queen conch is a relatively sedentary species caught with diving gear. Therefore, a decrease in landings would most likely be due to disturbed ocean/weather conditions, as these conditions are not conducive for scuba diving. In addition, fishers at the Vieux-Fort landing site report the highest average landings per month. This could be directly related to the fishing practices used by fishers in the area, as many fishers utilise FADs to search for large pelagic fish, such as tuna and dolphinfish, as well as the high number of fishing trips conducted by fishers at that landing site.

Regardless, the pelagic fishery seems to be more successful at the beginning of the year, from January to May. A regional study suggests that this increase is due to the change in sea conditions associated with rougher seas between February and April (Mahon, 1987), when it is more difficult to catch reef fish using fish pots, so more fishers turn to deep-sea fishing when searching for large pelagic species. This trend was also noted at a regional meeting on joint fisheries in the Caribbean in 1986 (Mahon, 1987). The report of that meeting indicates that the trend observed today is consistent with that reported by fishers in Saint Lucia before the national sampling process became more structured (Mahon, 1987). However, there appears to be slight variation, as the historical trend shows that the peak months were between April and May. The decline in landings for these species could be due to less favourable sea conditions during the hurricane season. This decrease in landings in the pelagic fishery is offset by an increase in landings of reef and near-shore fish, where more traps are being used. For the lobster fishery, there is a gradual decrease in landings from March to July, coinciding with the seasonal closure of the lobster fishery. This closure is enforced from 1st March to 1st August each year (Chapter 7.15 Fisheries Act, 2023), but landings still appear to occur during this period. The queen conch fishery, on the other hand, has no major seasonal variation in landings.

The type of fishing gear also seems to have varying influences on the composition of the catch. Trap fishing is quite restrictive in terms of catch composition, as mesh openings allow smaller fish such as snappers and lobsters to enter. Traps are also deployed in shallow and sheltered areas, which further limits the catch composition, with a composition of mainly small reef fish. The hooks used in trolling vary in size, thus allowing them to catch a wider range of species. Unfortunately, the length of the fish caught is not recorded by either fishermen or data collectors, making it difficult to assess whether the gear is catching juveniles. This information would be useful for fishery managers to assess which areas are popular breeding, spawning, and feeding grounds for certain species. In addition, it is not unusual that catch composition varies slightly at different landing sites on the island because fishers are opportunistic and land whatever is caught at the time. Nonetheless, some sites record higher landings of certain species, but this is mainly influenced by the traditional practices of fishers in the area. Moreover, at the sites with lower landings, the number of vessels also decreased; hence, fewer people were engaged in the fishery.

5.2 Effort

The total fishing effort has fluctuated over the years as fishers change the number of trips conducted throughout the year based on the migratory patterns of certain fish. Saint Lucia's fishers are vulnerable to the effects of natural disasters such as hurricanes. Depending on the severity of the disaster, fishers lose vessels and fishing gear, which can influence the number of vessels at fishing sites (Government of Saint Lucia, 2013). From 2000-2021, Saint Lucia was hit by eight (8) hurricanes and tropical storms, which may have affected the composition of vessels at the various landing sites. Furthermore, many fishermen are considered part-time fishers, as they engage in various forms of employment. According to the 2012 Fisheries Framework Survey, the fishing sector in Saint Lucia is considered one of multiple occupations

(Government of Saint Lucia, 2018), with 79% of fishers working in the sector solely for cultural and traditional reasons. Over the years, the tourism sector has increased and with it the number of employment opportunities for locals. It is therefore possible that some fishers have left the fisheries sector for more secure employment, so the number of vessels and fishing efforts may have decreased for that reason.

During the study period, the number of fishing vessels found at the landing sites decreased at many sites, namely Castries, Choiseul, Gros-Islet, and Soufriere. Many fishers have switched from the use of traditional canoes which could accommodate fewer fishermen, to stronger fibreglass pirogues. These boats can accommodate a larger crew, so many fishers may have decided to share the cost of operating a single boat instead of multiple boats; as such, the number of vessels at some sites may have decreased. However, this could only be confirmed if vessel registration information from the licencing and registration system (LRS) was linked to the TIP system; this information was not available for this study.

In the case of the Gros-Islet landing site, the number of vessels may have decreased because fishers were injured and dropped out of the fishing sector. The diving practices employed in the queen conch fishery can be quite dangerous, and the department has received multiple reports of fishers becoming paralysed and dying due to poor diving practices. This trend could have possibly resulted in the decline in vessels, since fishers may have had to sell their vessels since they were no longer active.

Additionally, the proximity of landing sites to consumers may be a factor in the number of vessels recorded at each site. Fishermen may request a change in their main landing site at any point in the year and many fishermen may have changed landing sites to move from a community with a smaller population to one with better economic opportunities. For example, fishers may switch landing sites closer to hotels and restaurants to reduce their overall operational cost because more markets are available.

Moreover, initiatives such as the implementation of a fuel rebate system and the allowance of tax exemptions on engines and fishing gear could have influenced this effort. Fishers can afford more powerful engines, thus allowing them to travel further to search for more valuable fish. However, these subsidy mechanisms may be counterproductive in maintaining a sustainable stock. These mechanisms would encourage more fishers to enter the sector, but if similar funds are not invested in the improvement of other fishing technologies, such as adjustments in mesh and hook size, the stocks may become exploited.

Over the years, FADs have been deployed across the island to address different changes observed by fishers, such as the changing migration patterns of fish and increasing pressure on near-shore fisheries. By creating an environment in which fish species can congregate, it has become easier for fishermen using FADs to catch pelagic fish, thus reducing their search time and overall effort. Moreover, the introduction of FADs has been seen as more cost-efficient for some fishers. Over the years, many sites have recorded a decrease in their use of bottom longlines. This gear is expensive because it involves the use of many lines and hooks. By switching to fishing around the FADs, fishers are most time guaranteed to catch a pelagic fish using shorter lines.

5.3 Catch per Unit Effort

Catch per Unit Effort (CPUE) is commonly used as an indicator of abundance. The analysis of catch and effort data has provided a better understanding of the stock dynamics of different fish populations, especially in data-limited situations like this one. Management decisions on fisheries are usually based on the results of an assessment of the fish stock. However, within the Caribbean, it has proven quite difficult to assess many of our large oceanic pelagics because they are widely distributed and highly migratory, shared fish stocks. However, by using the catch rate, an estimate can be made which in turn will assist in shaping a regional approach to the management of these fish stocks.

Over the years, there have been multiple external projects, such as those funded by agencies such as the Japan International Cooperation Agency (JICA), and projects supported and funded by the Government of Saint Lucia, which promoted the transition to offshore fisheries (Friedlander, Beets, & Tobias, 1994). Many nearshore fisheries and, by extension, marine habitats have become significantly impacted by the pressures of overfishing, human-induced habitat destruction, and poor waste disposal practices. As a result, government officials have invested heavily in the use and deployment of fish aggregating devices (FADs). Areas where FADs have been deployed have promoted areas of high fish abundance, not necessarily because there were more fish, but because conditions for fish aggregation have improved, resulting in higher catches and lower fishing effort (trips), thus resulting in higher CPUE (Bealey, Perez Moreno, & Van Anrooy, 2019). This trend was observed at the Dennery landing site after 2013 and at the Vieux Fort landing site after 2008, when it is believed that FAD usage increased by fishers. However, the exact dates of deployment are unknown. This trend suggests that FADs made it easier for fishers to catch large pelagic fish.

However, for species such as skipjack tuna, CPUE trends have declined. For this study, the number of trips was used as the measure of effort, including the trips when no catch was recorded. During the study period, the fishing effort for skipjack tuna remained constant and possibly increased, but catch decreased over time, thereby impacting overall CPUE values. Moreover, it was observed that, over the years, the number of trips when skipjacks were caught also decreased at different landing sites. This could possibly be linked to a collective behavioural change that could be influenced by climate change (Erauskin-Extramiana, et al., 2019), as their landings near the FADs also decreased in recent years.

Additionally, fishermen at the Dennery landing site have started travelling to the west coast (Zone A) in search of oceanic pelagic species which may suggest that the abundance of certain fish is higher in this zone thus making it easier to catch certain species. In recent years, more FADs have been deployed on the west coast of the island which could have encouraged more aggregation areas, thus making fish more accessible to fishers. However, it has been theorised that the deployment of multiple FADs in one area may decrease fishing success. According to Cabral et al. (2014), fewer FADs deployed in an area create fewer areas of fish aggregation which would increase the number of pelagics found in one spot, thereby increasing the catch probability. Conversely, areas that are heavily saturated with FADs results in the stock being more evenly distributed thus reducing the likelihood of fishers catching more than one fish at one site (Cabral, Alino, & Lim, 2014). This could be seen in landing data, as the landings of several species, such as skipjack tuna, dolphinfish, and gulf sierra mackerel, have been declining in recent years despite an increase in the number of trips to FADs. Therefore, if fishers prefer using certain FADs, then it may prove difficult for multiple fishers to have a successful trip, resulting in 'zero catch' trips. However, it is difficult to assess this without precise spatial data.

Although FAD usage over the years has proven beneficial in relieving the pressure of nearshore fisheries, there has been concern that the overutilisation of FADs may result in the unsustainable harvesting practices of many species (Davies, Mees, & Milner-Gulland, 2014). In the case of blue marlin, the catch rate increased steadily at the beginning of the study period, and fishers reported high levels of catch near FADs. The blue marlin lives in the epipelagic zone making it easier for them to be caught by shallow trolling lines, thereby, increasing the catch rate. However, the yearly catch decreased at the Vieux-Fort landing site and the overall use of FADs, thereby influencing the overall CPUE values. Considering that CPUE could be used as an indicator of abundance, it could be assumed that the stock has decreased, possibly due to collective behavioural changes. This decreasing trend has been further supported by international reviews, as billfish fisheries have been under review by various fisheries bodies, including the Western Central Atlantic Fishery Commission (WECAFC) and The International Commission for the Conservation of Atlantic Tunas (ICCAT). However, based on the results of this project their rate of capture has been increasing when fishers utilise FADs. These devices were deployed to reduce the pressure on coastal fisheries, but this may be creating another issue for the billfish fishery as it increases the rate of capture on an already critical stock, thus hindering the management efforts of ICCAT.

Furthermore, it was observed that for most species, the CPUE decreased in 2010. In 2010, Hurricane Tomas caused damage estimated at 43 percent of the country's GDP (The World Bank, 2011). The loss of vessels and gear, as well as the damage to the landing sites, limited the ability of fishers to fish consistently. As effort was measured using the number of trips, fishers recorded a decrease in both catch and effort values for that year, resulting in lower CPUE. Nevertheless, yellowfin and skipjack tuna recorded a high CPUE because of their high catch and effort values. This could have been a result of favourable conditions being created for these species.

Lastly, although the Generalized Linear Model (GLM) seemed to fit most of the nominal CPUE data, the search time and crew size were not included in the GLM model. Moreover, the '*fad*' factor was not considered in the model development. It is believed that these factors, especially search time, may have allowed for a better representation of fishing effort.

6 CONCLUSION AND RECOMMENDATIONS

Data on fisheries catch and effort data collected from 2000-2021 in Saint Lucia show that the landings recorded at the ten (10) primary landing sites have been constant over the years. The catch varies per landing site based on catch composition, and areas such as the Dennery, Micoud, and Vieux-Fort landing sites have recorded heavier catch per trip because fishers at these sites are known to catch large oceanic pelagic species, such as tuna, dolphinfish, and blue marlin. Additionally, the results from the cluster analysis revealed that the species composition was grouped into four (4) clusters with large ocean pelagics caught in the highest abundance by weight at all landing sites.

Fishing effort, measured using the number of trips at the country level, has also remained constant at the different sites. Areas such as Dennery, Micoud, and Vieux-Fort have all recorded an increase in the number of trips, whereas sites such as Choiseul, Castries, Gros-Islet, and Savannes-Bay have shown a decline in effort trends. Moreover, trolling gear has been the most popular gear used by fishers over the years, with fish pots, handlines, and gillnets also being favoured. Furthermore, the number of fishing vessels engaging in fishing activities at these sites has also varied over the years.

6.1 Recommendations for improving fisheries management strategies

- Integration of Length Based Sampling in the data collection process.

Currently, the Department of Fisheries only gathers catch weight during sampling. Although the weight is recorded, the data exploration that can be performed with this data is limited. By gathering the length of some of the sampled fish, or at least the length of some of the more valuable species, such as dolphinfish and tuna, can assist the department in determining the impact of management measures. For instance, length-based information can assist in determining whether the mesh sizes used in the nets result in juvenile or undersized fish species being caught. Moreover, this information would be useful in guiding decisions made on gear design and usage for certain fisheries, since the revision of hook and mesh size may lead to larger fish being landed, which in turn would result in higher returns for the fishers. Length-based stock assessment models can also be used to make assumptions about the stock status.

In addition, because the department currently faces issues with conducting regular habitat assessments, the acquisition of biological data is quite time-consuming. Therefore, length data received from this length data and possibly maturity staging would help fisheries officers make better inferences when it comes to mapping nursery and breeding grounds.

- Encourage fishers to collect spatial data.

Although the general zones for fishing are recorded by data collectors, it would be beneficial to the department if fishers provided precise fishing locations (using GPS coordinates). This would help the department determine the areas where fishers have exhibited greater effort. This, in turn, could be useful, especially when issues related to marine zoning and marine use arise.

The identification of ideal fishing grounds could also assist in reducing effort, especially in terms of search time, which in turn would reduce the total expenses incurred by fishers in relation to fuel costs.

- Continued training for data collectors

Over the years, data collectors have received support in such a way that they can improve their data collection techniques. However, fish identification is sometimes not performed at the species level. This in turn could affect the final data analysis as comparisons are limited to the ‘family’ level. Therefore, if collectors become more efficient in performing this identification, better reviews and management strategies can be implemented.

- Improve data collection and monitoring process

Currently, data are analysed using TIP and presented in Microsoft Excel format; however, this study has proven that a more comprehensive analysis can be performed using R software and its associated programs. Therefore, it may be useful for the department to consider the adoption of this software in data management strategies.

In addition, improved documentation of project deliverables and FAD deployment could help in CPUE calculations. One of the limitations of this study was the uncertainty related to the years of FAD deployment. This makes it challenging to describe the influence of this device on the CPUE values produced.

Hours spent at sea and crew size were not included in the GLM model; however, exploratory work indicated that this could influence the CPUE.

- Review management strategies to include the use of the Ecosystem Approach to Fisheries and the Precautionary Approach

The absence of data should not be a reason why managers do not react cautiously. A pessimistic approach to stock size may be more useful than an optimistic one. Subsidies and fuel rebates may be counterproductive in ensuring sustainability; therefore, more money should be used to promote better technological practices. Additionally, subsidy programs should consider scientific advice on stock status to ensure sustainability.

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REFERENCES

Bealey, R., Perez Moreno, M., & Van Anrooy, R. (2019). *The Caribbean billfish and management and conservation plan*. Rome: Food and Agriculture Organization.

Brander, K. (1975). *Guidelines for collection and compilation of fishery statistics*. Rome. Food and Agriculture Organization

Cabral, R. B., Alino, P. M., & Lim, M. T. (2014). Modelling the impacts of fish aggregating devices (FADs) and fish enhancing devices (FEDs) and their implications for managing small-scale fishery. ICES *Journal of Marine Science*, September 2014.

Government of St.Lucia. Chapter 7.15 Fisheries Act. (2023, January 22). Retrieved from https://www.govt.lc/media.govt.lc/www/resources/legislation/FisheriesAct.pdf

Davies, T. K., Mees, C. C., & Milner-Gulland, E. (2014). The past, present and future use of drifting fish aggregating devices (FADs) in the Indian Ocean. *Marine Policy*, 45, 162-170.

Department of Fisheries. (2015). Draft Data Sampling Plan for Saint Lucia Fisheries.

Department of Fisheries. (2022). Landings and Price 1981_2021.

Edwin, Y. M. (2011). An appraisal of the fisheries data collection system in Saint Lucia. UNU-FTP, Reykjavik, Iceland. Retrieved from https://www.grocentre.is/static/gro/publication/250/document/yvonne_2011prf.pdf

Erauskin-Extramiana, M., Arrizabalaga, H., Hobday, A. J., Cabré, A., Ibaibarriaga, L., Arregui, I., Chust, G. (2019). Large-scale distribution of tuna species in a warming ocean. *Global Change Biology*, 25 (6), 2043-2060.

Food and Agriculture Organization. (1995). Code of Conduct for Responsible Fisheries. Rome.

Food and Agriculture Organization. (2002). A Fishery Manager's Guidebook- Management Measures and Their Application. Rome.

Food and Agriculture Organization. (2015). AQUASTAT Country Profile- Saint Lucia. Rome.

Food and Agriculture Organization. (2022). The State of the World Fisheries and Aquaculture. Rome.

Friedlander, A., Beets, J., & Tobias, W. (1994). Effects of fish aggregating devices design and location on fishing success in the U.S. Virgin Islands. *Bulletin of Marine Science*. 55 (2-3), 592-601.

Government of Saint Lucia. (2013, September). Food and Nutrition Security Policy for Saint Lucia 2013. Saint Lucia.

Government of Saint Lucia. (2018). Saint Lucia's Sectoral Adaptation Strategy and Action Plan for the Fisheries Sector (Fisheries SASAP) 2018-2028 under the National Adaptation Planning Process. Saint Lucia.

Mahon, R. (1987). *Report and proceedings of the Expert Consultation on shared fishery Resources of the Lesser Antilles region.* Food and Agriculture Organization.

Maunder, M. N., & Punt, A. E. (2004). Standardizing catch and effort data: a review of recent approaches. *Fisheries Research,* 70 (2-3), 141-159.

McCluskey, S. M., & Lewison, R. L. (2008, June 28). Quantifying fishing effort: a synthesis of current methods and their applications. United States of America. *Fish and Fisheries*. 9 (2), 188-200.

McKenna Jr., J. E. (2003, April 03). An enhanced cluster analysis program with bootstrap significance testing for ecological community analysis. *Environmental Monitoring and Software.* 18 (3), 205-220.

Murray, P. A., Barnwell, S. B., & Clemetson, A. (1996). *A manual of CARICOM procedures for entry and reporting of fisheries data with the TRIP Interview Program.* CARICOM. Belize City, Belize.

R Core Team. (2015). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. Vienna, Austria.

Saint Lucia International Finance Centre. (2008). Saint Lucia Factbook.

Suzuki, R. (2019, December 5). *shimo-lab/pvclust* (Computer Software). GitHub. Retrieved from https://github.com/shimo-lab/pvclust

The World Bank. (2011, March 10). *Saint Lucia after "Tomas": 20,000 to benefit from rehabilitation of public infrastructure.* Retrieved from: https://www.worldbank.org/en/news/press-release/2011/03/10/saint-lucia-after-tomas-20000-to-benefit-from-rehabilitation-of-public-infrastructure

Venables, W. N., & Dichmont, C. M. (2004). GLMs, GAMs and GLMMs: an overview of theory for applications in fisheries research. *Fisheries Research.* 70 (2-3), 319-337.

Wagner, T., Midway, S. R., Vidal, T., Irwin, B. J., & Jackson, J. R. (2016). Detecting unusual temporal patterns in fisheries time. *Transactions of the American Fisheries Society*, 145(5), 998-994. https:// doi:10.1080/00028487.2016.1150879

World Bank. (2019). COAST insurance: An assessment of Saint Lucia's fisheries sector. Retrieved from: https://www.ccrif.org/en/publications/external/coast-insurance-assessment-st-lucias-fisheries-sector

8 APPENDICES

APPENDIX 1: Data collection form used by Data Collectors

ST. LUCIA DATA MANAGEMENT PROGRAMME

FIELD DATA SHEET

Landing Site ________ Weather ________ Time arrived at site ________ Time departed from site ________

Date ________ Sea State ________ Name of collector ________ Total Vessels Out ________

Landing Order												
Boat ID Number												
Time-Departure												
Time Returned												
Area Fished/Zone												
Fuel Used(Gal.)												
Gear Primary												
Gear Secondary												
Number of gear used (Trol, Pots, Nets, L-ling)												
Number of Sets (Nets, Longlines)												
Range of depth Pots, Nets, L-lines)												
Nets & Pots (mesh size)												
Nets & Pots (hours/days soak time)												
Total Number of Hooks												
Weight Type (VE, FE, WT)												
SPECIES NAME	Weight (lbs)	GP	Price Per lb	Weight (lbs)	GP	Price Per lb	Weight (lbs)	GP	Price Per lb	Weight (lbs)	GP	Price Per lb
Crew Name (full) 1												
Crew Name (full) 2												
Crew Name (full) 3												
Crew Name (full) 4												
Trip Interview Program Sequence number												

Include reason for no/low catch or for early return: state of currents: weather condition. Fill in form when there is effort but no catch. *VE-Visual estimate, FE-Fishermen estimate, WT-Weight measurement, GP-Gutted Weight

*No. Sharks Caught*__________ *No. Tunas Caught*__________ *No. Wahoo Caught*___________

*No. Dolphin Caught*__________ *YFT more than 20lbs*__________ *YFT more than 60lbs*___________

COMMENTS:

APPENDIX 2: List of variables in data frames

Table 2. Showing the data tables used for data analysis.

Data Table	***Variable Name***	***Description***
SAMPLED CATCH DATA	*.id*	The associated ID for each trip recorded by the Fisheries officer into the TIP database. This number is automatically generated by the TIP and is a unique seven (7) digit code (Murray, Barnwell, & Clemetson, 1996)
	rid	record ID for the trip
	sid	species ID
	nodccode	is the associated code for the specie
	gid	gear ID
	areafish	is the corresponding fishing ground/area used by the fisher
	weight	the weight (recorded in pounds) of the fish that was landed
	price	this is the unit cost (in Eastern Caribbean Dollars) of the fish landed
	meastype	This represents the weight and physical condition of the fish landed, as well as the units of measurement (Murray, Barnwell, & Clemetson, 1996)
	value	the total cost (in Eastern Caribbean Dollars) of the fish that is landed. It is calculated by multiplying the weight by the price per pound of the fish caught
	numtrips	this is the number of trips recorded per vessel for the day
FISHING DAYS AND FISHING VESSELS PER LANDING SITE	*lid*	landing site ID
	month	recorded as the first day of each month when the data was entered per site
	n	number of vessels recorded at the landing site for the month
	n.days	the raised estimate of the number of fishing days for the month at the landing site
	n.vid.day	the average number of vessels at the landing site per day for the month
LANDING SITES GPS	*landing_site*	the name of the landing site
	long	longitudinal degree measurement of the landing site
	lat	latitudinal degree measurement of the landing site
TYPE OF FISHERY	*fid*	fishery ID
	fishery	type of fishery

TYPE OF GEAR	*tid*	gear code used to identify the type of trip based on the primary gear that was used
	trip	type of gear
SPECIES	*sid*	species ID
	common	the common name of the specie
	local	the local name of the specie
	latin	the latin name of the specie
	valid_name	the scientific name of the specie
	order	represents the general grouping of the organism
	family	family grouping that the specie belongs to
	genus	genus name used in the species classification system
GEAR USE AND AREA FISHED	*.id*	which is the associated ID for each trip recorded by the Fisheries officer into the TIP database. This number is automatically generated by the TIP and is a unique seven (7) digit code (Murray, Barnwell, & Clemetson, 1996)
	gid	gear ID used to record the gear code using the OECS coding scheme
	gearnum	records the number of sets of the gear fished
	gearqty	the number of individual units of each gear used
	soaktime	recorded as either the soak time of the gear or the trip duration from setting to hauling for each set of the gear
	areafish	the zone that the fisher caught their catch
ESTIMATED TRIP	*.id*	which is the associated ID for each trip recorded by the Fisheries officer into the TIP database. This number is automatically generated by the TIP and is a unique seven (7) digit code (Murray, Barnwell, & Clemetson, 1996)
	tid	gear ID
	vid	vessel ID
	fid	fishery ID
	date	date of the sampling
	lid	Landing site ID
	t1	the time the vessel left the landing site
	t2	the time the vessel returned to the landing site

	fishmode	represents the mode of fishing activity that the vessel was engaged in during the sampling time
	landtype	indicates whether the landings information is complete for the fishing trip
	crewsize	number of fishers who were part of the fishing trip on the sampling day
	daysout	number of days from the day of departure to the day of return to shore when the catch was unloaded
	daysfish	number of days that the fisher fished

APPENDIX 3: Gears used by Saint Lucian fisherfolk.

Table 3. Showing Gear used by Saint Lucian fisherfolk.

GEAR ID	GEAR NAME
BLIN	Bottom line
BSNE	Beach seine
CNET	Cast net
DIVE	Diving (Free/Skin diving)
DNET	Dip net
FPOT	Fish pot
GNET	Gillnet
HAND	Catching by hand
HARP	Harpoon
HLIN	Handline
HOKA	Hookah
LPOT	Lobster pot
PALN	Palangre
PLIN	Pole & line
POTS	Pots
REEL	Rod and reel
SCUB	Scuba diving gear
SGUN	Speargun
SLIN	Surface long line
SNET	Scoop net
TRAL	Trawl
TROL	Trolling
VLIN	Vertical line

APPENDIX 4: SPECIES TABLE

Table 4. Species used in Cluster Analysis.

SID	FAMILY	LATIN NAME	COMMON NAME
SCOMAT	Scombridae	Thunnus atlanticus	Blackfin Tuna
ISTINI	Istiophoridae	Makaira nigiricans	Blue Marlin
CORYHI	Coryphaenidae	Coryphaena hippurus	Dolphinfish
SCOMSO	Scombridae	Scomberomorus concolor	Gulf sierra
SCOMAB	Scombridae	Thunnus albacares	Yellowfin Tuna
SCOMPE	Scombridae	Katsuwonus pelamis	Skipjack Tuna
HOLOAD	Holocentridae	Holocentrus adscensionis	Squirrelfish
SERRFU	Serranidae	Epinephelus fulvus	Coney
CHELMY	Cheloniidae	Chelonia mydas	Green Turtle
DASY	Dasyatidae	Dasyatidae	Stingrays
SCOMOB	Scombridae	Thunnus obesus	Bigeye Tuna
SCOMAA	Scombridae	Thunnus alalunga	Albacore Tuna
CETATR	Delphinidae	Tursiops truncatus	Porpoise
CETAMA	Delphinidae	Globicephala macrorhyncu	Pilot Whale
CARCCU	Carcharhinidae	Galeocerdo cuvier	Tiger shark
CETA	Balaenidae	Cetacea	Whales
CARCTA	Odontaspididae	Odontaspis taurus	Sand tiger shark
ENGR	Engraulidae	Engraulidae	Anchovies
NO FISH	No fish caught		
CITTPI	Tegulidae	Cittarium pica	West Indian Topsnail
PALI	Palinuridae	Palinuridae	Caribbean Spiny Lobster
CARADU	Carangidae	Seriola dumerili	Greater Amberjack
CARALA	Carangidae	Caranx latus	Horse eye Jack
EXOCAF	Exocoetidae	Hirundichthys affinis	Four wing Flyingfish
CARACR	Carangidae	Selar crumenophthalmus	Bigeye Scad
CARAPU	Carangidae	Decapterus punctatus	Round Scad
STROGI	Strombidae	Strombus gigas	Queen conch
CLUPS	Clupeidae	Sardinella spp.	Sardines
CARA	Carangidae	Carangidae	Jacks
CARAHI	Carangidae	Caranx hippos	Crevalle Jack
HEMIBR	Hemiramphidae	Hemiramphus brasiliensis	Ballyhoo
PALIAR	Palinuridae	Palinuridae	Caribbean Spiny Lobster
LUTJCH	Lutjanidae	Ocyurus chrysurus	Yellowtail Snapper
ACANBA	Acanthuridae	Acanthurus bahianus	Ocean Surgeonfish
LUTJJO	Lutjanidae	Lutjanus jocu	Dog Snapper

PCANPA	Pomacanthidae	Pomacanthus paru	French Angelfish
SCARVI	Scaridae	Sparisoma viride	Stoplight Parrotfish
HOLOMA	Holocentridae	Holocentrus marianus	Longjaw Squirrelfish
BALIVE	Balistidae	Balistes vetula	Queen Triggerfish
MALAPL	Malacanthidae	Malacanthus plumieri	Sand Tilefish
LUTJBU	Lutjanidae	Lutjanus buccanella	Blackfin Snapper
LUTJOC	Lutjanidae	Etelis oculatus	Queen Snapper
CARALU	Carangidae	Caranx lugubris	Black jack
LUTJCA	Lutjanidae	Lutjanus campechanus	Red snapper
BALI	Balistidae	Balistidae	Triggerfishes
BALIPU	Balistidae	Canthidermis sufflamen	Ocean triggerfish
LOBOSU	Lobotidae	Lobotes surinamensis	Trippletail
CARARI	Carangidae	Seriola rivoliana	Almaco Jack
SPHYBA	Sphyraenidae	Sphyraena barracuda	Great Barracuda

APPENDIX 5: TABLES FOR TOTAL LANDINGS (USING RAISED ESTIMATES)

Table 5. Total Landings recorded for Saint Lucia from 2000-2021.

Year	Total Landings (recorded in metric tons)
2000	996.56
2001	1545.32
2002	1302.44
2003	1203.53
2004	1213.73
2005	1105.52
2006	1114.32
2007	1231.53
2008	1420.10
2009	1517.00
2010	1450.06
2011	1285.73
2012	1339.77
2013	1319.13
2014	1274.30
2015	1338.14
2016	1437.66
2017	1355.43
2018	1181.54
2019	1065.72
2020	1031.06
2021	1207.81

Table 6. Total Landings by landing sites.

Total Landings from 2000-2021(weight in mt)											
Year	*Bannanes*	*Castries*	*Choiseul*	*Dennery*	*Gros Islet*	*Micoud*	*Savannes Bay*	*Soufriere*	*Vieux Fort*	*Laborie*	*Anse La Raye*
2000	2.89	111.51	15.62	191.40	142.71	68.91	98.64	73.38	260.82	-	-
2001	-	126.64	223.90	323.69	216.54	92.78	37.10	83.98	382.49	44.13	-
2002	-	90.77	157.85	325.99	187.21	56.22	-	90.13	347.73	46.52	-
2003	-	135.51	54.45	297.31	155.11	47.03	-	93.67	367.59	52.86	-
2004	13.44	135.54	58.47	310.37	114.16	72.89	-	80.43	373.32	55.11	-
2005	23.89	84.46	74.47	282.19	133.83	66.52	-	102.82	291.89	45.45	-
2006	14.48	46.05	62.05	307.47	108.05	81.42	-	55.63	365.56	73.61	-
2007	12.28	59.34	70.15	369.70	111.46	80.70	-	77.70	365.66	84.56	-
2008	6.40	64.45	125.03	321.93	188.05	101.46	-	71.81	423.83	109.46	7.68
2009	23.35	75.24	97.25	430.51	159.96	98.63	-	119.93	412.41	49.70	50.01
2010	13.33	49.34	92.75	374.90	112.52	108.79	-	155.10	475.05	42.84	25.43
2011	-	87.53	98.15	260.37	76.22	100.97	-	93.78	537.46	5.68	25.56
2012	-	43.69	79.16	305.34	104.37	115.52	-	81.86	525.56	48.68	35.58
2013	-	18.28	81.25	306.40	140.64	100.58	-	35.01	541.92	62.90	32.15
2014	-	166.54	62.50	320.98	76.42	59.25	-	43.48	437.37	49.17	58.58
2015	-	106.47	57.42	320.08	103.43	77.73	-	56.99	496.67	63.40	55.95
2016	-	95.36	54.91	359.18	85.53	111.95	36.22	34.33	526.22	72.25	61.70
2017	-	72.28	66.55	382.43	43.27	125.04	35.93	38.23	486.79	66.68	38.23
2018	-	108.87	63.44	262.15	66.73	58.69	22.41	34.82	438.83	66.17	59.43
2019	-	85.48	43.39	135.66	53.23	134.52	24.00	35.94	425.66	74.18	53.66
2020	-	71.15	36.72	256.21	57.04	149.34	13.59	35.91	288.20	67.58	55.31
2021	-	67.65	51.89	387.60	38.92	106.78	23.06	34.17	372.28	60.95	64.51

APPENDIX 6: TOTAL LANDINGS FOR THE SIX (6) SPECIES USED IN THE CPUE CALCULATION

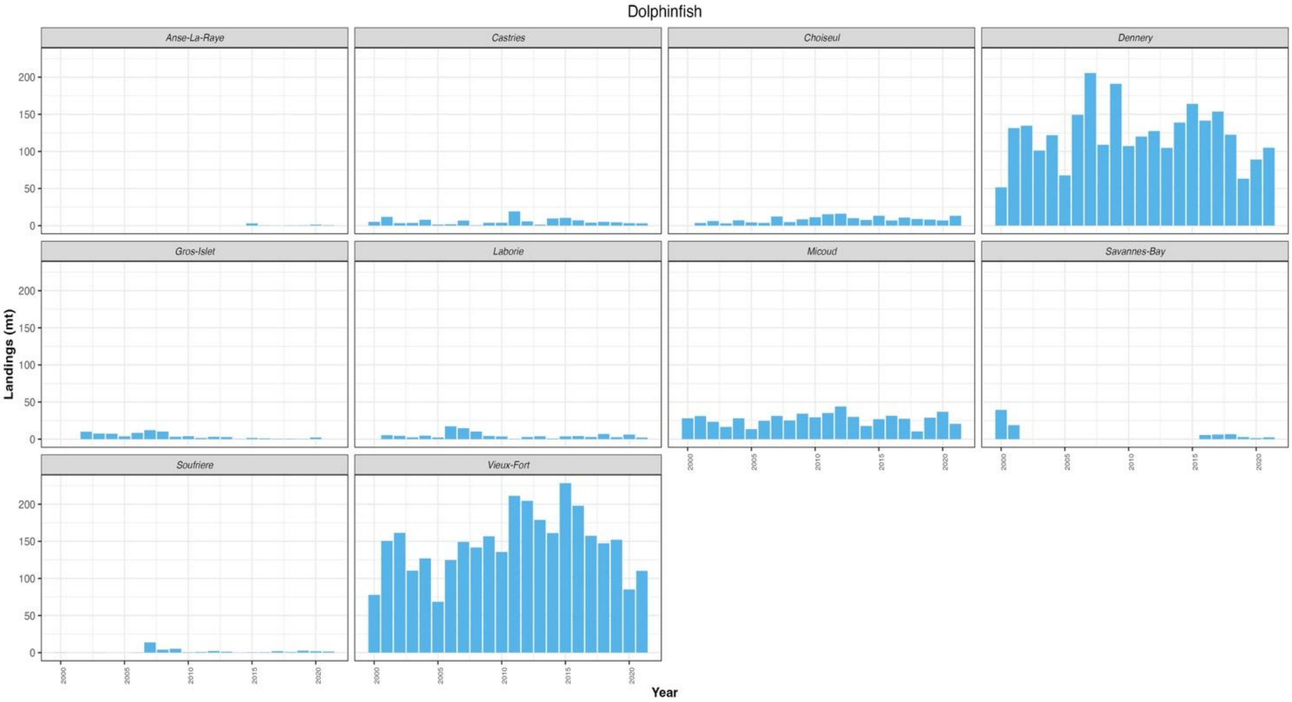

Figure 46. Total landings of dolphin fish from 2000-2021 using trolling gear.

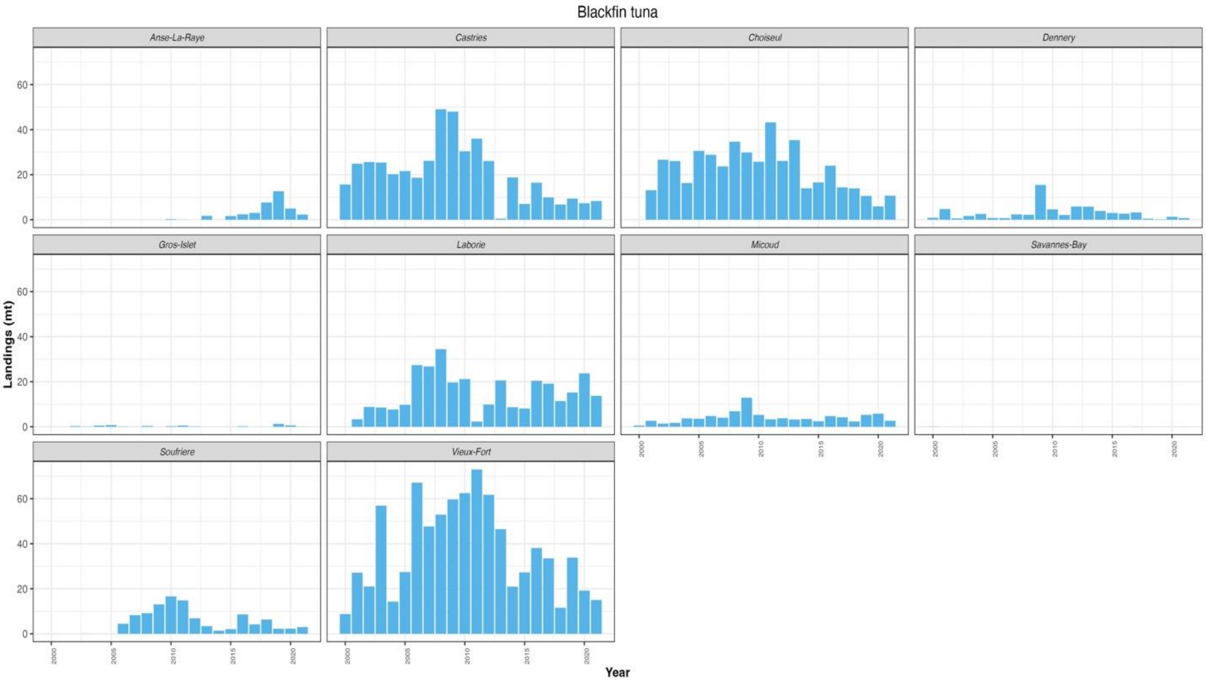

Figure 47. Total landings of blackfin tuna from 2000-2021 using trolling gear.

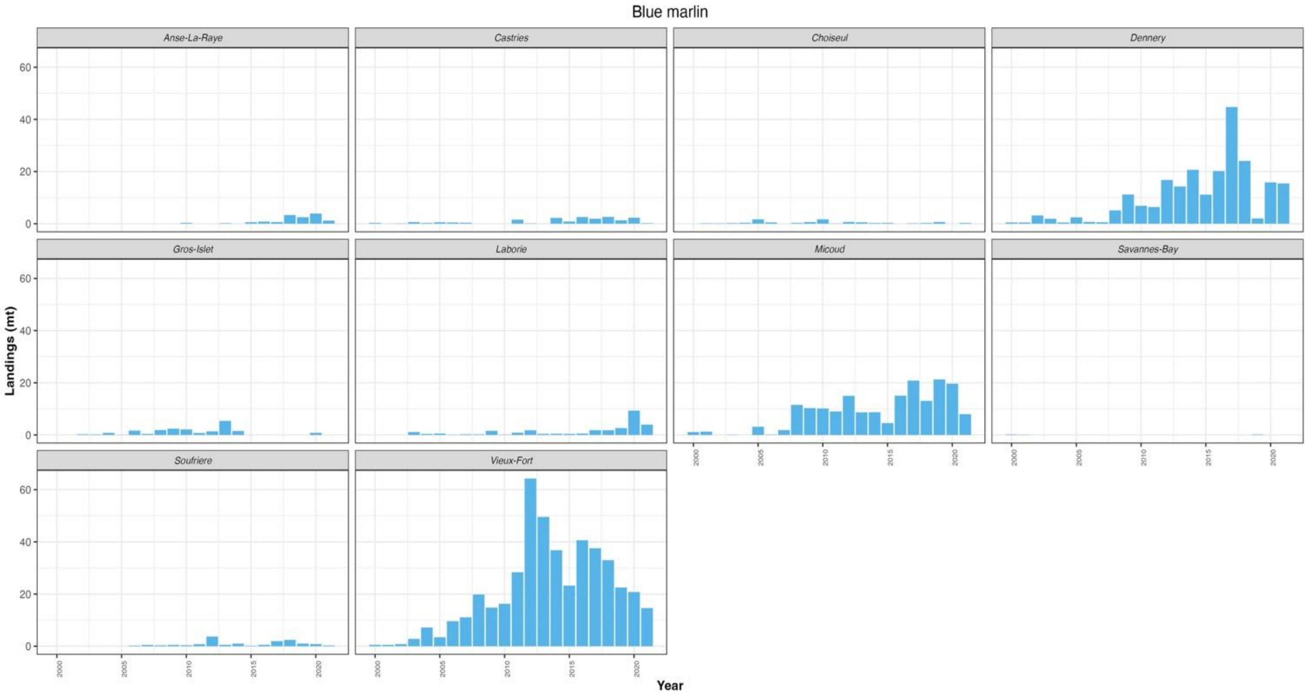

Figure 48. Total landings of blue marlin from 2000-2021 using the trolling gear.

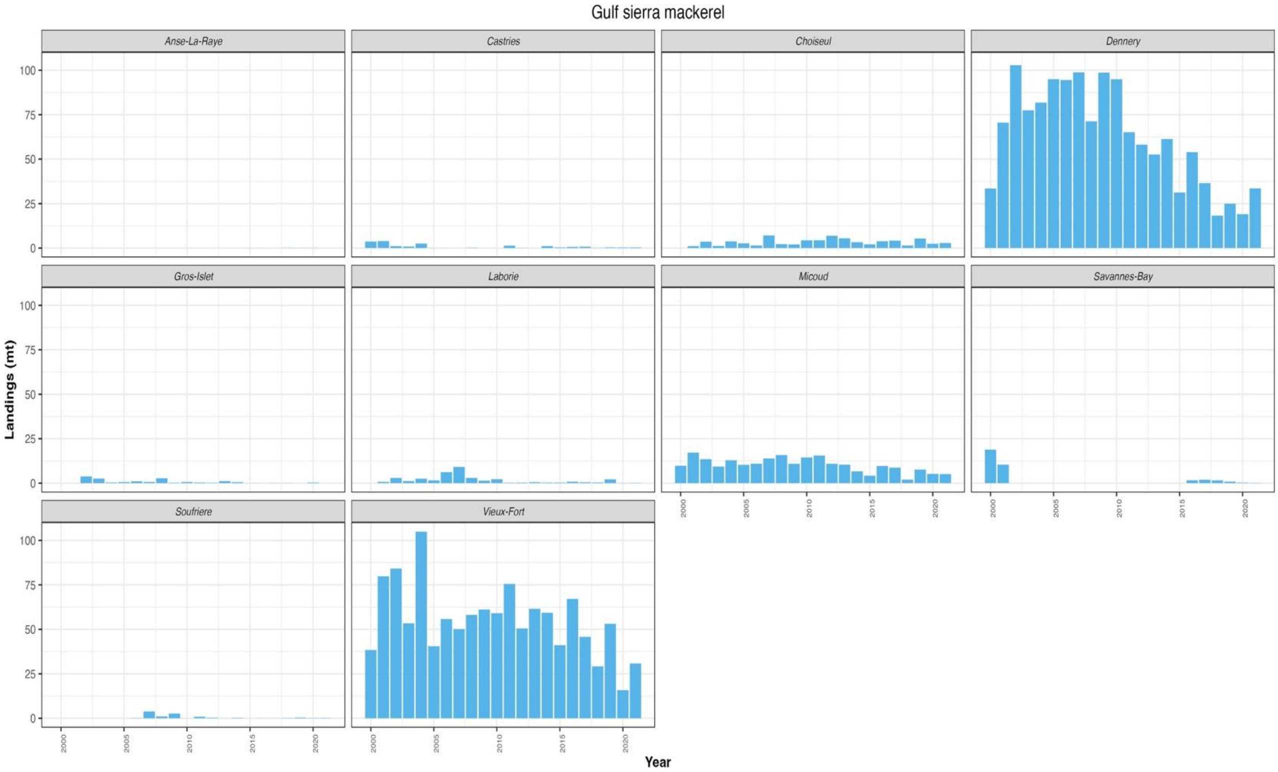

Figure 49. Total landings of the gulf sierra mackerel from 2000-2021 using trolling gear.

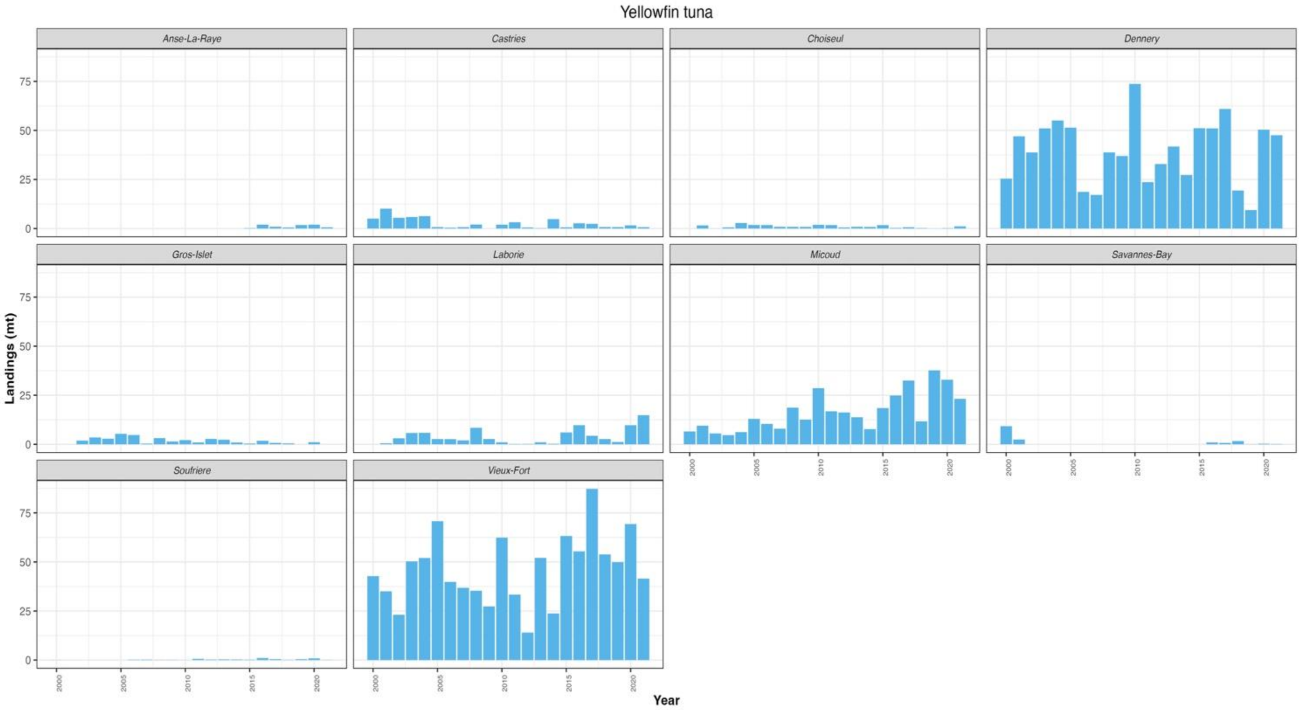

Figure 50. Total landings for yellowfin tuna from 2000-2021 using trolling gear.

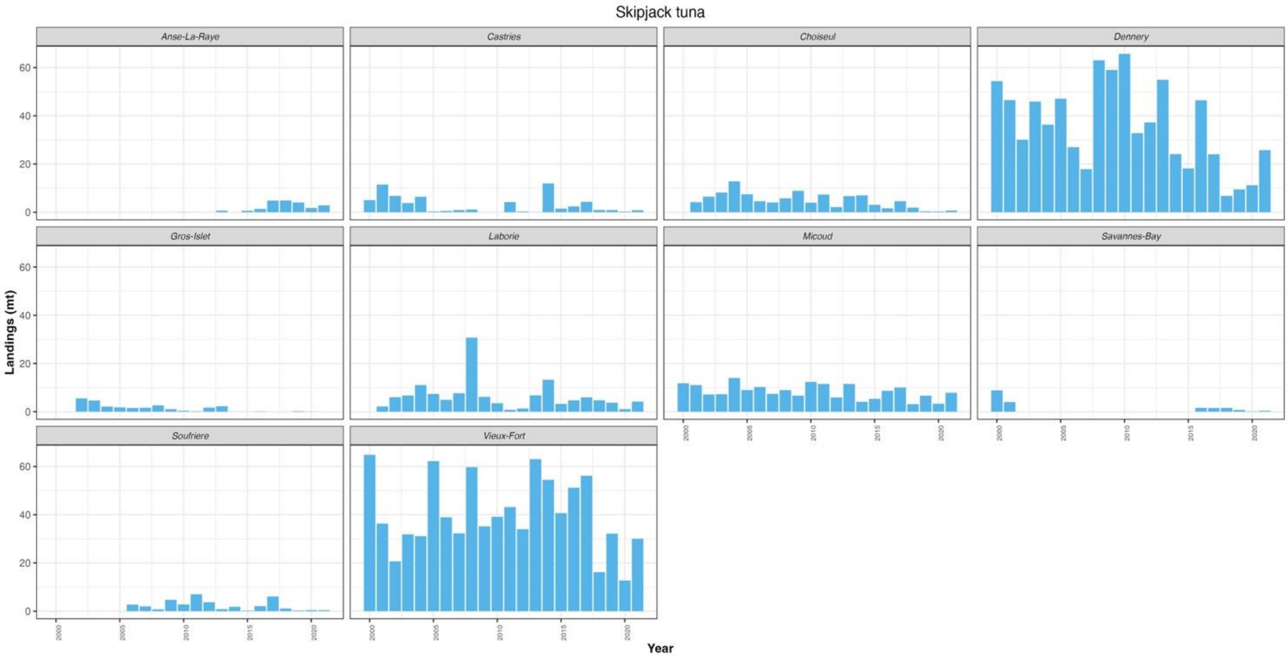

Figure 51. Total landings for skipjack tuna from 2000-2021 using trolling gear.

APPENDIX 7: AREA FISHED FOR THE SIX (6) LARGE OCEANIC PELAGICS

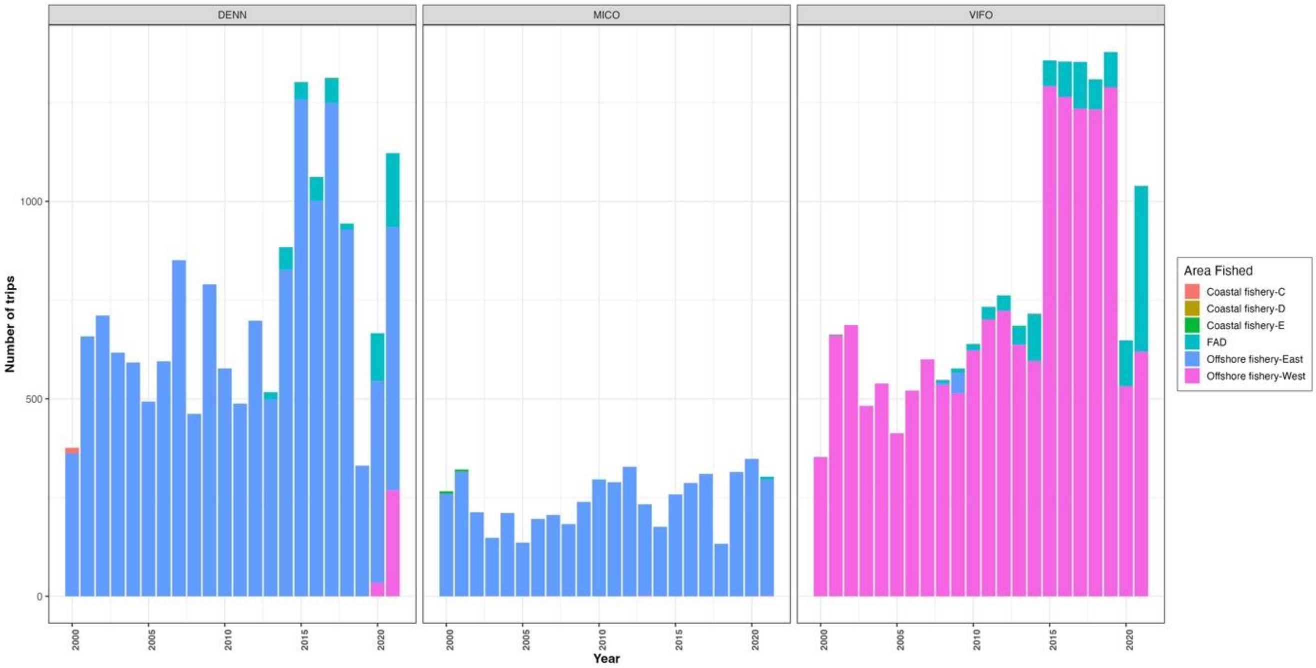

Figure 52. Area fished for dolphinfish using trolling gear from 2000-2021.

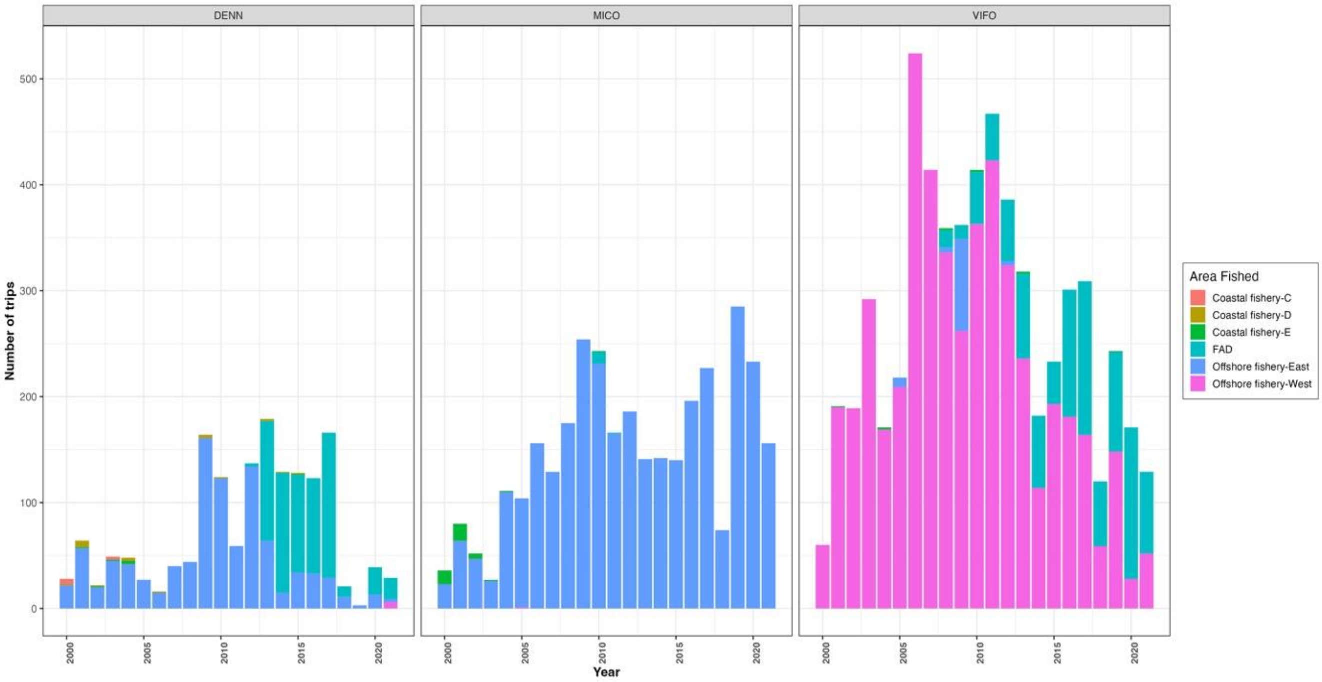

Figure 53. Areas fished for blackfin tuna using trolling gear from 2000-2021.

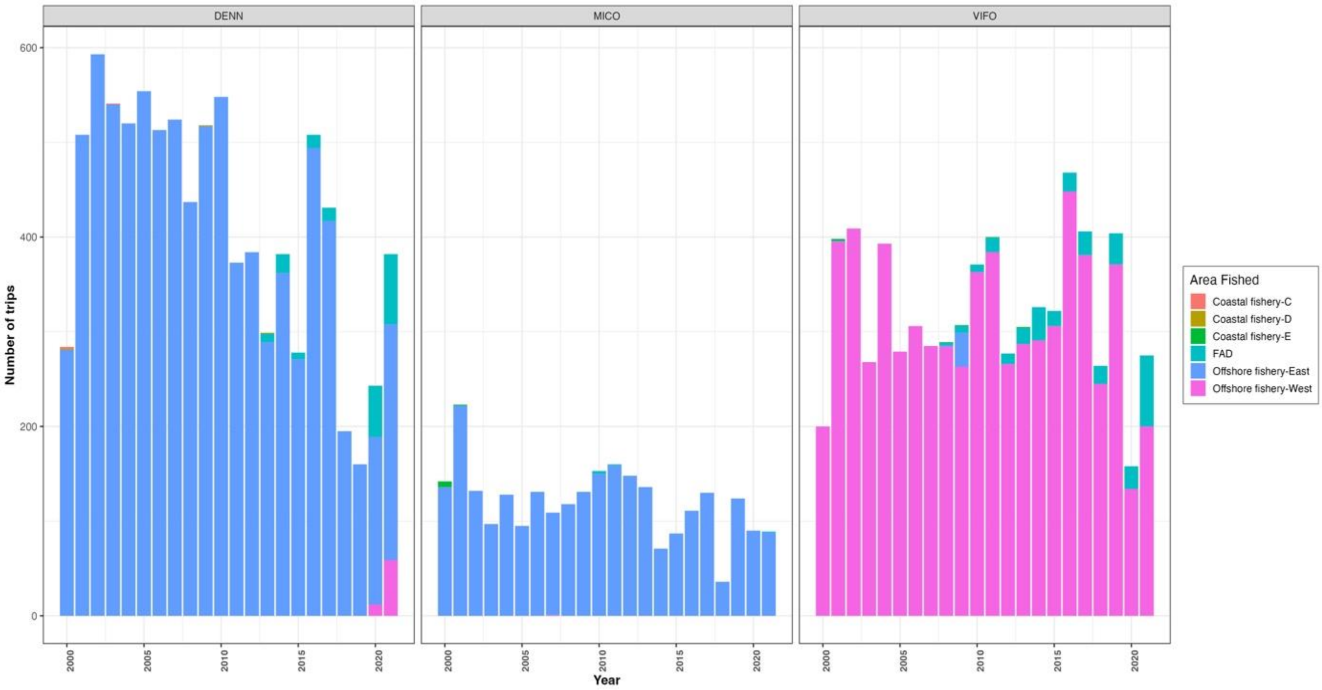

Figure 54. Area fished for gulf sierra mackerel using trolling gear from 2000-2021.

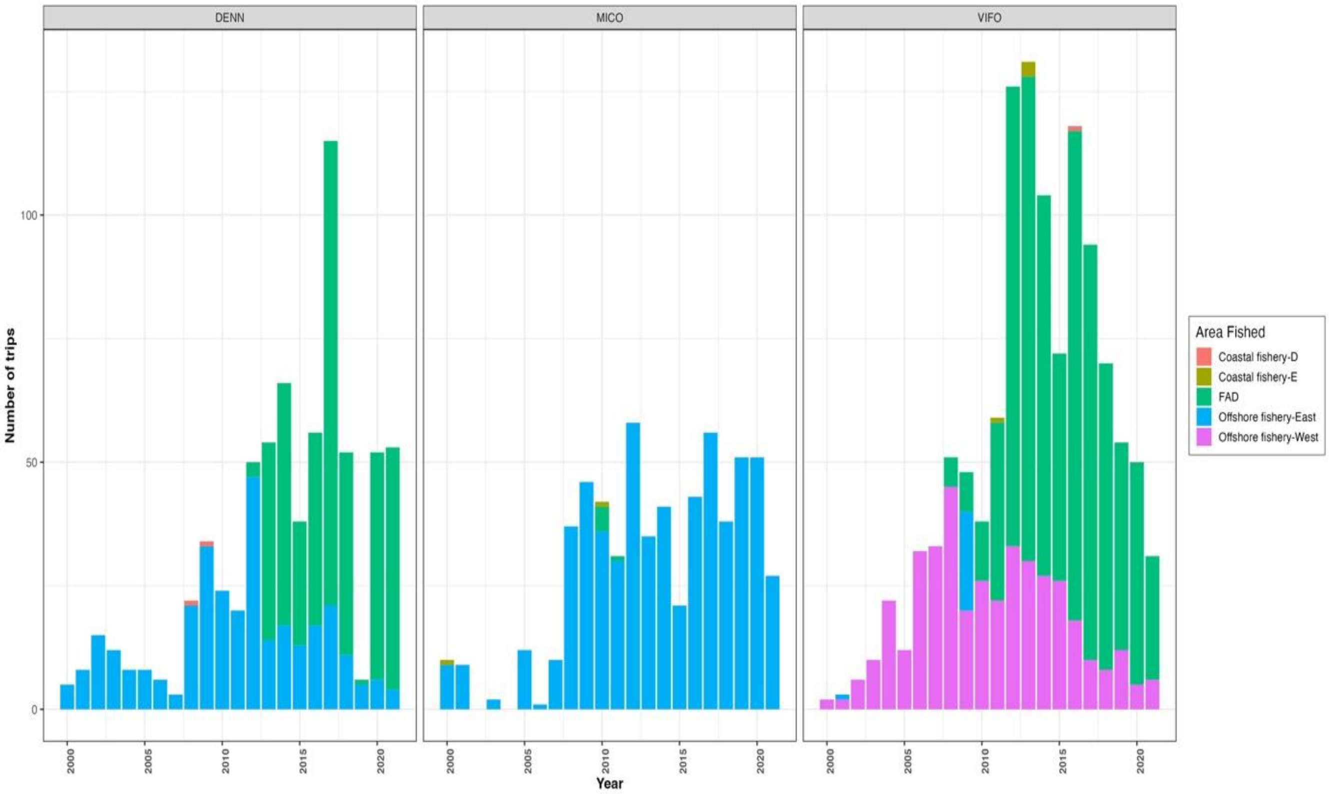

Figure 55. Area fished for blue marlin using trolling gear from 2000-2021.

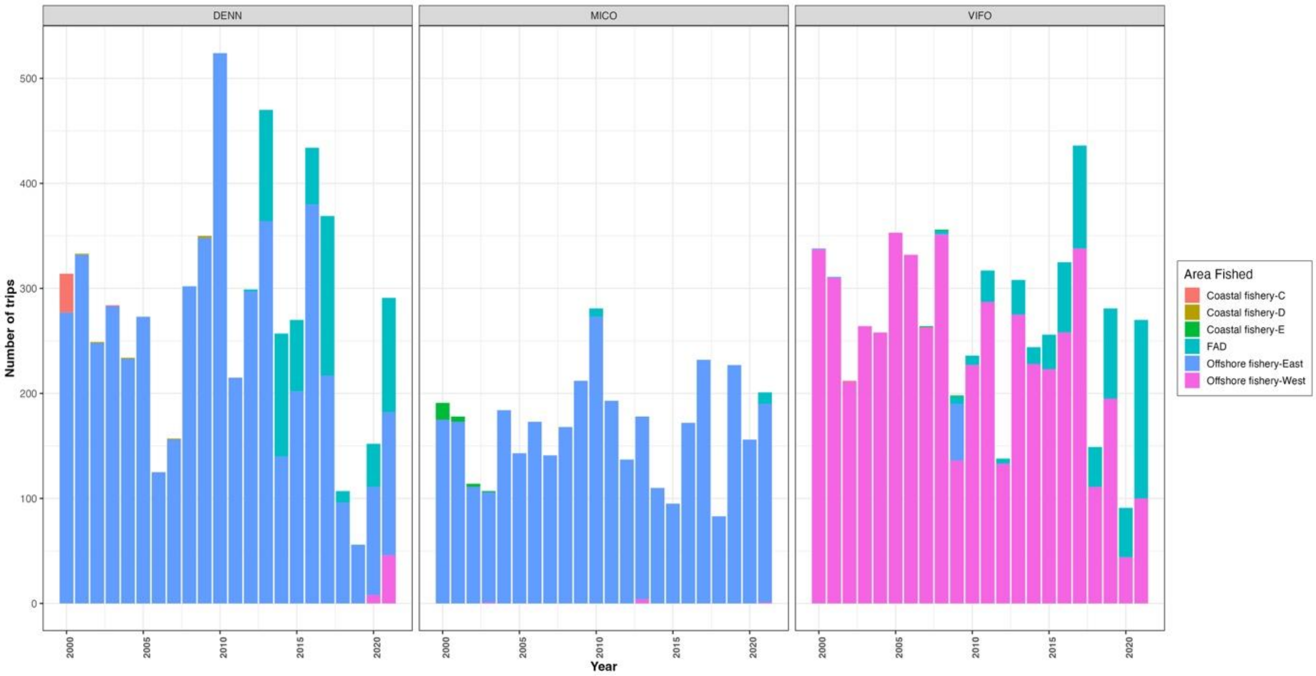

Figure 56. Area fished for skipjack tuna using trolling gear from 2000-2021.

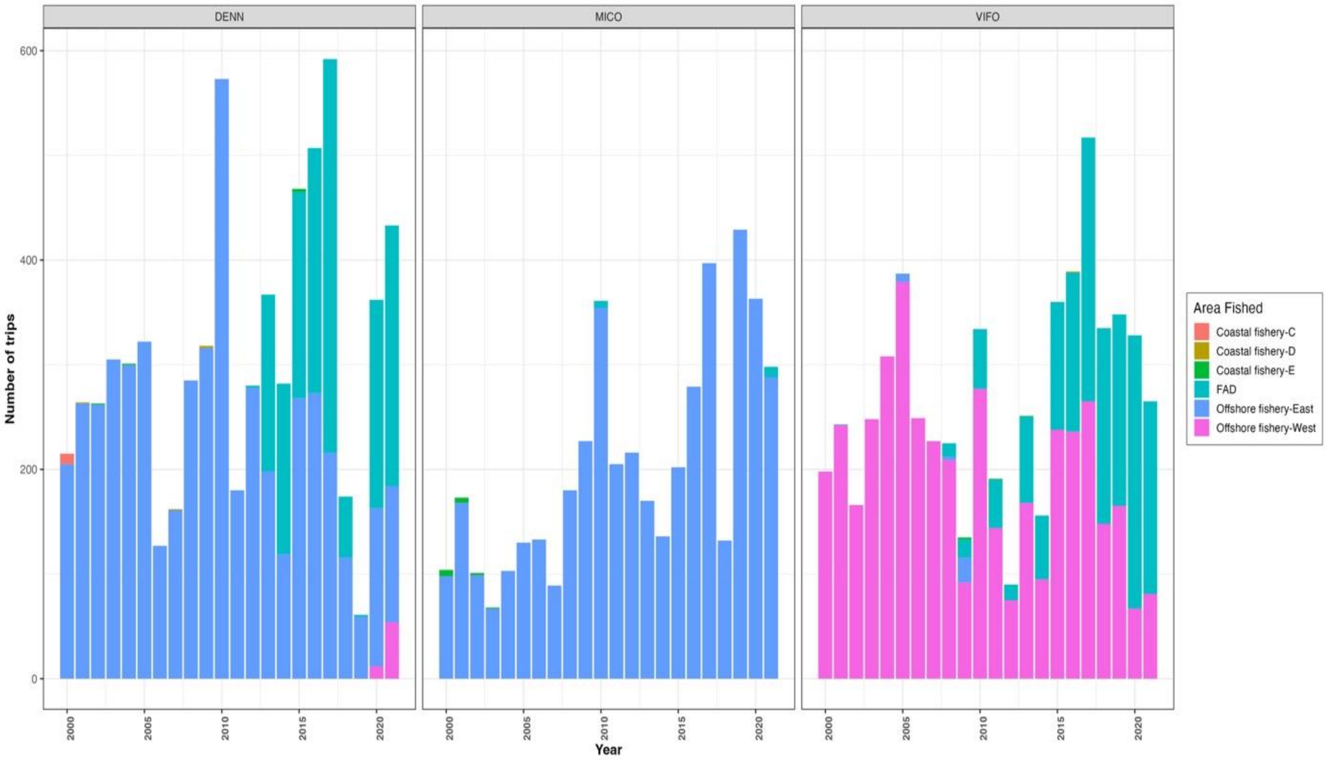

Figure 57. Area fished for yellowfin tuna using trolling gear from 2000-2021.

APPENDIX 8: MAP SHOWING FAD LOCATION

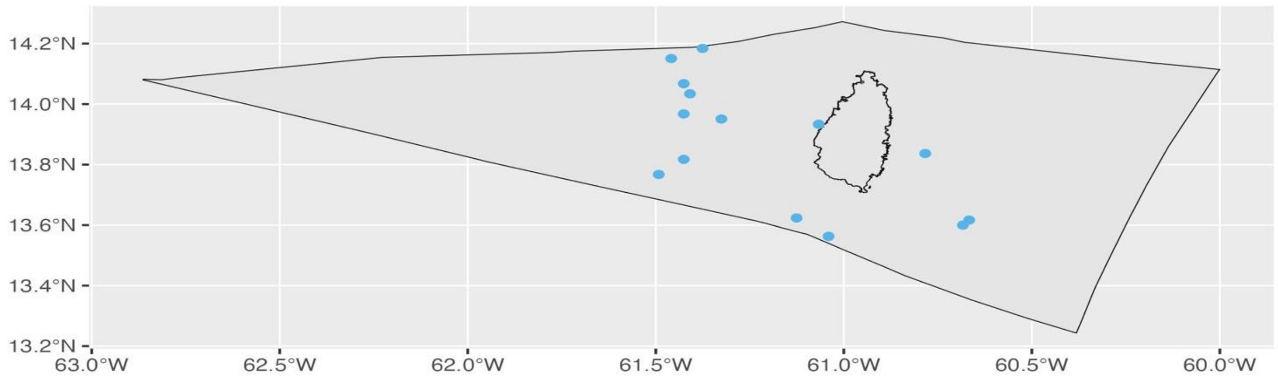

Figure 58. Approximate location of FADs deployed around Saint Lucia as of December 2022 (outline indicates Saint Lucia's EEZ). Source: M. Straughn, personal communications, 7 March, 2023.