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COLLECTION, MANAGEMENT AND PRIMARY ANALYSIS OF FISHERIES DATA IN THE COMMONWEALTH OF DOMINICA

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ABSTRACT

This study examined the field sampling catch and effort data collected for Dominica from 1994 to 2014 and reconstructed catch and effort series for that period. Documentation was prepared for the data collection system, databases used and reporting of fisheries data by the Fisheries Division of Dominica. Finally, a CPUE analysis was prepared for the dolphinfish (*Coryphaena hippurus*) fishery of Dominica. The available data produced from the existing data collection and data management system proved useful for preparing some primary analyses. National fishing effort has fluctuated around 120 thousand trips per year, gradually increasing since 2000. The total national estimated catch is at around 1000 tonnes per year, but declining in the long term since 1994. Dolphinfish catch is around 200 tonnes annually, slightly increasing in the long term. The average catch-rate of dolphinfish for the period was 38 kg per trip. The analysis includes only data from the Dominican fishery, so it cannot account for the entire multinational dolphinfish stock, but the CPUE trends seem to indicate that the stock is stable at the current harvest levels. However, analytical stock assessment of the dolphinfish data is required to evaluate whether the stock is at a level where it is most productive in terms of annual yield.

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ABBREVIATIONS AND ACRONYMS

AIC	Akaike Information Criterion
ASM	Annual Scientific Meeting
CARICOM	Caribbean Community
CARIFICO	Caribbean Fisheries Co-management (Project)
CARIFIS	Caribbean Fisheries Information System
CFRAMP	CARICOM Fisheries Resource Assessment and Management Program
CPUE	Catch Per Unit Effort
CRFM	Caribbean Regional Fisheries Mechanism
DBF	DataBase File
FAD	Fish Aggregating Device
FAO	Food and Agriculture Organisation of the United Nations
FIC	Fisheries Industry Census
FRP	Fibre-Reinforced Plastic
GDP	Gross Domestic Product
GLM	Generalized Linear Model
HLIN	Hand Line
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICES	International Council for the Exploration of the Seas
IFREMER	French Research Institute for Exploration of the Sea
JICA	Japan International Cooperation Agency
LRS	License and Registration System
MS	Microsoft
NOAA	National Oceanic and Atmospheric Administration
SQL	Structured Query Language
TIP	Trip Interview Programme
TROL	Trolling
UFD	Unified Fisheries Database
UN-OHRLLS	United Nations Office of the High Representative for the Least Developed Countries Landlocked Developing Countries and Small Island Developing States
WECAFC	Western Central Atlantic Fisheries Commission

1 INTRODUCTION

1.1 The Commonwealth of Dominica

The Commonwealth of Dominica (or Dominica, for short) is a small island developing state (UN-OHRLLS, 2011) of 73,607 persons situated in the Eastern Caribbean Archipelago between the French overseas territories of Guadeloupe and Martinique (Figure 1). The local economy is based largely on agriculture, with bananas being the top export up until the early 2000s. Since 2003, the economy has shifted towards eco-tourism (CIA, 2016), as the country seeks alternative forms of earning foreign income.

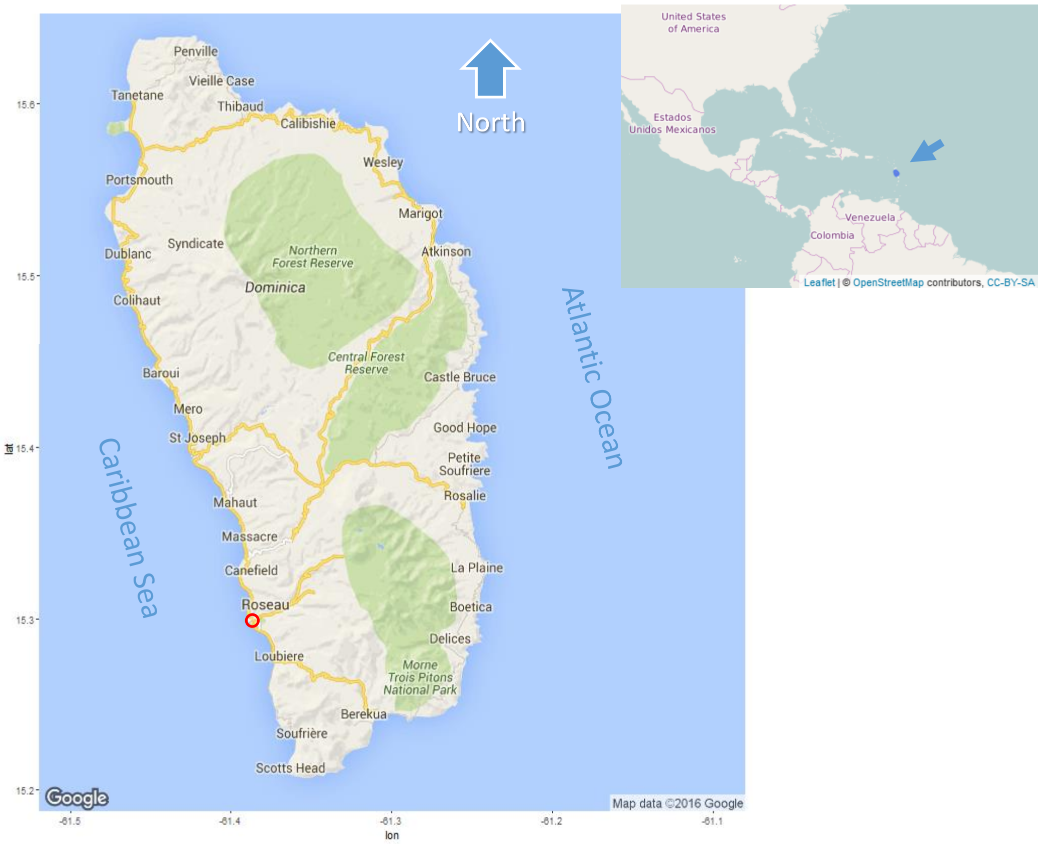

Figure 1. Map of the Commonwealth of Dominica. Insert shows the Americas and the location of Dominica.

Due to the rugged terrain, most communities were established on the coasts, creating an interface between land-based activities (agriculture) and marine-based activities (fisheries). Many farmers are also fishers, diversifying income generation. Agriculture and fishing drive the community economy, provides daily meals and is often the only form of employment for many. Although the national economy is largely service-based (70.9%), agriculture remains important, accounting for 14.8% of the Gross Domestic Product (GDP) (CIA, 2016). Fisheries, however, was assessed to represent only 0.33% of the GDP of Dominica (Eastern Caribbean Central Bank, 2015).

1.2 The Fisheries of Dominica

Fisheries in Dominica is small-scale and artisanal in nature, comprising of individual fishers or sometimes fisher groups, utilizing small, open fishing vessels making short trips that last only a few hours each day (Theophille, 2012). Fish exports are virtually non-existent; nearly all the landings are locally consumed.

The sector is made up primarily of fishers, who are supported by fisheries organisations, boat and gear builders, vendors (who are frequently also fishers) and outboard engine mechanics. Most fishers operate part-time, supplementing their income with agricultural endeavours (42% of fishers) or as construction labourers (29%). They fish an average of 3.9 days weekly and are most active in the months of April to June, where at least 64% to 67% of fishers are reportedly operating (Theophille, 2012).

About a third of fishers operate within five miles (about 8 km) from the coast. These tend to be the older fishers who work the traditional dug-out canoes. Nets are used from canoes targeting small coastal pelagics such as ballyhoo (*Hemiramphus brasiliensis*), jacks (*Carangidae*) or mackerels (*Scombridae*). Fish pots or traps are used for demersals such as snappers (*Etelis* and *Lutjanus*) or groupers (*Epinephelus* and *Mycteroperca*) (Theophille, 2012).

The remainder of the fishers operate up to a reported 80 miles (about 129 km) offshore, using keel or fibre-reinforced plastic (FRP) vessels (also known as pirogues). These fishers are predominantly the younger generation (newest entrants operate within this spectrum). The keel and FRP boats are multi-purpose vessels that are usually under 25 feet (7.62 metres) in length, open with no deck, powered by at least one outboard engine (mainly 30 to 85 horsepower), and carrying a two-man crew. Small coastal pelagics, large migratory (ocean) pelagics and demersals are caught from these boats at varying distances and depths, with the implementation of an assortment of fishing gear and methods (fish pots, hook and line and nets). The most commercially important large pelagics are dolphin fish (*Coryphaena hippurus*), yellowfin tuna (*Thunnus albacares*) and blue marlin (*Makaira nigricans*). Hook and line gear/methods are the most commonly used on these types of vessels, sometimes in conjunction with Fish Aggregating Devices (FADs). In 2011, there were approximately 434 fishing vessels, of which 20% were canoes, 52% keels and 28% FRP (Theophille, 2012).

1.3 Challenges and Opportunities in Fisheries

The main challenges faced by the local fisheries sector include:

1. A growing number of persons seek access to the fisheries sector as a source of income generation or recreation adding pressure to resources that are largely unassessed (Figure **2**). However, most fishers operate part-time, productivity is low and they have little sense of responsibility for cooperatively managing the limited marine resources (Government of the Commonwealth of Dominica, 2014).
2. The Fisheries Division is the sole authority that collects data from the fisheries sector. While the sampled ports are geographically well distributed, the data collected is limited mostly to catch and effort. The field sampling strategy is not well defined and supervision is limited, so direction is lacking as to how, when or why data collection should be conducted. Additionally, fishers are at times unwilling to share information from their fishing activity to data collectors.

3. Electronic data for the fisheries sector exists for as far back as 1994. However, the data is stored in various formats and not within a single, central and easily accessible database. The data is still largely unused as there is limited local capacity for fisheries data analysis.
4. Most of the local catch consists of migratory pelagics, for which FADs are being used more frequently. However, policy and regulations for management of FADs within the local fishery is lacking, prompting a need for more to be done to avoid user conflict while allowing for sustainable harvest of the fishery resource. This is especially important because of increasing pressure on coastal resources by fisheries and other coastal developments (Barnwell, 2014).
5. The dolphinfish fishery, one of the most important fisheries for Dominica, is largely unmanaged and there is little analysis to explain or document the exploitation of the stock locally. An assessment was attempted in 2010 for dolphinfish in the Eastern Caribbean, but Dominica was not prepared to contribute data towards the task at that time (CRFM, 2010).
6. Many economically important species, such as dolphinfish, are highly migratory and transboundary, requiring multi-national assessments and management approaches.
7. Populations of lionfish *(Pterois volitans)*, an alien invasive species, once native to the South Pacific (NOAA, 2016), have already spread throughout the Eastern Caribbean (including Dominica) and are growing largely unchecked. There are regional efforts focussed at gathering data on lionfish distribution, its impact on local marine resources and the resulting fishery that is developing around efforts to “fish down” the lionfish stock (CRFM, 2014).
8. The fisheries sector is particularly vulnerable to the impact of climate change as the island is prone to landslides, coastal erosion, coral bleaching and destruction to coastal infrastructure and equipment, due to increased sea temperature and more devastating storms (Edwards, 2015).
9. Regulations for managing the fisheries sector is lacking and the limited regulations that do exist are out of date. Regulatory development and reform in the fisheries sector is a slow process (Government of the Commonwealth of Dominica, 2014).

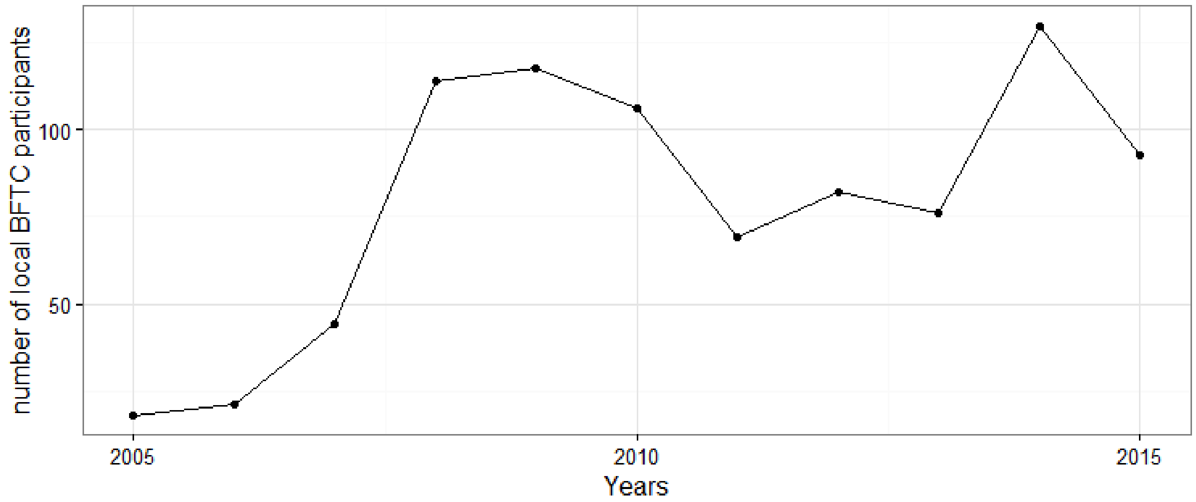

Figure 2. The number of participants per year attending the entry training programme for fishers in Dominica, the Basic Fisherman Training Course (BFTC). Source: The Fisheries Division of Dominica.

1.4 The Study

1.4.1 Goals and Objectives of the Study

The goals and underlying objectives of this study were:

1. To examine the data collection and data management systems of the small-scale fisheries of Dominica with a view to improving those systems, by
    a. Documenting the methodologies for data collection and data analysis, and
    b. Exploring methods for improving the collection, management, analysis and reporting of fisheries data for Dominica, which will entail,
        i. Determining the weaknesses and strengths of the existing systems,
        ii. Preparing recommendations for improving the existing systems, and
        iii. Exploring the use of R and R packages for reproducible research.
2. To explore the available fish catch and effort data (from 1994 to 2014) and perform some primary analysis, including a CPUE analysis of the local dolphinfish fishery as a case study, by
    a. Cleaning and collating the data,
    b. Reconstructing catch and effort for Dominica using an improved method for raising estimates and comparing against previous reports,
    c. Improving capacity in analysing and reporting fisheries data, and
    d. Conducting a CPUE analysis for the dolphinfish fishery of Dominica as a case study.

2 LITERATURE REVIEW

2.1 The Collection, Management and Analysis of Data in Small-Scale Fisheries

2.1.1 Data Collection

Broadly, data collection is essential for making informed and rational decisions on how various aspects of the fishing sector is managed, describing relationships which exist within the sector and predicting how certain actions can affect the future outcome of those interactions (Brander, 1975). More specifically, total catch needs to be estimated, along with the catch rate for major species harvested by a nation (Mahon, 1987). Effort, a factor used in determining the catch-rate, can give an indication of the performance of the fleet (Brander, 1975). To that end, the CARICOM Fisheries Resource Assessment and Management Program (CFRAMP), precursor to the CRFM, has helped the island nations of the Eastern Caribbean (including Dominica) since 1992 to develop their data collection capability (Mohammed, 2003). CRFM member states are now struggling with maintaining data quantity and quality as funding for data collection has diminished over the years (CRFM, 2014).

The methods used for data collection in fisheries are influenced substantially by factors such as the characteristics of the fishery, the local importance (social or economic) and the available staff and resources (FAO, 1997). Mahon (1987) outlined some of the early methodology for fishery data collection implemented in the Eastern Caribbean. The method utilized existing systems, following the path of catch from fisher to end user, and could be easily modified by the local Fisheries Divisions, if necessary.

Catch and effort data collection from small-scale fisheries typically works well with a questionnaire or interview-based sample survey system as opposed to complete enumeration or logbooks, which may be costlier to implement (FAO, 1999). As an example, in the small-scale fisheries of Malta a combination of logbook data and sampling surveys are implemented. The sampling survey accounts for most of the data collected from that fishery as logbooks are more difficult to implement within the small-scale fleet (ICES, 2012).

In the real world, fish and fishing effort is not distributed evenly or randomly. This makes for complexities in data collection as to when and how often data collection is necessary. In more developed situations where facilities exist that receive the catch directly, field data collection may be necessary only occasionally. Hence, the cost of data collection is low. Collection costs increase in situations where fishers are interviewed and in such circumstances, it is important to consider how to utilise that limited interview time, maximizing the amount of data that can be captured while not hindering the important work of the fisher. This means that the questionnaire needs to fit the situation (Brander, 1975).

Catch data is easy to collect, even in small-scale fisheries. Effort data presents the potential of an added challenge and cost due to the complexities of defining effort accurately and consistently. Biological data is costlier to collect as it involves specially trained staff, additional equipment and, at times, additional finances for the purchase of fish (Brander, 1975).
Sampling units are the ports where data collection takes place. When choosing sampling units, it is necessary to first implement a sampling frame or frame survey, which lists all ports within the country along with characteristics such as geographical location, numbers and types of boats and fishery. These ports are grouped or stratified based on characteristics they have in common. Within each group, a fixed proportion of ports can be chosen for data collection. This can be done by randomly choosing a starting port, then using a fixed interval to choose the other ports

along the coastline until the quota of sampling units for each stratum is met. All of this is an effort to maintain a sustainable sampling strategy while keeping the sampling as statistically unbiased as possible (Brander, 1975).

Data quality depends on sampling accuracy and precision. Accuracy determines how closely the sampled data reflects the population data. Accuracy improves as the sample size of a population increases. Having a representative sample can achieve good accuracy, even if that sample is small. This is an important point because beyond a certain sample size the accuracy gained is no longer significant enough to warrant the additional human and financial resources invested towards that activity. A sample size is representative if it accounts for at least 90% accuracy when the data is processed. Precision, on the other hand, refers to variability of the samples. Like accuracy, precision also increases with an increase in sample size. Stratification is another method which reduces variability, improving precision. More strata mean higher costs, however, so it is important to weigh the cost-benefit relationship here also (Stamatopoulos, 2002).

Of course, the quality of the final data is dependent on the effectiveness of the data collectors and the level of supervision they are afforded during the collection phase. Maintaining a data collection regime is costly. It is imperative that the existing human resource (data collectors and supervisors) work reasonable hours, are well trained, resourced and generally able to function efficiently and effectively to maximise benefits of data collection (Stamatopoulos, 2002).

2.1.2 Data Management

Management systems for data are a result of the growing quantities of data gathered (Ocean Studies Board, 2000). FAO (1999) prescribes that databases should be secure, allow for validation of the information entered, easy access and analyses of that information, and keep the data in a standardised format that is representative of what was collected on the field. At a national level, most countries already have databases, and as Barnwell (2014) points out for the CRFM region, each country has their own databases for the storage and management of fisheries data. According to Masters (2012), reporting for the CRFM, the databases used by the CRFM member states include CARIFIS (44% of member states), Access (38%), LRS (13%), .NET/SQL Server (6%), Oracle (6%) and TIP (6%).

Regional databases are recommended for the management of data for shared (transboundary) fishery resources. One of the measures put forward during a CRFM working group meeting for managing the Nassau grouper (*Epinephelus striatus*), for example, was the development of a regional database (CRFM, 2015). Meetings discussing the FAD fishery also mentioned a great deal about information sharing (CRFM, 2013). FAO (1999) outlined requirements for regional databases, focusing primarily on the standardisation of national data, media and reports.

2.1.3 Resource Assessment

Catch and effort is considered very basic data within fisheries (Mohammed, 2003; Magnusson & Hilborn, 2007), however, it can allow for an indication of the biomass landed by the defined unit of effort or Catch Per Unit Effort (CPUE). Maunder et al (2006) found that CPUE can be used as an index of abundance in small-scale situations if the catch-effort data is standardized for changes over time. However, CPUE may be a poor indicator of stock size, as in the case of the northern cod where fishing effort increased as the abundance of the stock declined (Rose &

Kulka, 1999). Limited data such as catch and effort is useful for advice, in combination with analytical stock assessment and a precautionary approach.

Standardising catch and effort data, or accounting for the annual variance in the data that cannot be linked to abundance, can be addressed by many methods. Maunder *et al.* (2004) offered a summary for a few of those methods but focused on variations to the Generalized Linear Model (GLM), which was the most common means of standardising catch and effort data. A number of considerations need to be made in the process of deciding which factors (time, gear selectivity, port and so forth) would provide the best fitting model for the available data.

2.1.4 Catch Reconstruction

Mohammed (2003) reconstructed catches and effort for the Caribbean nations of Barbados, Grenada and the Grenadines, St. Lucia and St. Vincent and the Grenadines for the period 1942 to 2001. The general methodology involved the use of FAO FISHSTAT data, disaggregated by species, for those nations along with existing local data from the respective Fisheries Divisions of those nations. Data for years beyond the range of the available dataset were determined via interpolation, which is a method of estimating an unknown data point between two known data points (or anchor points), using existing data. In this case, data from previous studies were used as anchor points.

Ramdeen *et al.* (2014) reconstructed catches for Dominica for the period 1950 to 2010 as a counter to the under-reporting of catches to the FAO. Ramdeen et al observed that the reconstructed catches were 1.8 times the official figures reported to FAO. The local fresh fish consumption rate was determined by utilizing regional nutrition data and population figures for the period. The consumption rate gave an indication of extraction rates in marine fisheries. The catch composition (proportion of species and gear in catches) was estimated across the years via earlier regional studies along with anchor points for certain years. Linear interpolation was used to estimate the unknown data between those years.

2.2 The Dolphinfish Fishery

2.2.1 Biology and Ecology

The common dolphinfish *(Coryphaena hippurus)* is a highly migratory marine epipelagic (FAO, 2016). It is a short-lived species, maturing within the first year (Oxenford, 1999). While the species is found in open waters and along the coast, individuals tend to aggregate beneath floating debris on occasion. Dolphinfish grow to a maximum size of 210 cm total length (TL) and weigh up to 40 kg, but is commonly observed at 100 cm (FishBase, 2015). The body is “slender” and “elongate”, with a “metallic blue-green” colour on its back and a head that is “slightly convex” (Figure **3**). In males, the head can be more “vertical” due to the presence of a “bony crest”. Fins are typically dark or black (FAO, 2016). The dolphinfish diet is varied and not very selective (Oxenford, 1999), although the diet is primarily other epipelagics (FAO, 2016). Within the Eastern Caribbean, flyingfish *(Exocoetidae)* and flying gurnards *(Dactylopteridae)* form a major part of the diet (Oxenford, 1985).

Figure 3. A gutted female dolphinfish at the Roseau Fisheries Complex. Photo credit: Brandon Registe.

Oxenford (1999) compiled a list from various studies denoting the distribution and seasonality of dolphinfish for regions in the Western Central Atlantic. The exercise showed that the species is caught year-round within that region (from North Carolina to northeast Brazil). In the Eastern Caribbean, dolphinfish is seasonal from December to June, in the Northern Caribbean from January to June and the in Southern Caribbean also from December but ending in July. The season began much later (March to May) in the Southern U.S.A. (as far north as the Carolinas) and Bermuda ending in between September and December.

2.2.2 Importance and Management

Worldwide, dolphinfish are caught with the use of nets, trolling lines or longlines (sometimes FADs are also used) amounting to a mean of 72,095 tonnes reported annually (FAO, 2016). Existing data shows that dolphinfish catch in the Eastern Caribbean is about 1,200 tonnes annually (CRFM, 2010). Although dolphinfish are of importance to both commercial and recreational fisheries, management of the species is lacking in most areas (Oxenford, 1999). Dolphinfish usually falls under the general management of large pelagics fisheries in the wider Caribbean, but not specifically to the species. However, due to the predator-prey relationship between dolphinfish and flyingfish, the species is receiving greater attention. Dolphinfish and flyingfish are usually targeted together by fishing fleets of the Eastern Caribbean. A bioeconomic analysis of this relationship showed that flyingfish, although having a lower value than predators such as dolphinfish, was more valuable when harvested directly as opposed to indirectly (Headley, 2010).

2.2.3 Status of the Stock

An assessment of the dolphinfish fishery at the 2010 Caribbean Regional Fisheries Mechanism (CRFM) Annual Scientific Meeting (ASM) showed that over the last two decades, and at current harvest levels, the stock was not overfished within the Eastern Caribbean. Relative abundance since 1994 was between 32.8 kg and 74.7 kg per trip. The indices of abundance were based on changes in the annual mean catch rate (catch per trip), standardizing the data through the application of a Generalized Linear Model (GLM) using vessel type, season and island as explanatory variables. The results were inconclusive, however, as the available data was limited only to a few countries of the Eastern Caribbean (Barbados, St. Lucia and St. Vincent). These represented only a fraction of the nations thought to be harvesting that particular dolphinfish stock. Data from other nations harvesting dolphinfish in the region, including Dominica, needs to be part of future assessments. At the time of the assessment, some CRFM member states (APPENDIX 6: LIST OF MEMBER STATES OF THE CRFM) did not have dolphinfish data and where there was data available (as in the case with Dominica), the data was not adequately prepared and so were excluded (CRFM, 2010).

3 MATERIALS AND METHODS

3.1 Software

3.1.1 Microsoft Office

Microsoft (MS) Office is a suite of applications produced by the Microsoft Corporation originally for the purpose of desktop publishing, that is, the production of documents on desktop computers. The Office applications have since expanded to touch screen-enabled devices, particularly mobile. The most prominent MS Office applications include Excel for spreadsheets, Word for rich text documents and PowerPoint for presentations. Some other MS Office applications include Access, for databases, Publisher, for designing advanced publications, Outlook, for email and calendar management and OneNote for taking and managing notes (Microsoft, 2016).

Apart from Word, used to produce this report, the most used MS Office applications in this study were Excel and Access. The data was stored in file containers that could be opened and altered by MS Access or Excel. These applications supported data management, cleaning and manipulation for this project.

3.1.2 The R Statistical and Graphical Software

R is a free, open-source, software application available for Windows, Macintosh (Apple) and Linux machines. It allows for data manipulation, statistical computation and graphics generation using script commands or codes. Add-on packages extend the base functionality of R, allowing for specific use cases. One package, called “rfishbase”, can access records from the repositories at FishBase.org using the R interface (scripts, commands), where the data can be analysed and results generated (Hornik, 2015; R Core Team, 2015; Boettiger *et al.* 2015).

R was used in this project for data manipulation, the generation of tables, graphics (plots and maps) and text. The major add-on packages used were “rmarkdown” and “knitr” for reproducible reports, “ggplot2” for plots, “dplyr” for manipulating data, “lubridate”, for working with dates and “ggmap” for creating maps.

3.2 Data

3.2.1 Data Collection

3.2.1.1 Catch and Effort

The data used in this study consists primarily of fish catch and effort data collected from field sampling exercises at various ports around the island of Dominica for the period 1994 to 2014. The field sampling involved documenting which boats fished and what, if anything, they caught from that trip. Fishers (usually the captain) are interviewed and the fish caught is identified and weighed. All the information is written on data collection forms for fish catch and effort (see appendix 1, p. 44).

A quota-based sampling system is employed at the sampling ports. Data collectors work at least three days weekly. Work on weekends is optional, based on the preference of the collector or if the site in question has a level of activity on those days to prompt collection duties (Guiste *et al.* 1996). Data collection activity is variable by activity at the port, personal preferences of the data collector and the willingness of the fisher to disclose details of his fishing activity and catch. At least one third of boats landed on sampling days are interviewed. There were attempts to conduct full enumeration (collect data from all boats) at developed ports such as Marigot and Portsmouth, however fishers were not always compliant and refused or delayed interviews, effectively hindering full enumeration. Data collectors are instructed to capture information from landings that they have witnessed directly. In some cases, however, secondary information (from another individual who witnessed the landings) is used if the source is thought to be reliable.

In most cases, collectors were assigned work at only one port; however, in the case of four collectors, two ports were assigned to each. Data collection currently takes place by nine persons at 13 of the 29 designated fish landing ports around the island (Figure **18** in APPENDIX 5: MAPS).

Most ports are equipped with weighing scales for the purpose of accurately measuring the weight of the catch. The data collectors may be tasked with guessing the amount of fish caught, however, if there is no weighing scale available or the available scale is not calibrated. Guessing may also occur if the quantity landed cannot be readily weighed by the available instruments, such as in the case of a boat load of small coastal pelagics. Experience with the local fishery can determine the accuracy of the final documented weight.

After data is collected on the field, it is returned to the office of the Fisheries Division in the capital, Roseau. The data at this point is compiled into a book. When the book is returned to the office, the data collector and the data officers (the Data Entry Clerk and or the Fisheries Officer responsible for data) discuss the content and any issues arising from the previous month. This exercise helps to correct or clarify any poor or ambiguous data observed and document any concerns hindering field data collection. The data book is returned to the office by the 15th day of each month; however, this is not always the case.

3.2.1.2 Supporting Data

Data collected from the Fisheries Industry Census (FIC) in 2008 and 2011 were also utilized in this study. The FIC comprised of an interview of fishers and other stakeholders within the fisheries sector, primarily capturing details on the socio-economics and interactions between stakeholders. Communities or villages were stratified into fifteen districts, with one enumerator or data collectors assigned to each district. Enumerators were the same persons used for fish catch and effort activities (some contracted temporarily after retirement), as they already knew the fishers and could verify the information they received from the responses. The data collected from this study helped fill gaps in knowledge for the sector, such as the number of fishing boats and expected annual fishing days for each port and the selling price of fish.

3.2.2 Databases

Data is stored in various databases and archives at the Dominica Fisheries Division. The databases were the Trip Interview Programme (TIP) and the Unified Fisheries Database (UFD) MS Access database. The TIP data, archived as DBF files, covered years 1994 to 1999 and 2001 to 2006. Data for 2000, 2007 and part of 2008 were available in MS Excel spreadsheets. The UFD stored data for the remainder of 2008 and the years 2009 to 2014. Secondary data sources were also used in this assessment. The databases for the 2008 and 2011 Fisheries Industry Census (FIC) were used as supplemental information. FIC data comprised of socio-economics and port statistics (fleet, activity, fisher population) for the years 2008 and 2011, based on interviews with fisherfolk in local fishing communities.

3.2.3 Data Preparation

In order to analyse the available data, it was necessary to collate the datasets into main tables that contained the necessary variables and spanned the years 1994 to 2014. The original datasets were backed-up and then the tables were prepared in this manner:

1. Deciding on dataset variables: The variables were selected based on what data was available within each data source and the analyses that would be performed.
2. Data extraction and collation: Data was extracted from their original file formats and imported to main tables in MS Access and or MS Excel.
3. Standardisation: The data was standardised so that it could be consistent across the years. In particular, codes no longer in use were translated to the codes used today.
4. Cleaning: Data entry errors were corrected, such as mistakes in spelling and improper use of codes.

Ultimately, the main tables consisted primarily of cleaned and standardised catch and effort data collected at ports around Dominica for the period 1994 to 2014. These main tables were:

- sampled catch (1994 to 2014)
- estimated annual catch (1994 to 2014)
- estimated annual effort (1994 to 2014)

3.2.4 Effort Data

Effort data consists of measurements of fishing activity. In this study, effort is defined as trips. Each active boat makes one fishing trip per fishing day, for the most part; therefore, a trip is one day's activity for a given boat. Trips were used as the unit of effort because this was the only consistent unit of measure for effort within the available data for the period. Since field sampling does not cover 100% of boat activity for 100% of the days fished annually, an estimate of trips was prepared for each year. The effort dataset consists of these variables:

- *port*: the port for which the effort was calculated
- *year*: the year for which the effort was calculated
- *boats*: the number of boats which were estimated to operate at that port for that year
- *days*: the estimated number of days for that year for which fishing was done at that port
- *trips*: the estimated trips (*boats * days*) calculated for the port for that year

3.2.5 Catch Data

Catch refers to fish landed at a port. It does not include fish that was caught but then discarded before landing. There are two datasets dealing with catch, one is detailed, showing sampled daily catch and the other summarizes estimated annual catch by port. The sampled daily catch includes these variables:

- *date*: the day on which the sampling activity measured the catch
- *species*: the name or code assigned to the species landed
- *port*: the name or code where the sampling was conducted
- *boat*: the identification of the boat which was sampled
- *boat type*: the category of boat which was sampled
- *gear*: the name or code of the gear which was used to catch the species
- *kg*: the weight measurement (in kilograms) of the species landed at that sampled port on that sampled day

Estimated annual catch includes these variables:

- *year*: the year for which the estimated catch was calculated
- *port*: the port for which the estimated catch was calculated
- *estkg*: the estimated catch value (in kilograms) calculated for that year and port

3.3 Methods

3.3.1 Grouping to Main Ports

Effort and catch data for ports were grouped in some cases. If the sampling record showed data pertaining to a location that was near a main port, these records were aggregated with the data for the main port. Therefore, locations such as Batalie (aggregated with Coulibistrie) would not show up as an individual port in this study (Table **1** and Figure **18** at APPENDIX 5: MAPS).

Table 1. A list of landing locations and the main ports to which they were grouped.

	Location	Location Code	Main Port	Main Port Code	Reason
1	Atkinson	AKN	Marigot	MGT	Closed
2	Batalie	BAT	Coulibistrie	CBT	Proximity
3	Canefield	CNF	Massacre	MSC	Proximity
4	Castle Bruce	CBE	Saint Sauveur	SSR	Low activity
5	Clifton	CLF	Capuchin	CPN	Proximity
6	Glanvillia	--	Portsmouth	PMH	Proximity
7	Roseau	RFC	Pottersville	PTV	Proximity
8	Salybia	SLB	Marigot	MGT	Closed
9	Tan Tan	TAN	Toucarie	TCE	Proximity
10	Tarou	TRU	Layou	LYU	Low activity
11	Tranto	TRN	Saint Sauveur	SSR	Low activity
12	Wesley	WSY	Marigot	MGT	Low activity

Main ports are those that have shown steady fishing activity over the years and in some cases, infrastructural development. Although some main ports are not developed, they retain significance in the local fisheries sector. Closed ports moved operations to a main port over the years. For example, fishers from Atkinson and Salybia have moved operations to Marigot, which was improved, providing safe berthing facilities to fishers in that catchment area (Government of the Commonwealth of Dominica, 2014). Low-activity ports near main ports were also grouped to the nearest main port. Proximally close ports were those where operations occurred near to a main port. Glanvillia was grouped to Portsmouth, although fishing operations continue from that location.

3.3.2 Estimation of Effort

Effort by trips is the product of the sum of the boats fishing for the year (boat activity) and the sum of the fishing days for that year. Boat activity and fishing days were determined before trips was calculated. After trips was calculated, effort for Portsmouth was raised by 50% to account for activity from Glanvillia, which represented at least 50% of the activity in the Portsmouth area.

3.3.2.1 Boat Activity

Field sampling records identify, for the most part, which boats were sampled on a given day, but not which boats fished. The non-sampled boats were not identified (but instead only counted), thus the actual annual boat activity was estimated. This estimate of boat activity was assumed to be the sum of boats sampled for each port for each year, as in most cases, the field sampling covered almost all operating boats. Records for the year 2000 did not have any boat identification information available therefore, the sampled boats for that entire year was estimated via interpolation using the information available for the other years. Boat activity is summarised for each year by port.

The interpolation method employed in this study can be described as:

$$y = y1 + (y2 - y1) / (n + 1)$$

where $y1$ is the top anchor point in an ordered list of data points, and $y2$ is the bottom anchor point, between which an unknown point (y) will be determined. The number of unknown points between anchor points is represented as n. The data points were ordered by year for this study, beginning with 1994 at the top. Unknown anchor points for 1994 and 2014 for a given port were estimated using an average of the available information for other years for that port.

3.3.2.2 Fishing Days

Not every day is a fishing day. Fishers from the east coast, for example, reported fishing for a maximum of six days weekly. Fishing days would also fluctuate monthly by individual fishers. May is the most active month, where almost 67% of fishers' report being active. December is the least active month; 51% of fishers are active at that time of year. Fishing days may be affected by the season (fish migratory patterns), weather or other factors (Theophille, 2012).
Fishing days were determined by comparing the sum of the sampled days against the expected fishing days for each port by year. The sum of sampled days is simply the number of days for which field sampling took place at a port for a year. This was calculated from the sampling records. The expected fishing days were determined from the results of the FIC for 2008 and 2011. Fishers were asked how many days they fished weekly. These responses were raised (by the number of weeks in one calendar year) to reflect an expected number of fishing days for each port annually in this manner:

$$\textit{expected annual fishing days} = \textit{mean number of days fished weekly} * 52$$

No other information was available to determine active days, so the 2008 and 2011 figures were used for the entire period covered in this study. When compared, where the sampling days were higher than the expected fishing days, the values for sampled days were used as the fishing days instead. In the cases where there was no information on sampling days, the expected fishing days' values derived from the FIC were used. Local knowledge was used to verify the results from this exercise.

3.3.3 Estimation of Catch

The sampled catch was raised to determine the estimated total catch for each year from 1994 to 2014. The estimate reflects catch from:

- total boat activity (sampled versus total landed boats) by sampled port for each year,
- total annual activity (sampled days versus expected fishing days) by sampled port for each year, and
- total port activity (sampled ports versus non-sampled ports) for each year.

Total Boat Activity

A table was prepared from the sampling record to calculate total boat activity. The variables include:

- *year*: the calendar year based on the date
- *port*: the port identification (name or code)
- *date*: the date for the sampling record
- *kg*: the sampled catch (in kilograms) for that port on that day
- *boat activity raising factor*: the factor used to calculate the boat activity kg
- *boat activity kg*: the value of the catch in kg, raised to reflect only total boat activity. This value was calculated as: *kg/ boat activity raising factor.*

The *boat activity raising factor* is a fraction of the *boats sampled* against the *total landed boats*. The information on *total landed boats* was available from the sampling record and the FIC results. Where no boat activity information was available it was estimated. For example, values for the year 2000 had to be estimated via interpolation as no boat activity details were available in the dataset for that year.

Total Annual Activity

The previous table (total boat activity) was summarised by year and port in order to further raise the catch to reflect total annual activity. The resulting table included the following variables:

- *year*: the calendar year
- *port*: the port identification (name or code)
- *boat activity kg*: the value of the catch in kg, raised to reflect only total boat activity
- *annual activity raising factor*: the factor used to calculate the annual activity kg
- *annual activity kg*: the value of the catch in kg, raised to reflect total boat activity and total annual activity. This is essentially the total estimated catch for that port for that year. This value was calculated as: *boat activity kg / annual activity raising factor*.

The *annual activity raising factor* is a fraction of the *total sampled days* (sum of days for each year when sampling was done for each port) against the *total expected fishing days*. The *total expected fishing days* for ports were obtained from the FIC 2008 and FIC 2011 values, which also provided a base for finding the anchor points at 1994 and 2014. Again, interpolation was used to estimate the missing values.

Total Port Activity

Additional rows were added to the total annual activity table to account for total port activity, that is, sampled ports plus non-sampled ports for the entire country. These new rows of data included estimated values for non-sampled ports for each year. Values for *boat activity kg* and *sampled days* were determined for each non-sampled port for the anchor years of 1994 and 2014. These values were borrowed, based on local knowledge, from the information of a sampled port that shared similar characteristics as the non-sampled port. The FIC results provided values for the *total expected fishing days*. The *annual activity raising factor* was then calculated (*total sampled days / total expected fishing days*). Finally, the *annual activity kg* was calculated (*boat activity kg / annual activity raising factor*) for each non-sampled port for each year.

The non-sampled ports include Jimmit, Mero, Pointe Michel, Soufriere, Toucarie and Woodford Hill. These ports were assumed comparable to the sampled port of St. Joseph for this study. Glanvillia was accounted for by increasing catch for Portsmouth by 50%.

3.3.4 Determining Annual Estimates for Species

The relative proportion of values for species caught within the sampled catch and effort data for a particular year was applied to the total annual estimates to derive the estimated annual value for that species. For example, dolphinfish represented 11.2% of the total sampled catches in 1994. This proportion, when applied to the total estimated catch for that same year, amounted to an estimated 154 tonnes of dolphinfish caught.

3.3.5 Determining CPUE for Dolphinfish

Dolphinfish is one of the most important fishery species for Dominica, making up more than a third of the catch in 2014 (Figure **10** and Table **10** at APPENDIX 3: TABLES FOR ESTIMATED CATCH). Despite the importance, there was no prior analysis for this species locally. Therefore, dolphinfish was chosen as a species of interest for CPUE analysis.

Data

A table named "trips.dol" was prepared in order to determine the CPUE for dolphinfish. This table includes 16,624 rows of sampled catch and effort data. The data shows catch (in kilograms) and trips for dolphinfish, summarised by date, port, boat type and gear between the years 2001 and 2014. Trips where dolphinfish was not caught were excluded. The variables in this table include:

- *year*: the year when the dolphinfish was caught
- *month*: the month when the dolphinfish was caught
- *date*: the date when the dolphinfish was caught
- *port*: the port where the dolphinfish was landed

- *boat type*: the boat type which caught the dolphinfish
- *gear*: the gear used for catching the dolphinfish
- *kg*: the sum of weight, in kilograms, for dolphinfish caught on that date for the port, boat type and gear
- *trips*: the number of trips where dolphinfish was caught, on that date for the port, boat type and gear

A new variable, "season", was added describing whether the date was in the first or second half of the calendar year, reflecting the high and low season characteristic of the dolphinfish fishery for Dominica. Another variable, "rate", was added, which is calculated from *kg/trips*.

Nominal CPUE Analysis

The nominal or raw CPUE represents a simple calculation of the sum of catches divided by the sum of trips for each year. This results in a useful indicator of performance as it shows how much fish is caught for each unit of effort over a period of time (Brander, 1975).

CPUE Regression Analysis (Models)

The purpose of CPUE regression models is to isolate the year-specific variation in catch-rates, after taking into account the effect of other factors. A linear model (LM) is used to predict the catch-rates as a function of explanatory variables, where the core explanatory variable is the year. Modelling followed this regression approach. The introduction of additional variables was done, one variable at a time, considering the improvement using the Akaike Information Criterion (AIC) value. The AIC value is based on the sum of squares and the number of parameters estimated in a model. Each parameter adds complexity to the model, which can make it more difficult to explain the variation. Therefore, the lower the AIC value, the better the model fits or explains the data without being too complex. A starting index value of 1.00 in 2001 was applied to all models. The R commands used for the models are available in APPENDIX 7: R COMMANDS USED FOR MODELLING DOLPHINFISH CPUE.

4 RESULTS

4.1 Effort

4.1.1 Total Effort and Effort by Port

There was an average of about 123 thousand trips each year for the period 1994 to 2014 (Figure **4** and Table **6** at APPENDIX 2: TABLES FOR ESTIMATED EFFORT). The year with the highest accumulative effort was 2009 with about 162 thousand trips and the year with the lowest effort was 1999, with about 93 thousand trips. The most active ports were Portsmouth, Marigot and Scott's Head (Figure 5, see a map of all ports at APPENDIX 5: MAPS, and tabulated data on effort by port is available in Table **7** at APPENDIX 2: TABLES FOR ESTIMATED EFFORT). A mean of 17 boats fished from a given port each year. There is a mean of 227 fishing days for each port per year. Effort increased for Marigot from 2006. This coincides with the construction of the Marigot Fishing Port Facility (completed and opened by 2005) after which nearby ports such as Wesley, Atkinson and Salybia were closed, consolidating most of the fishing activity in the North East to Marigot.

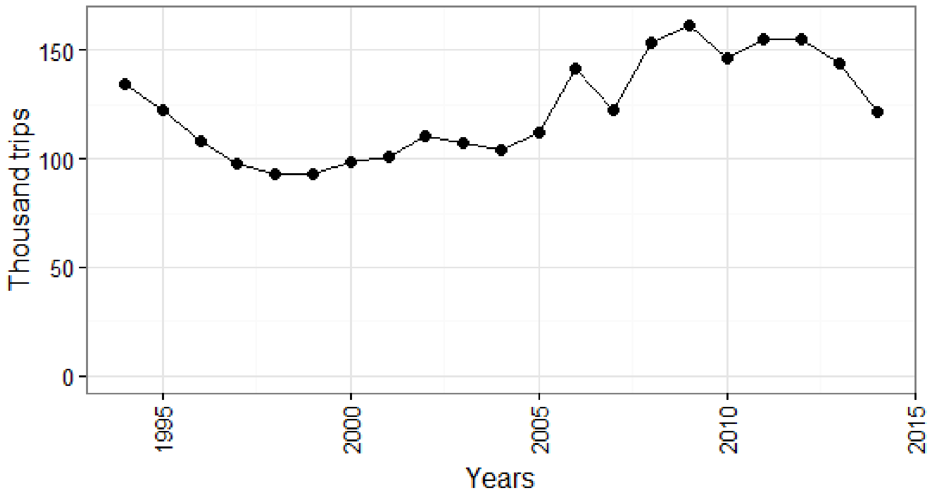

Figure 4. Estimated effort for Dominica from 1994 to 2014.

Due to the number of ports accounted for in this exercise, only the main ports are shown and the remaining ports are grouped into a category called "other"(Table **1**). Those ports within the "other" group are Anse du Me, Calibishie, Capuchin, Jimmit, Massacre, Mero, Point Michel, Salisbury, Soufriere, Stowe, Toucarie, Vielle Case and Woodford Hill (see map of all ports at APPENDIX 5: MAPS).

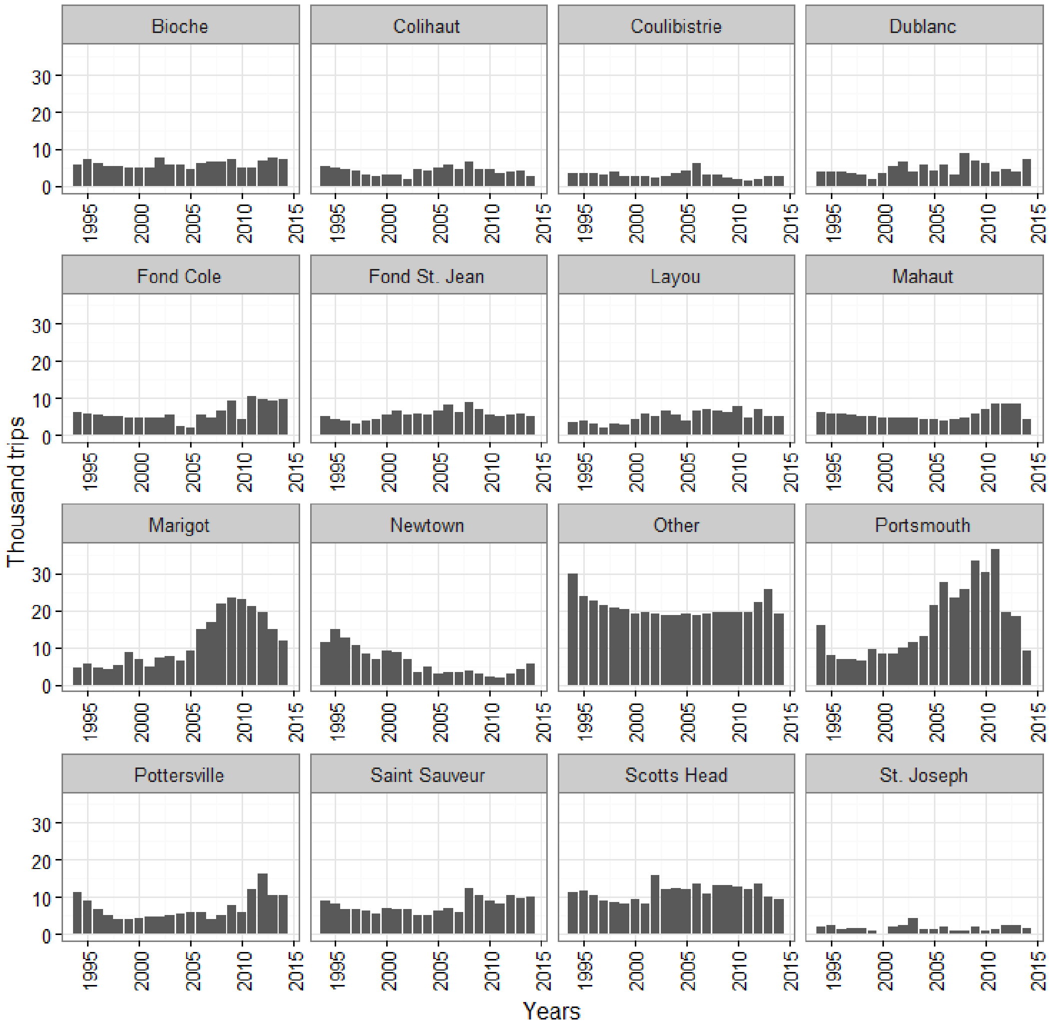

Figure 5. Estimated annual effort by port from 1994 to 2014.

Ports in Dominica are mostly located on the west coast (Caribbean Sea), due to calmer waters that allow for safe mooring and landing (Figure **6**). Few ports are located on the Atlantic side, which is less favourable to safe mooring and landing due to the turbulent sea and difficult terrain. Fishers from the west coast are known to fish in the Atlantic and return the catch to their home port.

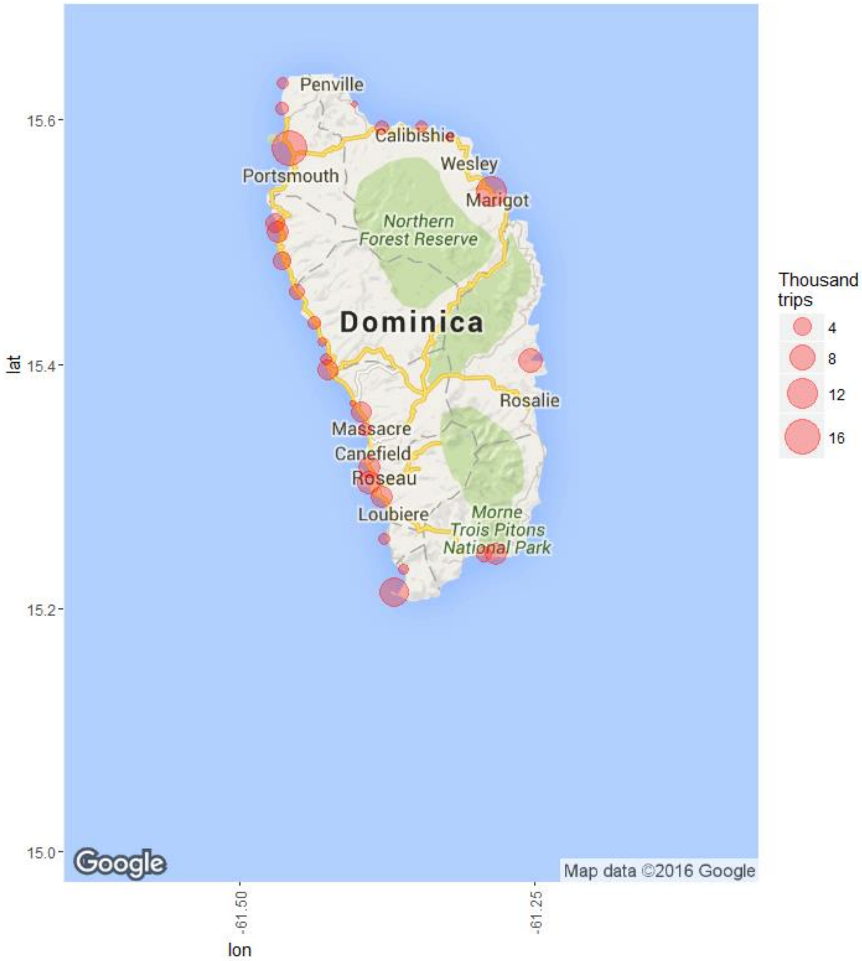

Figure 6. Map showing mean annual effort by port for the period 1994 to 2014.

4.1.2 Effort by Species

Cumulatively, over the entire time series, most trips are attributed to the catch of a mix of demersals (referred to in Figure **7** below as "Other Demersals" and amounting to about 2.9 million trips), snappers (1.1 million trips) and jacks (1 million trips) (Table **8** at APPENDIX 2: TABLES FOR ESTIMATED EFFORT). If the mean annual trips are considered, however, the species with the highest effort are skipjack tuna (about 35 thousand trips), blackfin tuna (34 thousand trips) and yellowfin tuna (30 thousand trips).

The multi-species nature of the local fishery means that on a single trip different species may be caught. Between 77 and 157 different species (or species groups) occur in the catch record annually. A mean of 20 different species were caught on any given day between 1994 and 2014. Each boat caught an average of two different species per trip. There are also trips where no fish was caught. There appears to be less trips where no fish is being caught in recent years.

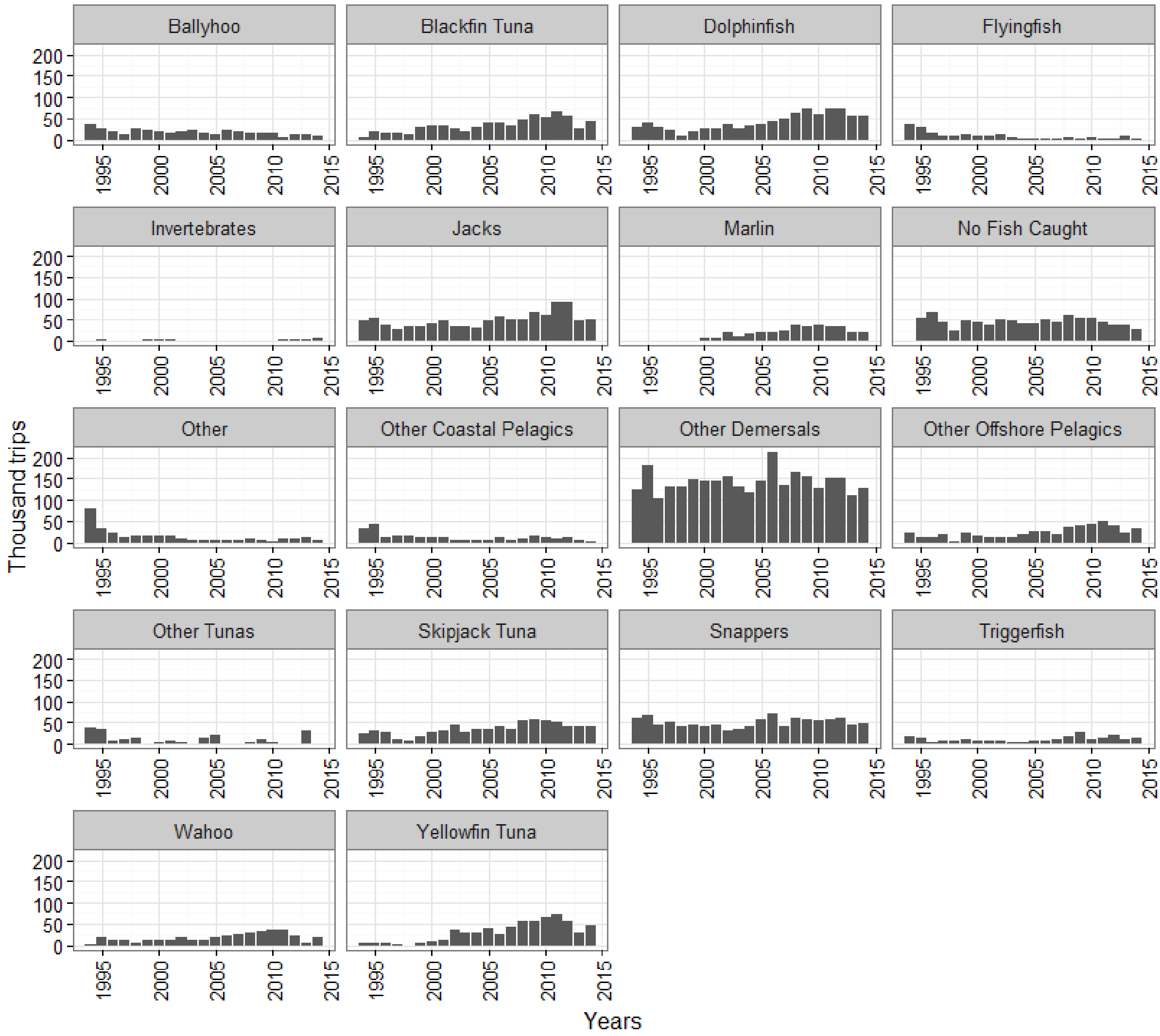

Figure 7. Estimated effort by selected species and groups from 1994 to 2014.

4.2 Catch

4.2.1 Total Catch and Catch by Port

There was an average of 1,134 tonnes landed each year for the period 1994 to 2014 (Table **9** at APPENDIX 3: TABLES FOR ESTIMATED CATCH). The year with the highest catch was 1994 with 1384 tonnes and the year with the lowest catch was 2014, when 803 tonnes were caught. There appears to be a decline in catch in the long term. Each port had a mean catch of 41 tonnes per year. The three highest producing ports were Portsmouth, Marigot and Pottersville (Figure **8**).

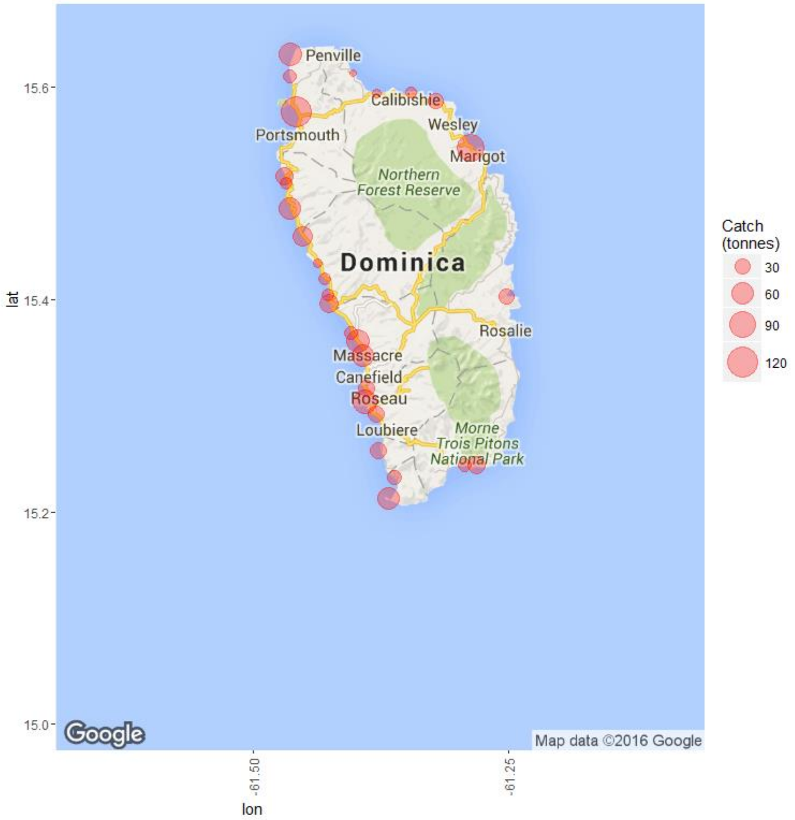

Figure 8. Map showing mean catch by port for the period 1994 to 2014.

The estimated catch prepared for this study was compared with catch data reported to FAO (FAO, 2016) and reconstructed catch data by Ramdeen *et al*. 2014 for the period (Figure **9**). There was no FAO data available for 2014 and Ramdeen *et al.* 2014 did not prepare reconstruction data beyond the year 2010. According to FAO, Dominica reported a mean of 872 tonnes annually for the period 1994 to 2013. This was a mean difference of 262.4 tonnes annually when compared with this study. The estimated values from this study were on average 30% higher than what FAO had on record. By contrast, the values from Ramdeen *et al*. ˆ2014were 258.1 tonnes (or 23%) higher than those prepared in this study (see Table **9** at APPENDIX 3: TABLES FOR ESTIMATED CATCH). Note that the method of estimation used by Dominica over those years was inconsistent and neglected to consider all non-sampled ports; therefore, there is not much confidence in the values reported to FAO.

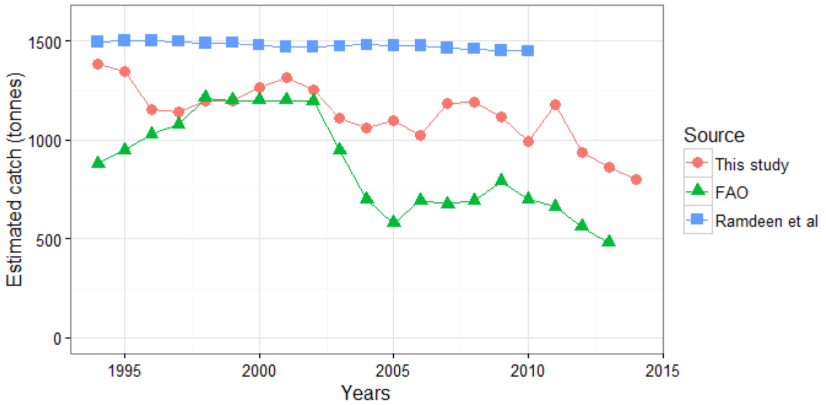

Figure 9. Comparison of total catch estimated for Dominica from this study, FAO (2016) and Ramdeen *et al.* (2014).

4.2.2 Catch by Species

Dolphinfish *(Coryphaenidae)*, ballyhoo *(Hemiramphidae)*, yellowfin tuna (*Thunnus albacares*), marlins (*Istiophoridae*), flyingfish (*Exocoetidae*) and jacks (*Carangidae*) are among the most commonly occurring species and species groupings in the catch (Figure **10** and Table **12** at APPENDIX 3: TABLES FOR ESTIMATED CATCH). Catch of small pelagics, such as ballyhoo and flyingfish, appear to be on the decline as catch in large pelagics, such as dolphinfish and yellowfin tuna, is increasing. In general, demersal catches show a decline since before 2000, however, catches for snappers have remained fairly stable for much of the time series.

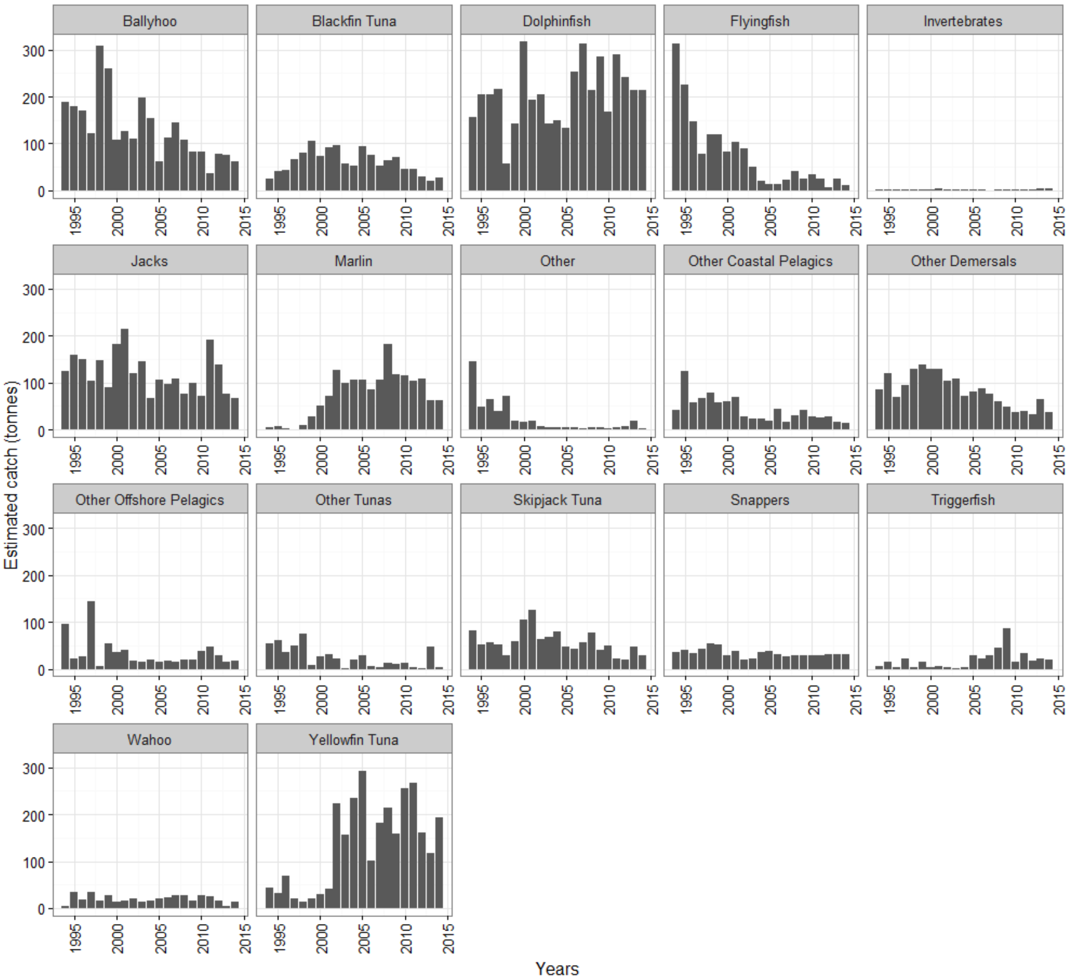

Figure 10. Estimated catch by selected species and groups from 1994 to 2014.

4.2.3 Catch by Fishery

Pelagics accounted for 78.5% (1998) to 93% (2010) of total catch annually (Figure **11**). Demersals accounted for 8% (2010) to 17.7% (1999). Guiste, Gobert, & Domalain (1996) found that between 1990 and 1992 pelagics made up 83% of annual landings and 65% of total fishing effort.

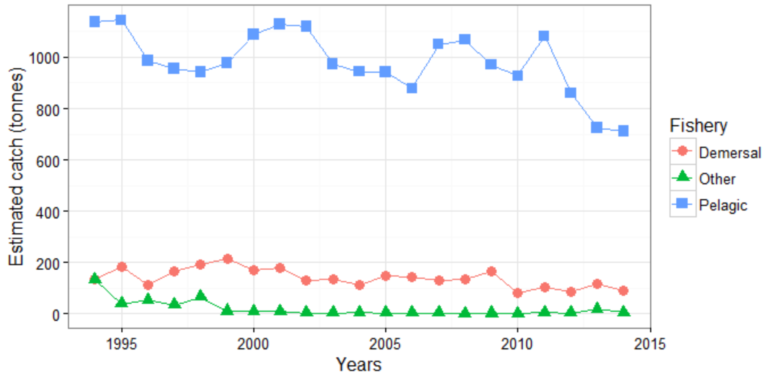

Figure 11. Estimated catch by fishery from 1994 to 2014.

4.2.4 Seasonality of Catch

The mean monthly landings shows some clear seasons for certain species (Figure **12**). Dolphinfish, for example, is caught mostly in the first half of the year (January to June). Skipjack tuna, ballyhoo, triggerfish and wahoo seem to also share this characteristic. By contrast, yellowfin and blackfin tuna appear to be more prevalent in the latter half of the year (July to December). Catches for marlin and flyingfish show two peaks within one calendar year. Demersals are caught in greater numbers during the second half of the year, beginning in June or July. Anecdotally, at some ports demersal catches increased with the end of the dolphinfish season.

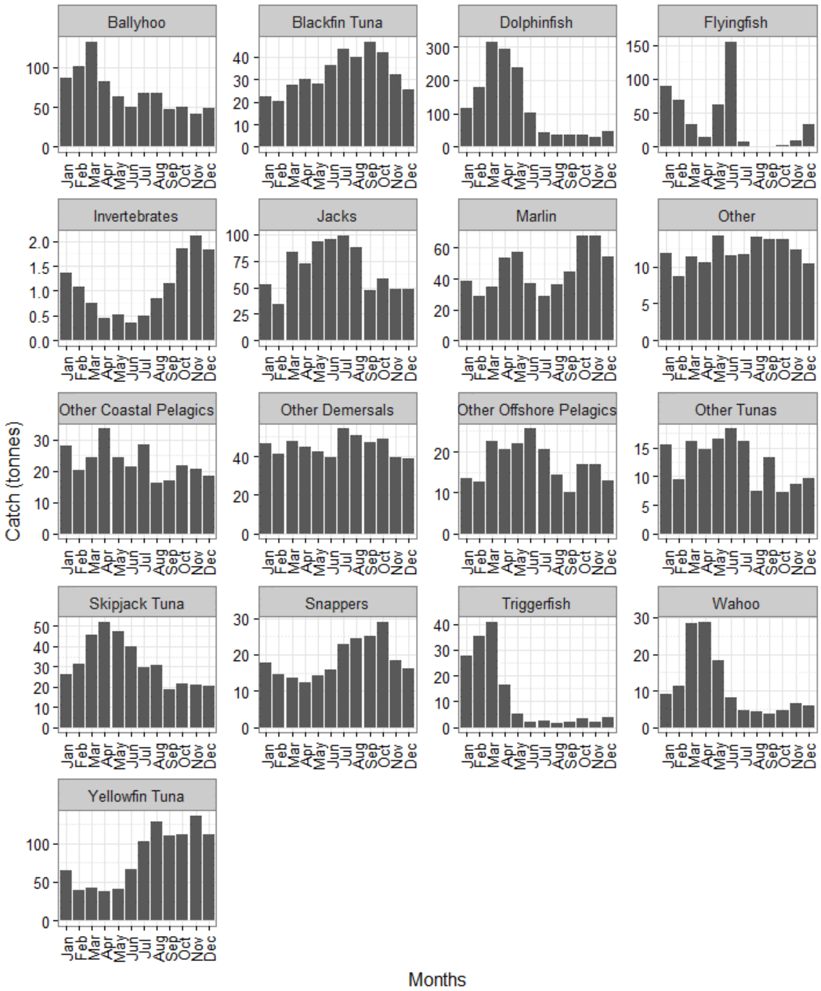

Figure 12. Mean monthly catch from 1994 to 2014, showing seasonality for selected species and groups.

4.3 Catch-Rate

Effort appears to be fairly stable in the long term (Figure **13**). Catch is showing a decline in the time series, never again meeting its 1994 level. There is a drop in both effort and catch for the last three years, however, indicating an overall decline in productivity for the fisheries sector. The catch-rate (CPUE) is showing a general decline after 2001 (Table **2**). There appears to be an improvement in the catch-rate for 2014, but both catch and effort declined for that year. Effort remained below its 1994 level until 2006 and then 2008, where it remained high until it declined again from 2013.

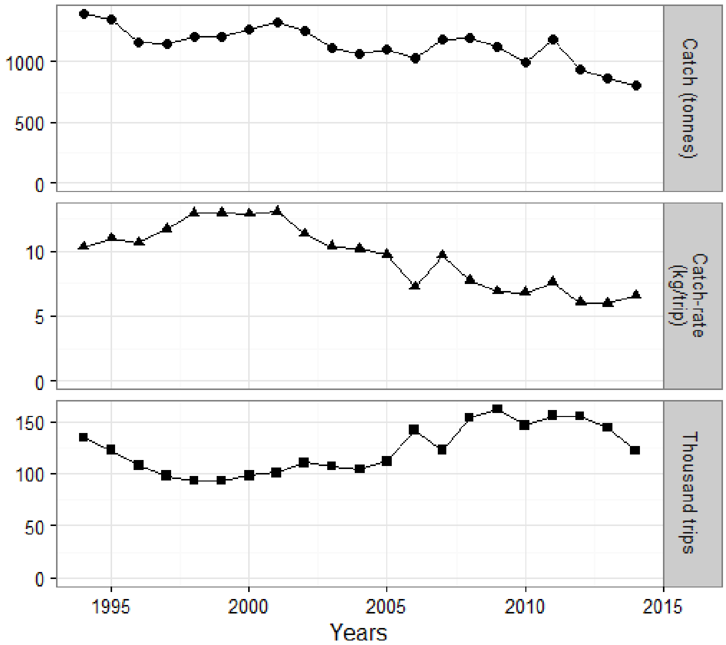

Figure 13. Catches, catch-rates and trips for Dominica from 1994 to 2014.

Of particular interest are the years where hurricanes or other natural disasters affected the sector. Eight major hurricanes affected Dominica between 1994 and 2014 (Edwards, 2015). A category 5 hurricane named Dean (maximum sustained winds of 280 km/h) hit Dominica in 2007 causing about $330,000 USD in damage to the sector. Total effort declined in that year, but total catch increased from the previous year. The catch-rate improved from 7.23 kg per trip in 2006 to 9.66 kg per trip in 2007. In the following year, 2008, both catch and effort increased (although the catch-rate lowered). Hurricane Omar affected the island in 2008, causing about $1.5 million USD in damage to the fisheries sector and extensive coastal degradation. Hurricane Ophelia, in 2011, caused only $45,000 USD in damage to fisheries infrastructure. However, there was also widespread flooding which caused further damage to the coastal ecosystem. The catch-rate reduced after 2011 and remained at 6 kg per trip until 2014, when it improved to 6.6 kg per trip. In December 2013, an unexpected storm brought torrential rains which caused flooding and massive damage to public and private infrastructure (Dominica News Online, 2013). Again, there was widespread impact on the coastal ecosystem. Perhaps in response, catches and effort declined for 2014.

Table 2. Catch, trips and catch-rates for Dominica from 1994 to 2014.

Year	Catch (tonnes)	Thousand trips	Catch-rate (kg per trip)
1994	1387	134	10.3
1995	1348	122	11.0
1996	1152	108	10.7
1997	1145	98	11.7
1998	1201	93	12.9
1999	1202	93	12.9
2000	1266	98	12.9
2001	1316	101	13.1
2002	1253	111	11.3
2003	1110	107	10.4
2004	1063	104	10.2
2005	1094	112	9.8
2006	1023	141	7.2
2007	1183	122	9.7
2008	1193	154	7.8
2009	1118	162	6.9
2010	997	146	6.8
2011	1180	155	7.6
2012	935	155	6.0
2013	860	144	6.0
2014	801	122	6.6

4.4 Analysis of the Dominican Dolphinfish Fishery

Dolphinfish catch appears to be slightly increasing in the long term while the national catch is declining (Figure **14** and Table **10** at APPENDIX 3: TABLES FOR ESTIMATED CATCH). On average, 205.5 tonnes of dolphinfish are caught each year over that period. The years with the highest dolphinfish catch were 2000 (316.9 tonnes), 2007 (314 tonnes) and 2011 (290.4 tonnes). In 2014, 213.3 tonnes were caught.

In 2011, the mean price per kg of dolphinfish sold on the local market was $3.24 XCD (Eastern Caribbean Dollars) or $1.20 USD (US Dollars) (XE.com, 2016). The mean price of other fish (excluding dolphinfish) was $2.75 XCD or $1.02 USD (Theophille, 2012). Using the mean price per pound from 2011, dolphinfish catch is valued at about 1.18 million USD annually, or about 21% of the annual estimated value of the total catch.

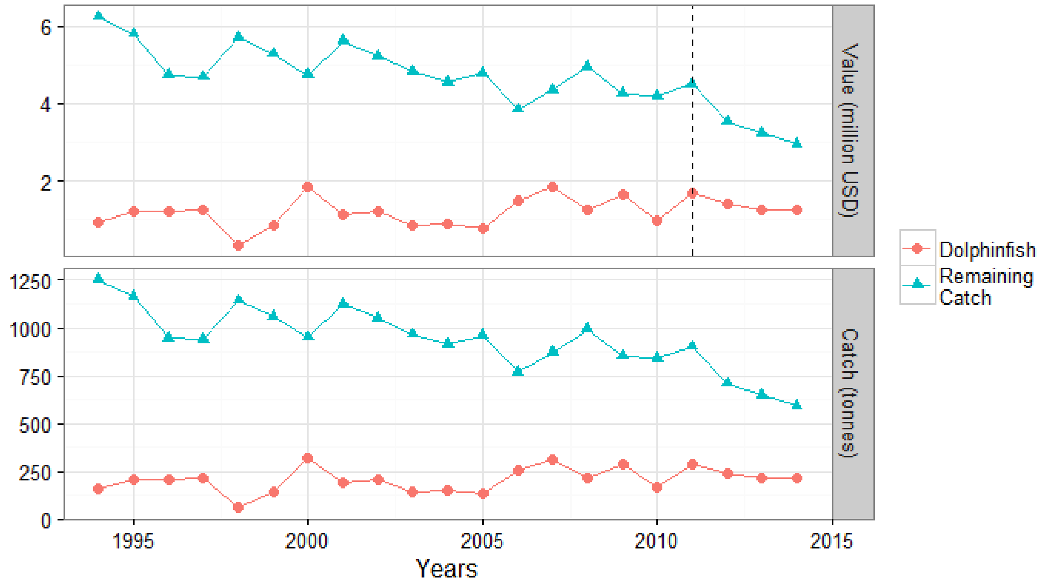

Figure 14. Catch (tonnes) and value (USD) for dolphinfish and remaining catch for Dominica.

4.4.1 CPUE Analysis for Dolphinfish

There are 16,624 observations in the dataset used for the analysis (Table **3**).

Table 3. The first ten rows of data used in the CPUE analysis for dolphinfish for Dominica, describing the table structure.

year	month	date	port	type	gear	kg	trips	season	rate
2009	12	2009-12-09	DBL	FRP	HLIN	10.88	1	low	10.88
2011	10	2011-10-10	PMH	FRP	HLIN	9.51	2	low	4.75
2013	5	2013-05-20	MGT	FRP	TROL	105.22	3	high	35.07
2014	12	2014-12-29	MGT	FRP	HLIN	80.27	2	low	40.13
2008	1	2008-01-03	SSR	FRP	HLIN	8.61	1	high	8.61
2012	4	2012-04-09	SSR	FRP	HLIN	72.57	1	high	72.57
2009	7	2009-07-03	SSR	FRP	TROL	6.80	1	low	6.80
2012	6	2012-06-29	FSJ	FRP	HLIN	49.89	1	high	49.89
2014	3	2014-03-21	SHD	FRP	HLIN	81.19	1	high	81.19
2009	2	2009-02-13	FSJ	Keel	TROL	14.51	1	high	14.51
…	…	…	…	…	…	…	…	…	…

Nominal CPUE

The catch-rate for dolphinfish from 2001 to 2014 shows a mean of 37.7 kg per trip (Table **5**). There was a drop of 40% in the catch-rate between 2001 and 2005. The catch-rate recovered over the next two years and began fluctuating every other year (Figure **15**).

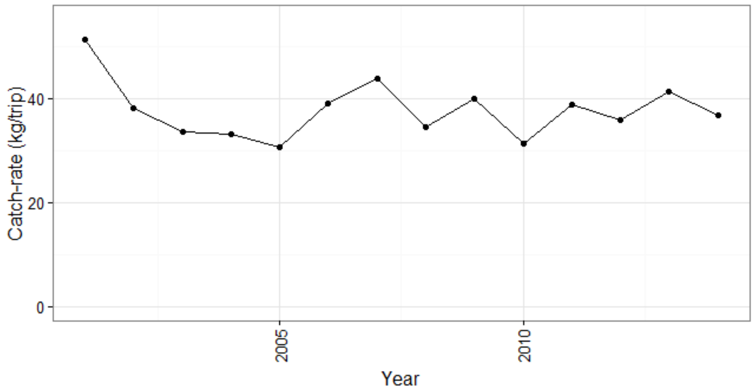

Figure 15. Nominal catch-rates for dolphinfish from 2001 to 2014.

Modelling

The dolphinfish stock appears to be stable and perhaps increasing in recent years (Figure **16** and 5). Five models were prepared to determine the indices of abundance of dolphinfish from the Dominican dataset. The models and their results are described below:

Model 0: The minimal model. This is a starter model containing only the core variables of the dataset, that is, log trips and year. The log of catch (kg) is predicted against these explanatory variables.

Model 1: The intermediate model. This model contains log trips, year, month and port as explanatory variables. The variables month and port added significant improvement over model 0, making this a better model for describing the catch.

Model 2: The CRFM 2010 model. This model attempts to use the variables as described at the 2010 CRFM Annual Scientific Meeting (CRFM, 2010). Explanatory variables include log trips, year, boat type and season. In this study, seasons are based on catches for dolphinfish in Dominica only, which tend to be higher from January to June and lower from July to December (Figure 12). Therefore, there were two seasons, the high season and the low season. The other variable used in the original CRFM model was “island”, but the CRFM dataset contained data from three island nations, unlike the one used in this study, which contains data only for Dominica. The addition of season with this model does not show an improvement over model 1 as the variations afforded by the variables port and month were not available.

Model 3: The full model. This model contains all explanatory variables from the dataset: log trips, year, month, port, boat type and gear, in this order of significance. Boat type and gear added marginal improvement over model 1.

Model 4: The full model using catch-rates as the response variable. The explanatory variables are listed in Table **4** below, with the sum-of-squares column indicating how much of the catch-rate variability is explained by each regression term. The model diagnostics and data fit is similar to model 3, but this model was chosen as the base model as it is easier to diagnose and explain the results. The resulting CPUE index is almost identical to model 3 (Figure **16**).

Table 4. Analysis of variance table for model 4.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Year	13	151	11.62	14.40	< 2.2e-16
Month	11	1388	126.15	156.40	< 2.2e-16
Port	17	588	34.60	42.89	< 2.2e-16
Boat type	4	76	18.96	23.51	< 2.2e-16
Gear	12	79	6.62	8.20	< 1.3e-15
(residuals)	16566	13362	0.81		

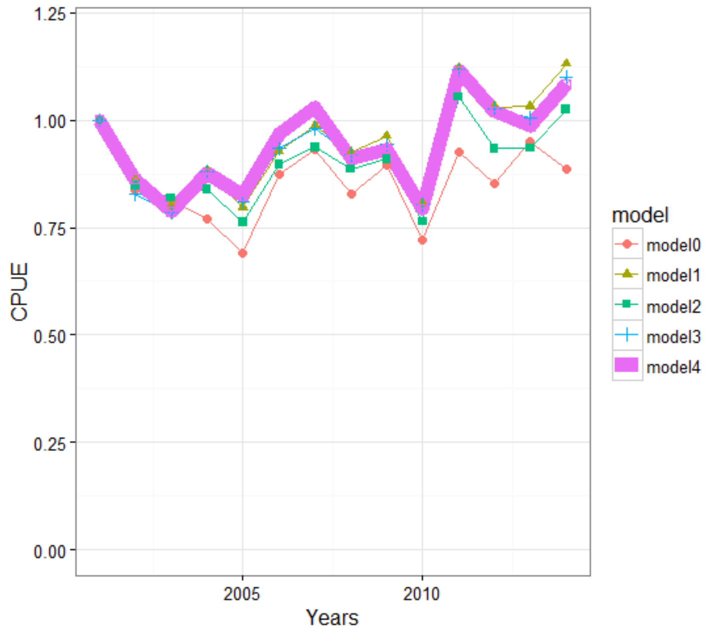

Figure 16. CPUE indices for dolphinfish for Dominica from 2001 to 2014. The line for model 4, the base model, is emphasised.

Table 5. Estimated catch, effort and CPUE for dolphinfish for Dominica.

Year	Catch (tonnes)	Trips	CPUE	
			Nominal (kg/trip)	Model 4 Indices
2001	192.3	1117	51.4	1.000
2002	204.2	1769	38.1	0.863
2003	143.6	1162	33.6	0.787
2004	149.8	1282	33.1	0.876
2005	134.1	1352	30.6	0.823
2006	253.7	2560	39.1	0.969
2007	314.0	2669	43.7	1.029
2008	214.6	2341	34.4	0.911
2009	285.6	2833	39.8	0.933
2010	168.1	1962	31.2	0.794
2011	290.4	2868	38.9	1.115
2012	241.3	2714	35.7	1.020
2013	214.0	2233	41.4	0.986
2014	213.3	2380	36.8	1.084

5 DISCUSSION

5.1 Data Quality

The fish catch and effort data of Dominica was found to be useful for analysis and future fisheries management needs in Dominica and across the Caribbean. The quality of the data appears reasonable, for the most part, and so is the *ad hoc* data collection scheme that is currently in place. The sampled ports represent a significant portion of the total ports (13 of 29 total ports). Geographically, they are well situated around the island and include ports of varying levels of catch, effort and infrastructural development. Additionally, species which appear in the catch record are often disaggregated, which allows for future analyses of currently less important species. The database used for data entry and storage is regularly maintained by competent staff and features can be added as needed.

That said, it is important to remember the current local deficiencies that exist in data collection and data management. The biases that arise from a loosely structured data collection system with limited supervision needs to be considered and addressed. Fisher cooperation in data sharing is another issue of concern. The collection system neglects to capture any information on the biology of species caught. A few records of length, sex and stomach content were collected for lionfish, but there is no regular programme to address biological data collection in any meaningful way on a national scale. The gaps in knowledge about ports and their fleets are still present as no regular frame surveys are done. Data collectors still have difficulty properly identifying juvenile fish and utilizing the collection form and in many cases, data is brought to the office after the monthly deadline, negatively affecting data entry. All of these problems will have to be addressed and the Fisheries Division is already making progress to solve them; data collectors are being trained to improve the quality of their work and fishers are being educated to appreciate the work of data collectors. Guidelines for improving some of the problems with data quality can be found in Stamatopoulos (2002).

5.2 Status of the Dolphinfish Fishery

The 2010 CRFM analysis for dolphinfish in the Eastern Caribbean found that the stock was abundant and not overfished. The CPUE analysis for Dominica, presented in this study, seems to agree with the CRFM findings, indicating that the abundance of the dolphinfish stock is stable at the current harvest levels (see Figure **16**). However, analytical stock assessment of the dolphinfish data is required to evaluate whether the stock is at a level where it is most productive in terms of annual yield.

The main weakness of the CPUE analysis in this study is that it does not cover the entire multinational dolphinfish stock; therefore, it cannot accurately be used as a measure of abundance for that stock. Only a small portion of the stock is accessible to Dominican fishing vessels. The results of this analysis are still useful for describing the local trends, and the catch and effort data are ready to be combined with datasets from the rest of the region for a more comprehensive analysis covering the entire stock. At that level, more useful management advice can be produced. Fortunately, there is now some local capacity for Dominica to participate more fully in regional stock assessments.

This study did not examine whether FADs have an effect on catch-rates for dolphinfish locally and if they do, to what degree. FADs are important to the capture of large migratory pelagics such as dolphinfish. The aggregating function of FADs can result in high catch-rates while the population declines, giving a false sense of the stock status. However, the available data was not sufficient to make any conclusions in that regard as FAD catches were only added to the data collection programme after 2012.

5.3 Status of the Fisheries Sector

Productivity in fisheries is declining since 2012; both the catch and effort are reducing. The catch-rate is improving slightly, however, which might mean the sector will improve in the near future. The fisheries sector has witnessed many changes within the study period, notably, the construction of major facilities at Roseau, Marigot and Portsmouth, devastating storms, the introduction of Fish Aggregating Devices (FADs) and an influx of new but part-time fishers. Persons who fully depend on fisheries have been the ones most affected by those changes and they will be the ones most at risk with the next major change. Avenues exist for growth in fisheries, especially for underutilised, but high value species. Newly exploited species, such as diamondback squid (*Thysanoteuthis rhombus*), can potentially redefine fisheries and open export markets. However, there is a distinct lack in information available to management for fisheries such as this and the sector in general. Traditionally exploited, high-value species such as dolphinfish need to be better understood before any major development of the fishery can be implemented. Further advances will have to be made in data collection and data management and the capacity for data analysis and reporting within the Fisheries Division.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Data Collection

A future study of the Dominican fisheries sector should be conducted to assess the accuracy and precision of the current data collection system. The results of this activity can help further improve the sampling methodology.

A field sampling manual, with improved sampling methodology, needs to be developed that clearly describes the objectives of data collection and the means by which data should be collected. Job descriptions, officially recognised by the government, should be prepared for data collectors, based on the field sampling manual. Training for data collectors is encouraged and should continue as a regular activity of the Fisheries Division. In general, more resources should be devoted towards data collection and regular supervision.

The feasibility of collecting biological data should be explored, especially easily obtainable data such as length. This can be done for important species, such as dolphinfish, ballyhoo, flyingfish, lionfish and yellowfin tuna a few times in the year. Data collectors should be trained to collect this information effectively and a new data collection form will have to be prepared for that activity.

Fishers should continue to be educated as to the value of data collection in fisheries and their role in sharing reliable data and co-managing the fishery resources. This is in support of the Fisheries Division, which has limited resources available for managing the sector.

A frame survey should be done annually to account for changes in the industry and provide more accurate information for estimating catch and effort.

Estimating historical catches was a challenge for this study as there was limited information on what the sector was like for many years in the time series. Therefore, historical changes in the fisheries sector should be documented. This can include information on changes in fleet size and structure, catch, effort, storm damage and infrastructural developments.

6.2 Database Development

Currently, MS Access presents the best database solution for the Fisheries Division of Dominica. However, future database development should include free and extensible solutions such as PostgreSQL. The current database, however, can be improved to reduce data entry errors.

6.3 Data Analysis and Reporting

Preparing quality data quickly and in a fashion that is useful to fishers and fishery managers (such as the Fisheries Division), is a goal that should be pursued from this study. This can help bolster the case for fisher cooperation in sharing information and better understanding resource management measures. Fisheries managers will receive the information they need in a timely manner for making decisions. Therefore, a strong case can be made for reproducible reporting of fisheries data. The R statistical software was essential to understanding and manipulating the data and producing the results for this study, all as a reproducible report. This framework makes it easy to analyse many species in a similar way.

The method used for estimating catch in this study was not comprehensive and therefore needs to be reviewed, improved, documented and made standard for each year. This will make future estimation tasks easier. The FAO reports for Dominica should be updated to reflect the new estimates.

Further training on the analysis of fisheries data is required for local staff. This study provided an opportunity for developing core skills for fisheries analysis. However, it is apparent that more training is necessary to allow for additional analysis of the sector.

The dolphinfish CPUE data for Dominica needs to be combined with similar datasets from other countries in the region, producing a comprehensive CPUE index that covers the distribution of the dolphinfish stock that can be used in an analytical stock assessment. Locally, annual CPUE analyses for dolphinfish should be prepared so that the lessons learned from this study can be utilised and improvements can be made in the analysis and management of the fishery. Lessons learned from this study should be extended to other CRFM member states.

6.4 Fisheries Management

It is recommended that fisheries management identify which stocks may require management actions, CPUE analysis should be conducted for as many stocks as possible. For many domestic stocks, the catch and effort data are ready to be analysed in the same way as was done for dolphinfish in this study. For example, the catches of ballyhoo and flying fish have declined in recent years, which calls for attention from the scientific and management perspective. Additionally, management objectives for each stock needs to be specified.

Given the current use of FADs it is likely that the catch-rates could remain high while the population is declining. Therefore, the use of FADs increases the need of independent scientific surveys.

Dolphinfish catches should continue to be monitored. Expansion of the fleet which targets the species should be done with caution. Fleets which target important species should be defined clearly and monitored, to quantify the effort directed towards each stock.

Fishers should be encouraged to participate, individually and through their groups and cooperatives, in the management of the national fish resources. Rapport between fishers and the Fisheries Division should be encouraged, along with educational and empowerment programmes.

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APPENDICES

APPENDIX 1: FISH CATCH AND EFFORT DATA COLLECTION FORM

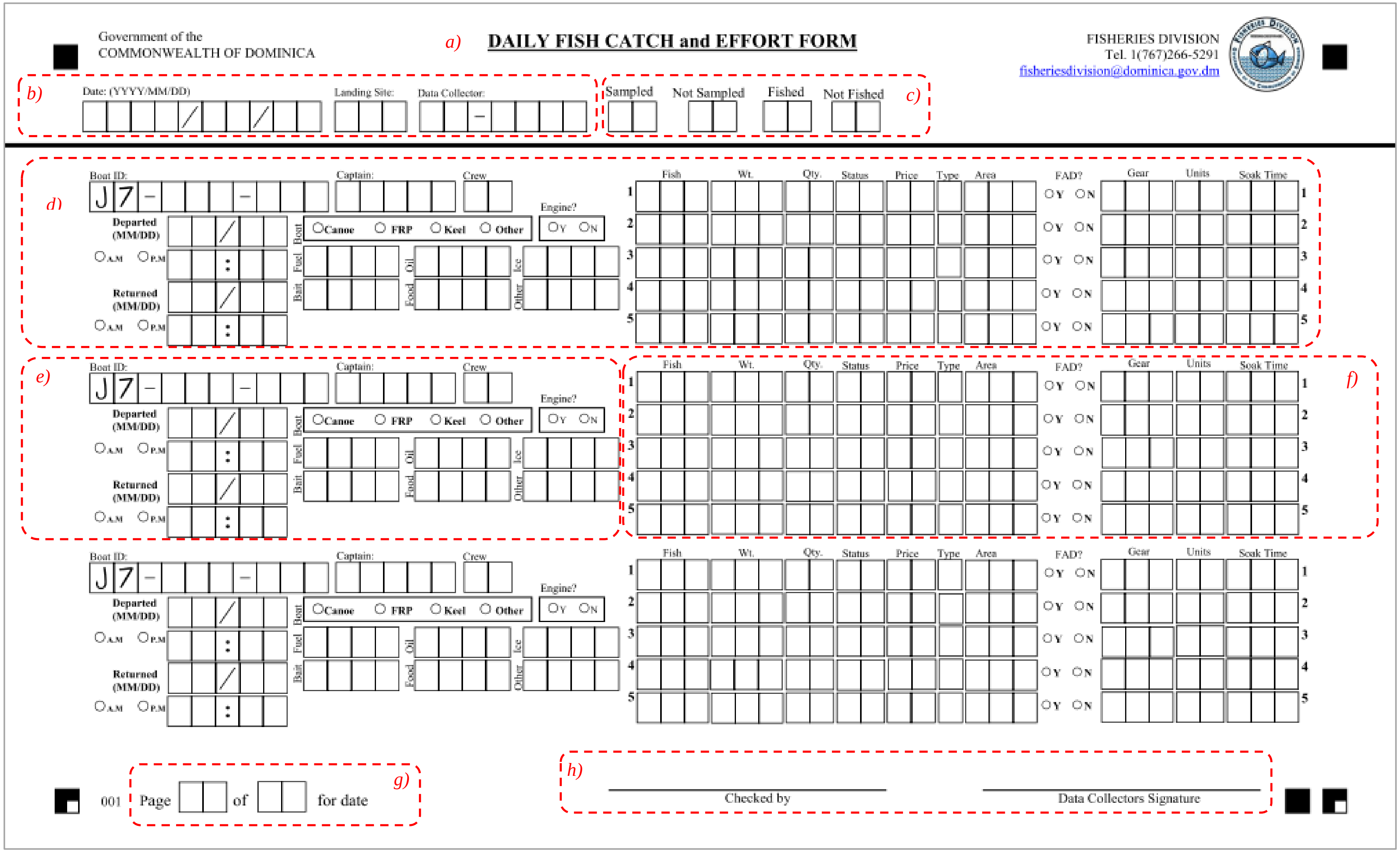

Figure 17. Field collection form for fish catch and effort data (2015 revision)

Description of the data collection form by sections:

a. Title: This section shows the title of the form and gives contact details for reaching the Fisheries Division.
b. Date, landing site and data collector
    - Date: date of sampling or data collection
    - Landing site: the code for the landing site or port being sampled
    - Data collector: the code for the data collector who did the sampling
c. Boat or vessel activity at site
    - Sampled: the total boats sampled at that site for the day
    - Not sampled: the total boats not sampled for that day
    - Fished: the total boats which went out fishing on that day
    - Not fished: The total boats which did not go out fishing for that day
d. Sampling records by boat sampled. Each data collection form/sheet can accommodate at most three sampled vessels.
e. Vessel and trip information:
    - Boat ID: The registration number for the sampled vessel
    - Captain: This is the Fisher registration number of the vessel captain
    - Crew: The number of persons who were on the vessel for the trip
    - Departed: The month, date and time (24 hour or 12 hour) when the vessel left shore for fishing
    - Returned: The month, date and time (24 hour or 12 hour) when the vessel returned to shore from fishing
    - Boat type: The type of boat which was sampled
    - Engine: Whether the boat used an engine for fishing or not. If not, it is assumed oars or sails were used.
    - Expenses for the trip. All values in Eastern Caribbean Dollars (XCD). Expenses include fuel, bait, oil, food, ice and "other".
f. Catch or landings information for the vessel: Five different species (or species groupings) can be accommodated per vessel. If more than five different species were caught, the list may be expanded by using those below (assigning the same Boat ID).
    - Fish: the code for the fish species (or species grouping) landed by the vessel
    - Wt.: the total weight for the species (or species grouping) landed. This is in pounds (lbs).
    - Qty.: the number of individuals comprising that species which was landed
    - Status: this denotes the landing state of the fish (e.g. whole, gutted, head removed)
    - Price: the price (in XCD) for the species (or species grouping) at the site for that day
    - Type: whether the price is per pound or per individual fish
    - Area: where the fish was caught (using the map grid shown at Figure 19. A grid map used in field sampling to identify fishing locations)
    - FAD: whether the fish was caught near a Fish Aggregating Device
    - Gear: a code denoting the gear used for catching the fish
    - Units: the number of units of gear used to catch the fish
    - Soak time: how long the gear was left in the water before hauling
g. Pages for date: This portion of the form allows for counting how many pages of data is available for the sampling date at that site.
h. Signatures:
    - Checked by: signature of the Fisheries official who checked the information on the data form
    - Data collector signature: signature of the data collector who provided the information on the data form

APPENDIX 2: TABLES FOR ESTIMATED EFFORT

Table 6. Effort for Dominica from 1994 to 2014: estimated annual trips for all ports, mean active fishing boats per port and mean fishing days per port.

Year	Trips	Boats per port	Fishing days per port
1994	134108	18	237
1995	122480	17	240
1996	107862	15	236
1997	97560	14	231
1998	92984	14	226
1999	92966	14	224
2000	98275	14	233
2001	100747	14	235
2002	110535	15	235
2003	106937	16	227
2004	104063	15	224
2005	112013	15	230
2006	141471	19	230
2007	122383	17	226
2008	153652	20	232
2009	161819	22	223
2010	146226	20	218
2011	155234	20	215
2012	154784	21	218
2013	143922	21	218
2014	134108	18	218

Table 7. Estimated effort by port by year.

Trips by year	Bioche	Colihaut	Coulibistrie	Dublanc	Fond Cole	Fond St. Jean	Layou	Mahaut	Marigot	Newtown	Other	Portsmouth	Pottersville	Saint Sauveur	Scotts Head	St. Joseph
1994	5838	5301	3510	3731	6325	5004	3582	6100	4500	11514	29922	15877	11322	8745	11076	1759
1995	7475	4914	3337	3724	5819	4488	4118	5810	5819	14880	23648	7902	8802	8160	11424	2160
1996	6321	4777	3397	3900	5537	3936	3106	5775	4400	12669	22740	6880	6600	6448	10296	1080
1997	5526	4272	3211	3456	5049	3307	2083	5490	4300	10507	21611	6716	4947	6750	8948	1387
1998	5340	3185	3770	3036	4961	3855	3142	5208	5211	8296	20778	6552	3698	5992	8368	1592
1999	4914	2708	2812	1972	4809	4200	2897	5175	8774	6687	20188	9412	3979	5481	8158	800
2000	4968	2964	2860	3627	4847	5586	4502	4898	6709	9238	19183	8471	4260	6786	9176	201
2001	5083	2976	2643	5236	4602	6762	5859	4866	4914	8671	19404	8308	4541	6575	8288	2017
2002	7803	1984	2149	6512	4573	5358	5088	4594	7364	6804	19180	9821	4821	6408	15847	2229
2003	5713	4750	2730	3857	5480	5733	6733	4564	7657	3520	18817	11337	5101	4920	11956	4070
2004	5808	4156	3328	5715	2600	5664	5687	4296	6318	4800	18871	12857	5380	4902	12454	1226
2005	4714	5102	4225	4199	1897	6670	3812	4268	8988	2949	18972	21252	5659	6312	11763	1232
2006	6221	5591	6292	5832	5615	8112	6845	4005	15043	3164	18854	27435	5937	6939	13525	2062
2007	6557	4446	2903	2945	4614	6264	6882	4446	16642	3379	19235	23184	3955	5697	10611	621
2008	6407	6581	3241	8653	6664	9019	6643	4649	21648	3595	19461	25854	5081	12408	13124	624
2009	7242	4507	2288	6877	9479	6919	6308	5927	23408	2924	19373	33334	7676	10578	13181	1797
2010	5075	4745	1924	6216	4373	5630	7716	7058	22933	2269	19627	30420	5727	8814	12743	956
2011	5019	3502	1387	3971	10423	5256	4934	8553	21024	1629	19657	36498	12111	8092	12081	1097
2012	6844	3795	1742	4641	9930	5544	7016	8597	19584	2870	22382	19527	16092	10542	13435	2245
2013	7744	4314	2779	3754	9436	6006	4978	8627	15067	4125	25809	18396	10595	9804	10194	2295
2014	7290	2646	2808	7252	9597	5280	5117	4321	11913	5783	19234	9048	10557	10086	9191	1564

Table 8. Estimated effort by species by year

Trips by year	**Ballyhoo**	**Blackfin Tuna**	**Dolphinfish**	**Flyingfish**	**Invertebrates**	**Jacks**	**Marlin**	**No Fish Caught**	**Other**	**Other Coastal Pelagics**	**Other Demersals**	**Other Offshore Pelagics**	**Other Tunas**	**Skipjack Tuna**	**Snappers**	**Triggerfish**	**Wahoo**	**Yellowfin Tuna**
1994	35564	4917	30465	34955	1638	47112	455	24	79192	32839	125336	24053	36846	23184	63093	17027	1614	4908
1995	26515	19052	37966	28466	3266	53070	604	53156	32887	43496	182618	11932	34319	30419	66645	13897	19870	6841
1996	18765	16085	31013	16019	546	36666	79	68996	23961	11981	103128	12721	5809	28729	43846	3296	11507	7129
1997	13739	16585	23546	9641	700	28595	107	45735	12501	15612	130098	18327	11581	9456	51267	6966	12281	3752
1998	25644	11688	10536	10022	591	35581	394	24688	16613	15817	130291	2835	15587	7043	41901	7753	6408	407
1999	22994	30820	19532	10821	3486	35271	1957	47751	15244	12019	148407	21344	282	17746	45624	9500	13296	4825
2000	18312	31081	26282	9016	2578	42526	5866	44077	14626	11366	144949	14428	4989	26465	40956	8250	11868	9479
2001	14881	33541	24447	7910	2963	46951	8149	39464	14098	11714	145706	13819	8119	31654	43085	7148	11367	12548
2002	19290	27217	35824	13220	465	35703	20034	51542	7790	4481	154342	13146	4434	45349	31877	6454	17934	34957
2003	21049	18020	26295	7294	531	35741	10801	47334	4359	6750	131317	13153	906	27717	34102	3938	11732	28850
2004	15892	30860	32944	2567	1384	30345	15983	40579	3990	4476	116374	19286	13514	35551	39780	4411	13691	29954
2005	14080	40755	35542	2740	1150	46682	20621	40228	6002	5817	145465	24523	19345	33133	59261	8443	20184	38565
2006	23829	40220	41387	3491	1114	58347	20467	50592	6267	13790	213754	24578	1081	40263	71623	8932	22456	26549
2007	17654	33717	51201	3929	520	49794	25835	44862	5514	4806	132639	20245	1187	34917	40367	9443	26129	42990
2008	16796	46866	62153	5330	1013	50176	38712	61935	8258	10635	164271	37668	4193	53207	60659	16660	29078	57592
2009	16613	60772	73991	3832	2099	66666	32861	55761	7246	15001	156268	40319	9289	57116	58328	26256	33849	57518
2010	14345	53623	58187	6334	1337	61676	36759	55024	3689	11914	127191	43814	4100	55366	56036	11861	36386	66903
2011	6335	65215	72439	2379	5547	91013	33246	45979	7833	7878	151172	50853	1135	52393	57348	15350	34802	71992
2012	12944	55246	73205	2044	4342	91548	33845	37291	8068	11481	150976	40265	571	42120	60170	19736	23019	54726
2013	11397	26310	54770	7700	3795	46770	19355	39200	13691	5076	110887	23412	32471	40608	46132	10911	5259	29487
2014	7961	41380	55887	2836	7069	50116	20340	28630	6730	3394	128209	31234	1441	39555	46949	13341	19535	47377

APPENDIX 3: TABLES FOR ESTIMATED CATCH

Table 9. Comparison of estimated catch for Dominica from this study, FAO (2016) and Ramdeen *et al*. (2014).

Year	**Estimated catch (tonnes)**		
	This study	**FAO**	**Ramdeen *et al***
1994	1384	882	1498
1995	1348	950	1503
1996	1153	1030	1503
1997	1144	1079	1499
1998	1198	1212	1491
1999	1199	1200	1492
2000	1265	1200	1480
2001	1317	1200	1473
2002	1252	1198	1472
2003	1112	950	1475
2004	1062	700	1482
2005	1098	579	1478
2006	1025	694	1479
2007	1185	676	1465
2008	1193	696	1462
2009	1115	790	1452
2010	996	700	1450
2011	1177	664	NA
2012	937	561	NA
2013	860	479	NA
2014	803	NA	NA

Table 10. Catch (tonnes) and value (USD) for dolphinfish and other species for Dominica.

Year	**Catch (tonnes)**		**Value (million USD)**	
	Dolphinfish	Remaining Total Catch	Dolphinfish	Remaining Total Catch
1994	155.4	1249.8	0.90	6.24
1995	204.9	1162.7	1.19	5.80
1996	203.5	948.2	1.18	4.73
1997	215.2	938.9	1.25	4.68
1998	57.7	1143.2	0.34	5.70
1999	142.4	1059.1	0.83	5.28
2000	316.9	948.8	1.85	4.73
2001	192.3	1124.1	1.12	5.61
2002	204.2	1048.5	1.19	5.23
2003	143.6	966.0	0.84	4.82
2004	149.8	912.8	0.87	4.55
2005	134.1	959.6	0.78	4.79
2006	253.7	769.8	1.48	3.84
2007	314.0	869.9	1.83	4.34
2008	214.6	991.7	1.25	4.95
2009	285.6	852.6	1.66	4.25
2010	168.1	840.9	0.98	4.20
2011	290.4	901.8	1.69	4.50
2012	241.3	707.4	1.41	3.53
2013	214.0	648.5	1.25	3.24
2014	213.3	591.8	1.24	2.95

Table 11. Estimated catch by port.

Catch (tonnes) by year	**Bioche**	**Colihaut**	**Coulibistrie**	**Dublanc**	**Fond Cole**	**Fond St. Jean**	**Layou**	**Mahaut**	**Marigot**	**Newtown**	**Other**	**Portsmouth**	**Pottersville**	**Saint Sauveur**	**Scotts Head**	**St. Joseph**
1994	25.24	78.38	54.84	27.24	35.37	59.1	56.89	94.60	64.38	84.39	476.43	106.72	91.17	43.64	55.13	33.15
1995	21.93	65.17	63.13	22.78	34.12	48.49	56.04	77.92	77.75	60.16	499.61	133.85	51.96	51.38	54.75	29.24
1996	18.35	69.03	40.76	22.78	33.01	38.91	48.61	56.36	30.76	53.96	484.19	95.15	62.87	26.88	50.09	20.00
1997	18.23	49.60	20.45	25.82	32.01	38.09	36.18	52.23	35.91	49.71	468.49	160.41	61.29	27.69	44.78	24.10
1998	21.03	45.56	35.04	28.86	32.28	37.08	45.61	50.33	43.82	45.45	452.48	184.36	81.48	23.40	41.88	32.26
1999	21.54	49.49	39.50	29.06	33.76	36.42	33.99	49.16	49.46	78.47	436.31	123.38	134.36	19.11	42.04	25.44
2000	33.37	61.78	46.89	35.99	35.25	59.26	63.30	48.31	47.66	26.10	420.62	110.70	126.37	37.41	85.14	27.56
2001	21.28	72.69	44.84	47.08	36.74	53.75	65.70	47.64	52.50	64.75	404.54	122.16	117.34	69.00	64.54	31.89
2002	17.69	68.85	54.68	69.67	38.23	47.24	45.21	47.06	99.83	20.44	388.36	116.22	107.05	27.11	80.31	24.74
2003	13.63	48.78	54.59	67.34	41.98	31.77	60.01	46.56	64.24	19.81	371.71	111.99	95.22	13.92	45.74	22.25
2004	16.34	57.80	61.12	63.09	29.33	30.78	52.00	46.10	69.30	20.45	354.53	108.84	81.46	18.21	44.27	8.97
2005	21.69	58.03	70.65	36.80	22.80	39.14	27.13	45.67	140.23	15.77	336.81	160.55	65.26	14.63	23.97	14.57
2006	16.17	49.87	55.55	48.33	23.90	42.82	41.52	45.27	123.29	14.19	318.53	121.11	45.88	23.36	36.02	17.60
2007	18.78	45.91	65.95	55.17	36.62	31.19	61.60	50.19	157.54	68.30	300.43	117.11	69.83	25.12	64.63	14.34
2008	19.55	57.62	56.97	46.25	61.31	46.68	39.02	94.80	144.35	33.70	281.60	95.28	101.06	36.84	71.78	6.35
2009	10.45	86.19	71.29	40.20	24.98	31.97	45.42	84.49	167.33	17.60	261.24	96.18	49.05	42.88	83.16	5.23
2010	11.17	60.62	59.64	36.42	23.02	23.53	46.43	88.69	143.61	13.53	240.87	130.47	27.39	21.38	57.49	12.33
2011	14.31	82.74	47.87	33.02	51.75	32.64	44.98	93.32	141.44	13.36	220.34	205.06	64.22	31.12	93.07	10.32
2012	15.67	52.69	51.91	32.94	37.03	34.79	39.15	90.74	111.74	10.53	198.57	110.91	33.72	33.52	65.40	15.94
2013	16.35	60.00	12.80	26.01	37.00	40.82	29.18	88.21	109.30	8.78	175.10	89.85	55.68	27.95	73.43	9.07
2014	23.01	30.53	39.83	43.44	41.20	23.92	22.60	115.28	104.88	8.52	135.06	60.54	49.81	47.23	44.58	10.38

Table 12. Estimated catch by species group.

Catch (tonnes) by year	**Ballyhoo**	**Blackfin Tuna**	**Dolphinfish**	**Flyingfish**	**Invertebrates**	**Jacks**	**Marlin**	**Other**	**Other Coastal Pelagics**	**Other Demersals**	**Other Offshore Pelagics**	**Other Tunas**	**Skipjack Tuna**	**Snappers**	**Triggerfish**	**Wahoo**	**Yellowfin Tuna**
1994	187.5	24.6	155.4	313.3	1.9	124.3	4.2	145.3	40.9	86.4	96.1	53.5	83.0	35.1	5.8	3.4	44.5
1995	179.2	41.8	204.9	225.7	2.5	158.9	6.8	48.1	123.8	119.6	20.9	61.7	51.8	40.6	15.7	33.3	32.3
1996	170.0	43.3	203.5	147.2	1.0	150.1	2.2	64.7	58.0	70.1	26.6	34.7	56.4	33.1	4.0	18.1	68.7
1997	122.7	65.8	215.2	78.6	2.7	103.3	1.1	39.0	66.7	94.1	144.2	50.3	51.1	42.6	22.7	33.3	20.9
1998	309.2	79.4	57.8	119.5	1.4	147.8	10.2	71.8	78.1	128.3	6.6	75.4	28.2	54.0	3.8	16.0	13.7
1999	260.5	106.6	142.4	118.7	2.9	91.2	27.0	18.1	57.6	139.4	55.1	8.2	59.4	51.6	15.1	28.1	19.8
2000	106.8	72.3	316.9	83.2	1.5	182.5	50.6	17.2	60.2	130.6	35.4	27.4	104.2	28.9	4.6	13.6	29.9
2001	125.6	90.9	192.3	103.4	3.7	213.6	71.0	18.0	70.6	128.8	39.9	31.6	125.3	37.9	5.5	17.0	41.3
2002	109.5	95.4	204.2	89.1	0.7	120.2	126.1	6.6	27.2	103.8	16.8	20.9	62.7	20.5	4.3	21.7	223.1
2003	196.6	56.6	143.6	51.3	0.8	146.0	99.3	4.2	24.3	108.1	15.7	2.0	67.1	22.5	2.1	13.2	156.0
2004	154.2	53.3	149.8	20.4	1.8	68.3	105.6	6.0	23.3	71.7	18.6	20.3	79.6	36.8	3.5	15.1	234.7
2005	61.5	93.4	134.1	12.6	1.2	107.4	106.3	5.3	18.9	80.3	15.7	28.9	48.4	37.6	28.8	20.6	292.7
2006	112.2	74.8	253.7	14.3	1.3	97.4	86.6	5.1	45.0	88.2	17.3	6.2	43.6	31.3	21.1	23.4	102.2
2007	144.7	53.1	314.0	21.6	0.7	108.7	105.9	3.3	16.2	75.4	14.5	4.0	57.3	25.9	28.4	27.6	182.6
2008	107.2	63.1	214.6	42.1	1.1	77.4	183.1	3.9	29.9	60.0	20.6	11.9	76.5	30.1	44.2	26.9	213.9
2009	82.3	70.8	285.6	25.2	1.1	100.3	117.6	4.1	41.3	48.7	20.7	11.4	39.3	28.5	87.0	16.2	158.2
2010	81.8	46.2	168.1	33.1	1.4	71.8	114.7	2.9	27.2	37.1	38.9	12.3	49.0	28.2	14.0	27.7	254.5
2011	37.3	45.1	290.4	24.4	2.1	191.3	104.1	5.6	25.3	40.4	47.2	2.7	20.9	29.7	33.0	25.3	267.2
2012	78.0	30.6	241.3	7.1	1.9	139.6	108.1	6.2	27.2	32.8	29.0	0.9	20.1	30.5	18.5	15.8	161.0
2013	76.3	20.3	214.0	25.9	3.5	77.3	62.0	19.1	16.5	64.4	14.0	46.4	48.1	31.3	21.0	5.4	117.2
2014	60.9	26.7	213.3	11.9	3.8	66.4	62.4	3.2	13.3	37.1	17.3	3.7	27.8	31.9	19.2	13.4	192.9

APPENDIX 4: SPECIES GROUPS

Table 13. Species groups used in this study.

Group	Species included
Ballyhoo	Balao *(Hemiramphus balao)*, ballyhoo *(Hemiramphus brasiliensis)* and common halfbeak ballyhoo *(Hyporhamphus unifasciatus)*
Blackfin Tuna	*Thunnus atlanticus*
Dolphinfish	*Coryphaenidae*
Flyingfish	*Exocoetidae*
Invertebrates	Conch (e.g. *Strombus gigas*), sea crabs, lobster (e.g. *Panulirus argus*, *P. guttatus*)
Jacks	*Carangidae*
Marlin	*Istiophoridae*
Other	Eels, octopus, sharks, squid, turtles, cetaceans and other species not elsewhere included
Other Coastal Pelagics	Needlefish *(Belonidae)*, sardines *(Clupeidae)*
Other Demersals	Angelfishes (*Pomachanthidae*), doctorfish (*Acanthurus chirurgus*), goatfishes (*Mullidae*), groupers (*Dermatolepis*, *Epinephelus* and *Mycteroperca* spp.), grunts (*Haemulidae*), parrotfishes (*Scaridae*), squirrelfishes (*Holocentridae*), surgeonfishes (*Acanthuridae*) and wrasses (*Labridae*)
Other Offshore Pelagics	Barracudas (*Sphyraenidae*), herrings (*Clupeidae*), mackerels (*Scombridae*), swordfishes (*Xiphiidae*),
Other Tunas	Bigeye tuna (*Thunnus obesus*), Albacore (*Thunnus alalunga*), other tunas
Skipjack Tuna	*Katsuwonus pelamis*
Snappers	*Lutjanidae*
Triggerfish	*Balistidae*
Wahoo	*Acanthocybium solandri*
Yellowfin Tuna	*Thunnus albacares*

APPENDIX 5: MAPS OF LANDING SITES AND ZONES IN DOMINICA

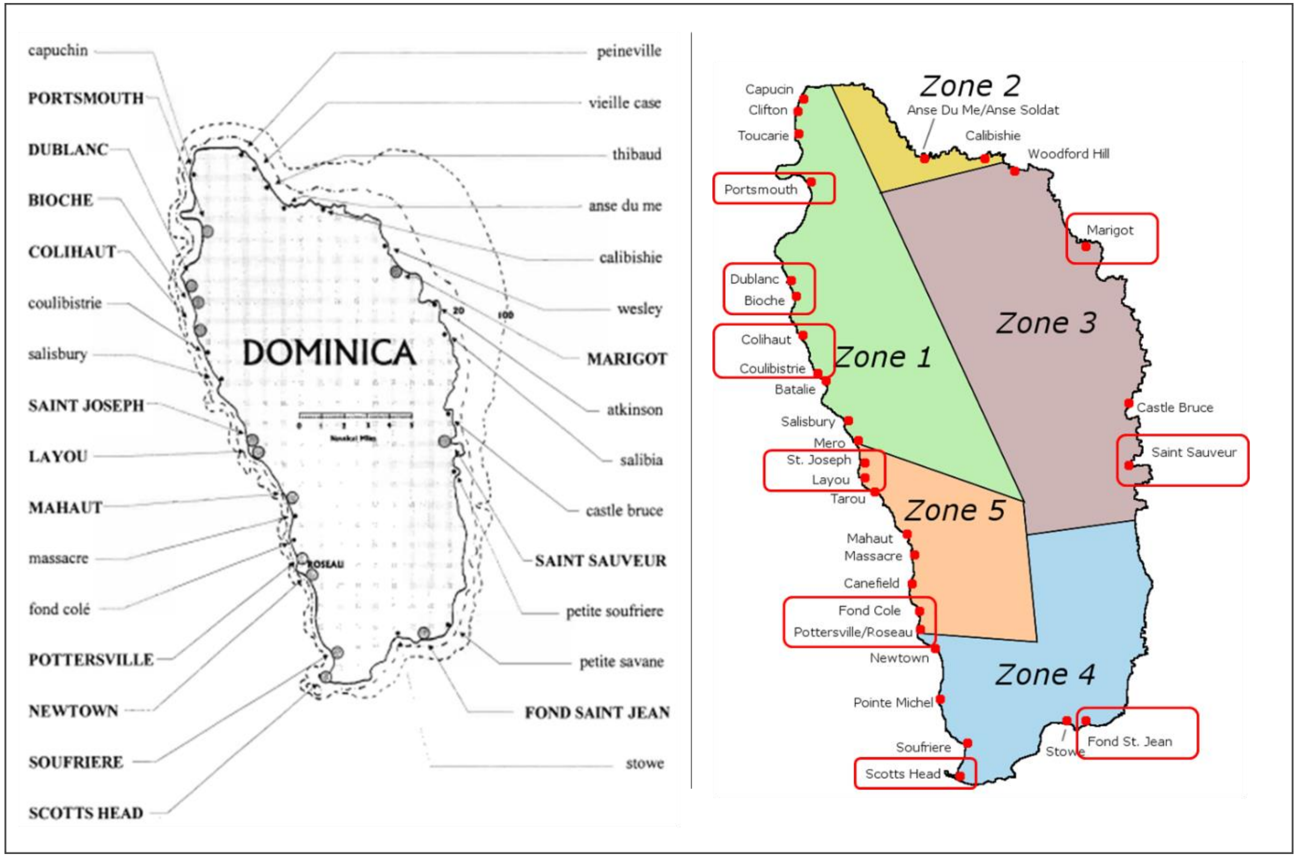

Figure 18. Landing ports and data collection sites in Dominica. The map on the left was published in 1996, showing data collection sites in bold caps (Guiste, Gobert, & Domalain, 1996). On the right is a similar map from 2015 showing data collection sites bounded by a red rectangle.

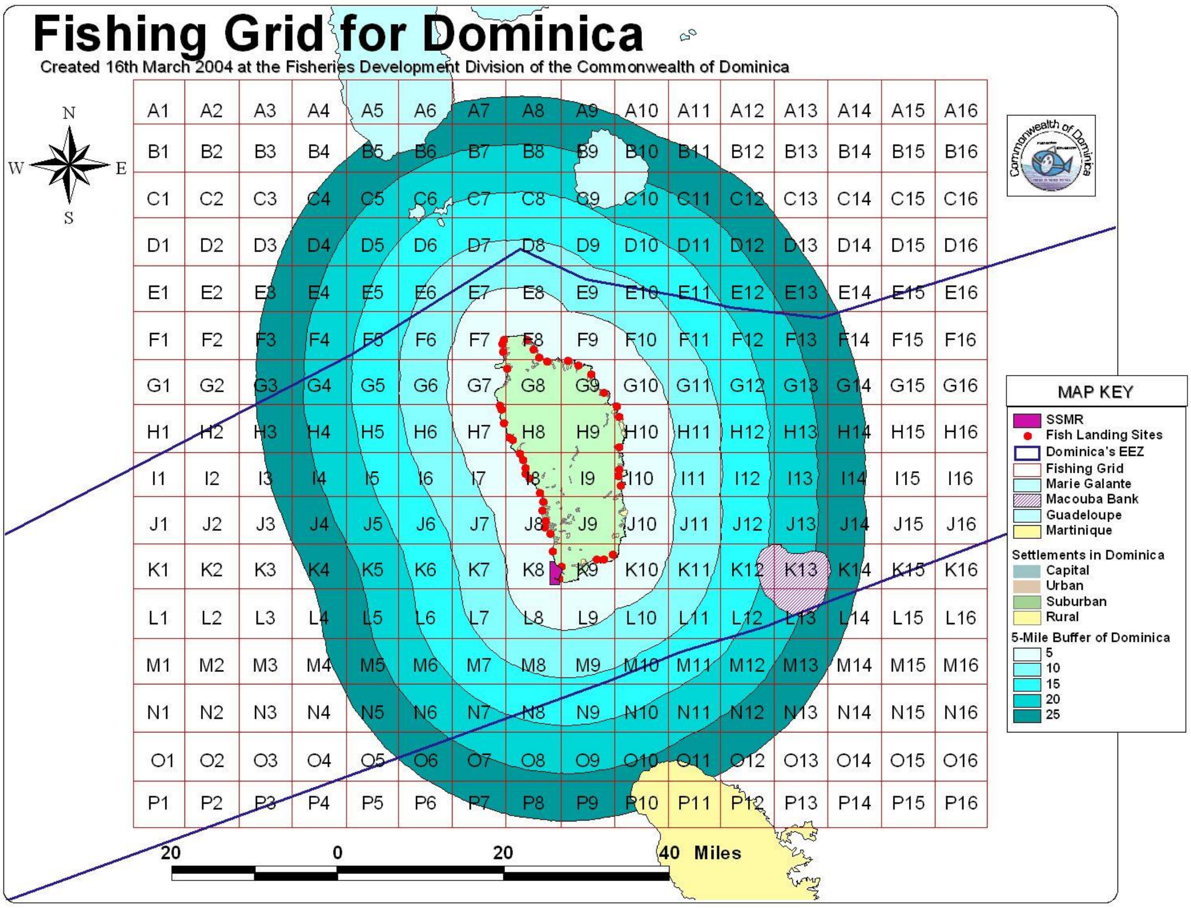

Figure 19. A grid map used in field sampling to identify fishing locations.

APPENDIX 6: LIST OF MEMBER STATES OF THE CRFM

1. Anguilla
2. Antigua and Barbuda
3. Grenada
4. Bahamas
5. Barbados
6. Belize
7. Dominica
8. Guyana
9. Haiti
10. Jamaica
11. Montserrat
12. St. Kitts and Nevis
13. St. Lucia
14. St. Vincent and the Grenadines
15. Suriname
16. Trinidad and Tobago
17. Turks and Caicos

APPENDIX 7: R COMMANDS USED FOR MODELLING DOLPHINFISH CPUE

Model0: minimal model
model.0 <- lm(log(kg)~log(trips) + factor(year), trips.dol[trips.dol$kg>0,])

Model1: intermediate model
model.1 <- lm(log(kg)~log(trips) + factor(year) + factor(month) + port, trips.dol[trips.dol$kg>0,])

Model2: CRFM model
model.2 <- lm(log(kg)~log(trips) + factor(year) + type + factor(season), trips.dol1[trips.dol1$kg>0,])

Model3: full model
model.3 <- lm(log(kg)~log(trips) + factor(year) + factor(month) + port + type + gear, trips.dol[trips.dol$kg>0,])

Model4: full model using catch-rates
model.4 <- lm(log(rate) ~ factor(year) + factor(month) + port + type + gear, trips.dol[trips.dol$kg>0,])