SAMPLE-BASED FISHERIES SURVEYS TO ESTIMATE TOTAL LANDINGS USING CENSUS DATA IN ICELAND AND SAINT VINCENT AND THE GRENADINES

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ABSTRACT

Catch and effort data is used as the main source of information by Saint Vincent and the Grenadines Fisheries Division to assess the performance of the fisheries sector. Data is collected thorough sampling of landings from landing sites. These sites are widely dispersed in the multi-island state. A census in space sampling and time sampling strategy is utilised. Monthly catch estimates are generated for each landing site and to produce annual catch estimates by estimating the sum for all landing sites. This study evaluates sample-based survey strategies for sampling and estimating fisheries data and utilises the findings to provide recommendations to fisheries managers in Saint Vincent and the Grenadines. The current data collection and estimation method being used by fisheries managers in Saint Vincent and the Grenadines was also evaluated. The study found Neyman (optimal) sampling strategy to be useful in producing reliable estimates utilising less samples compared to unstratified and proportional sampling. This is important to Saint Vincent and the Grenadines where the budget is limited and sample sizes tend to be low.

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Glossary of Acronyms

CPUE: Catch Per Unit Effort
CRFM: Caribbean Regional Fisheries Mechanism
FAO: Food and Agriculture Organisation
Fpc: Finite population correction
GOSVG: Government of St. Vincent and the Grenadines
Kg: Kilograms
Kt: Kilotonnes
Lbs: Pounds
MAFFRT: Ministry of Agriculture, Forestry, Fisheries and Rural Transformation
Pers comm: Personal communication
Pers obs: Personal observation of the author
t: Tonnes
SVG: Saint Vincent and the Grenadines
SVGFD: Saint Vincent and the Grenadines Fisheries Division

1 INTRODUCTION

Fisheries resources are important for the socio-economic well-being of the world's population (Pauly, Watson, & Alder, 2005). Food security in particular is a major source of concern for policy makers and fisheries managers. In some developing countries fish is the major source of animal protein and some people are entirely dependent on fish as a source of food (Stamatopoulos, 2002). Unfortunately, fisheries resources globally are under threat of overexploitation, particularly in developing countries, where there are serious food security issues (Pauly, Watson, & Alder, 2005). Thus, there is need for appropriate fisheries management measures to ensure that fisheries resources can be used sustainably (FAO, 1995). In particular this needs application in developing countries where economies are weak and there is limited capacity to reverse these trends.

Fisheries statistics are the primary means used to assess the performance of a fishery. Fisheries statistics are also used to determine the contribution fisheries make to national economies. A group of data, approaches and concepts form the basis of fisheries data collection. Basic fisheries data includes catch, catch by species, fishing effort, first sale prices (prices at landing), and weight of catch. This basic data can then be used in a variety of ways (Table 1).

Significant effort goes into ensuring that fisheries data and their resultant statistics are of value to managers and other stakeholders. Not only must field data be collected in an appropriate manner, but adequate support systems must also be in place at the office for the receipt and management of these data. In most small-scale fisheries, the fisheries are often highly distributed over a large area making it difficult and expensive to collect fisheries data. As a result, the use of census approaches is impractical, instead sampling techniques are nearly always employed (Stamatopoulos, 2002). It is important that these sampling techniques are cost effective and sustainable (Graaf, Stamatopoulos, & Jarrett, 2017).

Table 1. Different uses for basic fisheries data (Stamatopoulos, 2002).

Issues addressed	Data used
Assessing food security	Total catch, catch by species, imports, exports, human population.
Assessing fishing mortality	Fishing effort.
Monitoring fishing operations	Locations of home ports and landing sites, numbers of fishing units by gear category, fishing effort by boat or gear category.
Assessing species or gear selectivity	Species composition, average weight and size of fish by boat or gear type.
Calculating abundance and exploitation	Catch by species, effort by boat/gear type.
Calculating fisheries importance to the economy	Total catch, catch and price by species.
Assessing fleet performance and profitability	Catch, fishing effort, average price of catch
Conducting socio-economic studies	Catch, fishing effort, prices of catch
Evaluating infrastructure investment at landing sites	Catch, fishing effort, prices of catch

Catch per unit effort (CPUE), also referred to as the catch rate, is frequently the most useful index available for the long-term monitoring of fisheries. It can be used to determine whether to increase or decrease fishing effort. CPUE can be used as an index for stock abundance where some relationship is assumed between CPUE and the stock size. Declines in CPUE may mean that the stock will not be able to maintain the current level of fishing effort while an increase in CPUE may mean that the population of the stock is increasing and hence more fishing pressure can be applied (FAO, 1999; Stamatopoulos, 2002).

2 FISHERIES MANAGEMENT IN SAINT VINCENT AND THE GRENADINES

St. Vincent and the Grenadines is a multi-island state located in the Western Central Atlantic Region in an area known as the Lesser Antilles (Figure 1). The country covers a total area of 389 km^2 and has a population of approximately 110,000 (United Nations Statistics Division, 2017). Thirty-two islands and cays make up Saint Vincent and the Grenadines. Of these, nine are inhabited (SVG Tourism Authority, 2009). The national economy is based mainly on agriculture and tourism. While fisheries contribute approximately 1.7% to the GDP (Fisheries Division, MAFFRT, GOSVG, 2014) the sector is very important to the livelihoods of thousands of Vincentians (FAO, 2002b), employing approximately 1,500 full time fishers, 1,000 part time fishers and 200 fish vendors (CRFM, 2017). There are also fish gutters, fish processors, fish exporters and restaurants that rely directly on fish caught in the local waters.

Numerous agencies and legal instruments govern the use of the coastal and marine space in Saint Vincent and the Grenadines. However, the direct management of the marine fishery resources lies within the mandate of the Fisheries Division in the Ministry of Agriculture, Forestry, Fisheries and Rural Transformation. Currently, the Fisheries Division has a staff of permanent and temporary workers who operate within different units as well as administration. The units of the Fisheries Division are: Biology and Research, Conservation, Data, Extension, High Seas, Public Education and Quality Assurance.

The fisheries sector in Saint Vincent and the Grenadines can be divided into high seas and domestic fisheries. The mean annual catch (2009-2015) for the high seas fisheries is 1,319 tonnes while the mean annual catch (2009-2015) for the domestic fisheries is 785 tonnes There are currently 33 vessels in the high seas' fisheries. These are tuna longline vessels registered to catch tuna and tuna like species in the International Convention for the Conservation of Atlantic Tunas (ICCAT) convention area. The main target species for these vessels are: yellowfin tuna (*Thunnus albacares*), big eye tuna (*Thunnus obesus*), albacore tuna (*Thunnus alalunga*) and swordfish (*Xiphias gladius*). The high seas unit is responsible for most of the administrative and monitoring, control and surveillance activities of these vessels while the Data Unit manages all catch and effort data for these vessels. The Biology and Research Unit, the High Seas Unit and the Data Unit collaborate in reporting catch statistics and other required information to ICCAT.

Figure 1. Map of Saint Vincent and the Grenadines.

Source: http://www.emersonkent.com/map_archive/st_vincent_grenadines.htm

The domestic marine fishing fleet of St. Vincent and the Grenadines consists of approximately 1000 vessels with approximately 800 of these being registered with the Fisheries Division. These vessels are of three main types (see Table 2).

Table 2. A description of the domestic fleet of Saint Vincent and the Grenadines. Fisheries Division, CARIFIS 2011 in (SVGFD, 2014).

Vessel type	**Description**	**No. registered**
Pirogue	These are open boats with a pointed bow and flat transom. However, the bow is much higher than that of the flat transom boats and they tend to be slightly larger, ranging from 7 – 10 m (19 – 30 ft) in length. They are constructed from fibreglass and powered by one or two outboard gasoline engines ranging from 40 -85 horsepower. These vessels are predominantly used in the trolling and demersal fisheries.	390
Flat transom (Bow and stern)	These are commonly called bow and stern or dories. They are open boats of 3 – 6 m (11- 27ft) in length. They are constructed from wood or marine plywood which in many cases are covered by epoxy or fibreglass, which provides a waterproof covering. They are often powered by one or two outboard gasoline engines ranging from 14 – 115 horsepower. In rare cases, oars may be the only form of propulsion. These vessels are used mainly in the lobster and conch fishery.	230
Double enders	Double enders or two bows are open wooden boats ranging from 3 – 9 m (10 – 29 ft) in length. Both ends of the boat are shaped like the bow of a boat. In most cases the only means of propulsion are oars, but occasionally, they may be powered by a small outboard gasoline engine specially rigged at one end of the boat. These engines range from 6 – 48 horsepower. These vessels are used mainly in the beach seine fishery.	69
Multipurpose	In SVG these vessels range from 10.6 -14.8 m -(34.7 – 48.5 ft) in length. The main type of longliner is a Yanmar type made of glass reinforced plastic (GRP) powered by inboard diesel engines ranging from 90 – 190 hp. They are multipurpose in nature and designed to operate up to 150 nautical miles from the islands staying 3 to 5 days. These vessels are used primarily for tuna longline fishing, but may be utilized for trolling, bottom longline fishing, pot fishing and angling.	30
Others	These includes, canoes, rowboats etc.	18

The vessels typically start fishing in the morning and return by midday or in the afternoon. Most vessels do not carry ice to sea and hence the quality of the fish is not as good as it could be. Profit margin in the domestic fisheries vary from US$ 1000 to US$ 7000 monthly per fisher. The latter figure is mostly due to a few fish aggregating device (FAD) fishers and a few seine fishers, particularly those involved in the bait fish fishery (*pers obs*, 2014-2017). The bait fish fishery is the capture and sale of nearshore schooling pelagics to tuna longline vessels from Grenada, Trinidad, and the United States of America.

The majority of boats in the domestic fishery operate within the exclusive economic zone of St. Vincent and the Grenadines and most fish in what can be considered coastal waters. Exceptions include the whaling boats from Barrouallie and some line fishing boats that fish for small and medium sized pelagics. These boats can at times reach as far as 50 miles offshore (by their own estimation). The species targeted in these domestic marine fisheries include oceanic and inshore pelagics as well as shelf and deep slope demersals (SVGFD, 2014).

There are also fresh water fisheries in Saint Vincent and the Grenadines. These fall under the jurisdiction of the Forestry Department and are currently not being managed. The most noteworthy of these is a commercial fishery for 'tri tri', the fry of a native river goby (*Sicydium plumieri*) which is caught in estuaries. The Fisheries Division does collect information on the landings of 'tri tri'. There is also the recreational catching of river shrimps, locally referred to as crayfish, as well as the harvesting of a fresh water snail species, referred to locally as periwinkle, and anecdotal evidence suggests that escaped tilapia is being fished recreationally from at least one river. While there is no formal documentation of these fisheries, the capture of river shrimps and the harvesting of periwinkle has declined strongly (*Pers obs*). The focus of this study will be on the commercial domestic fisheries.

The overall policy for the fisheries sector is the sustainable use of all fisheries resources to maximize benefits to all Vincentians in the present and future. Therefore, management regimes should serve to enhance the opportunities for fisheries to play a greater role in contributing to national food security thereby improving nutrition. Protection of the marine environment in an effort to maintain and enhance its carrying capacity is also heavily emphasized. Additionally, fisheries development goals and strategies should ensure improvement of the socio-economic conditions of all stakeholders within the Vincentian population. Additionally, management objectives strive to maintain or restore populations of marine species at levels that can produce maximum sustainable yield influenced by relevant environmental and economic factors and taking into consideration relationships among species. Management objectives also include cooperation with other nations in regards to shared and migratory stocks and there is a heavy emphasis on the protection of the marine environment (SVGFD, 2014).

The policy framework and management objectives of the fisheries sector can be best achieved through the utilization of scientific approaches to fisheries and stock management, and properly collected and properly managed and analysed data is key to this.

The Data Unit is responsible for collecting and storing all catch and effort data for the domestic marine fisheries. Along with the Extension Unit, they are also responsible for collecting data on vessel registration. There are currently 5 data collectors collecting catch and effort data with 3 operating on the main island of Saint Vincent and 2 operating in the Grenadines. Currently, they do not collect biological data. Catch and effort data are collected at landing sites (Figures 2 and 3 and Table 3). The landing sites are zoned and categorized. There are 36 landing sites divided into 6 geographical zones (SVGFD, 2014; Jackson, 2017). Landing sites can be categorised as either primary, secondary or tertiary based on three main variables. These variables are, the number of fishing boats that regularly land fish at the site, the amount of fish regularly landed at the site, and the level of infrastructural development at the site (SVGFD, 2014). There are two primary sites (Kingstown and Barrouallie), fourteen secondary sites and twenty tertiary sites (SVGFD, 2014). The category of a site determines the frequency of sampling. Primary sites are most frequently sampled while tertiary sites are least sampled (Jackson, 2017). In addition to these on-shore landing sites, several trading vessels take fish directly from fishers and they are also classified as landing sites (SVGFD, 2014).

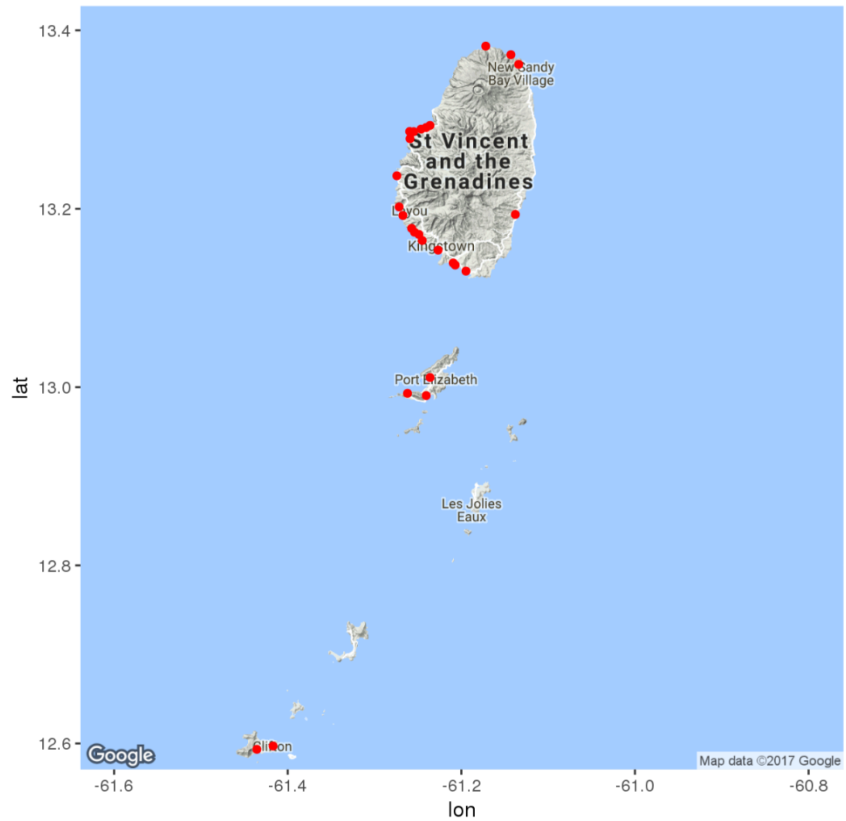

Figure 2. Landing sites (red dots) in Saint Vincent and the Grenadines.

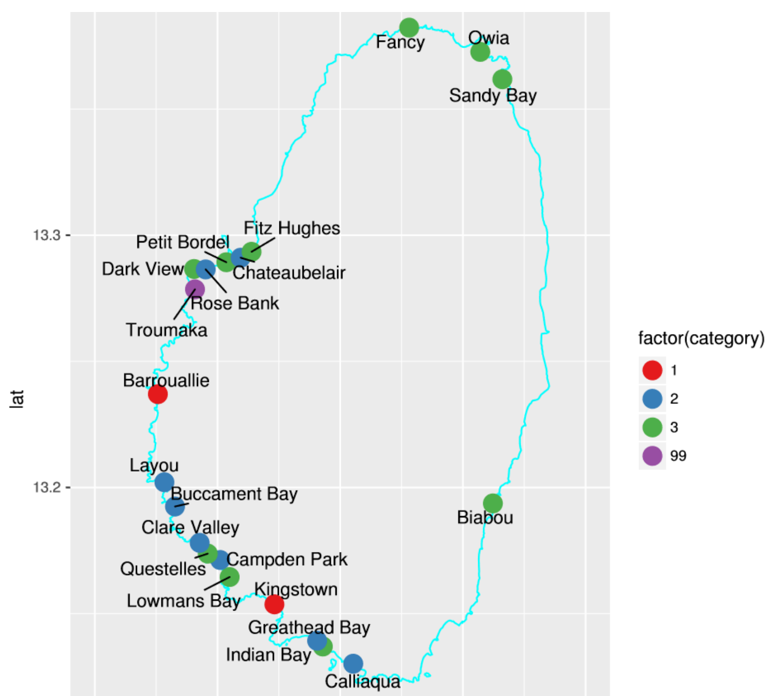

Figure 3. The location of landing sites in Saint Vincent.

Table 3. Fish landing sites in Saint Vincent and the Grenadines and their designated zone and categories. Modified from Fisheries Division Statistics, 1996-2000 in (FAO, 2002a).

Landing site	**Zone**	**Category**
	Zone 1	
Kingstown		1
Calliaqua		2
Campden Park		2
Great Head Bay		2
Indian Bay		3
Lowmans		3
Questelles		3
	Zone 2	
Barrouallie		1
Buccament Bay		2
Clare Valley		2
Layou		2
	Zone 3	
Chateaubelair		2
Rose Bank		2
Dark View		3
Fitz Hughes		3
Petit Bordel		3
	Zone 5	
Biabou		3
Fancy		3
Sandy Bay		3
Owia		3
	Zone 6	
Admiralty Bay		NA
Friendship Bay		NA
Paget Farm		NA
Port Elizabeth		NA
Trading vessels		NA
	Zone 7	
Clifton		NA
Aston		NA
Canouan		NA
Saline Bay		NA

1 represents a primary site.
2 represents a secondary site
3 represents a tertiary site

Catch and effort data are collected using a stratified sampling methodology (SVGFD, 2014). In this approach, the sampling frame (all of the identified landing sites within the country) is first partitioned into groups or strata and the sampling is then performed separately within each stratum (SVGFD, 2014). The strata are the primary, secondary and tertiary categories identified above. Simple random sampling is then used to select days of the month in each stratum when each landing site will be sampled.

While each day is considered a potential fishing day, sampling is not carried out on Saturdays, Sundays and major holidays. This simplifies data analysis and is not thought to introduce error since fishermen fish whenever they can regardless of what day it is (SVGFD, 2014). The method combines conceptual simplicity of simple random sampling with potentially significant gains in reliability. Information obtained from data collectors by the author indicate that on sampling days a full census is done on the boats that went fishing. Hence the field data collection strategy utilised by the Fisheries Division corresponds to the census in space, sampling in time sampling strategy (Stamatopoulos, 2002).

Landings are estimated using the "day effort at a landing site". Catch Per Day Effort (CPDE) is calculated for each of the species and this is used for estimating the landings. Catch per gear and vessel type is also estimated. The total amount of fish landed in the country is obtained by summing the totals of all the estimates for the individual landing sites. The estimated catch for any site is obtained by multiplying the sampled weight (x) by number of days fishing took place in a month divided by the number of days sampled. The value obtained when the number of days in a month is divided by the number of days sampled is referred to as the raising factor (rf). The catch per unit effort for most of the vessels and fishery type is calculated using the gear, the number of trips per year and sample weight in lbs per year (SVGFD, 2014).

Kingstown is the only site at which a total census is carried out. Licensing and Registration Programme (LRS) of fishers and fishing vessels started in 1995 and forms an integral part of the entire data collection effort. The Fisheries Division also collected detailed information on the area fished. It is intended that this information can add a spatial element to the data collected and would help in creating fishing ground maps.

Up until 2000, the catch and effort data were stored and processed in two DOS based relational databases developed to meet the needs of the Organisation for Eastern Caribbean States (OECS) member states. These were the Trip Interview Program (TIP) which was used for the entry and storage of the catch and effort data, and the Licensing and Registration System (LRS) software which was used for the entry and storage of licensing and registration information. At present catch and effort data is being stored and processed in Microsoft Excel.

3 FAO GUIDELINES FOR SAMPLE-BASED FISHERIES

Small-scale fisheries are often highly dispersed making the collection of data difficult and expensive. The costs involved in the collection of fisheries data include field and office personnel costs, field operations costs and other overhead and maintenance costs related to office infrastructure and operations. As a result, the use of census approaches is expensive and impractical, instead sampling methodology is nearly always employed. FAO has created sampling guidelines introducing fisheries managers to different sampling procedures that can be utilised in their fisheries. The techniques described can be applied to any reference such as a geographical stratum, a reference period or a specific boat or gear category. The estimation of secondary data such as catch by species, economic values and average fish size can also be conducted on the basis of the estimated total catch (Stamatopoulos, 2002; Graaf, et al., 2015).

It is important to know how to estimate fishing effort which is then used to estimate the total catch. There are four approaches that can be used in the estimation of fishing effort. These are: 1. complete enumeration through a census of fishing activities; 2. census in space and sampling in time; 3. sampling in space and census in time; and 4 sampling in both space and time. The approach to use depends on local conditions in the region and the availability of human resources (Stamatopoulos, 2002).

Total catch can be estimated from sample CPUE multiplied by estimated effort (Catch = CPUE x Effort). Total catch refers to all species taken together and is usually estimated within the context of a geographical area or stratum, a given reference period (e.g. a calendar month) or a specific boat or gear category (Stamatopoulos, 2002). The CPUE is an overall average derived from sampling and expressing how much fish (all species together) is caught by a unit of effort within the same context as that for the estimated catch. The effort represents the total number of boats-days within the same context used for total catch and CPUE. The total effort is usually assumed to be known (Stamatopoulos, 2002).

Once the total catch has been estimated, the estimated catch by species can be calculated by multiplying the proportion of a species found in the samples by the total catch (Species = SP x Catch) (Stamatopoulos, 2002). Using the catch by species and the estimated effort, it is possible to calculate the species-specific CPUEs.

In addition to following the appropriate sampling protocol, it is important that data collectors are adequately briefed. They need to know the purpose of the data collection programme, develop strong familiarity with the data recording form(s) they will be using, be familiar with the different issues that will arise concerning gear usage (e.g. use of gears sequentially and concurrently), they need to be familiar with each landing site and be able to observe the appropriate customs when approaching fishers and other persons at the landing. It is important that the information provided to data collectors is precise and unambiguous (Stamatopoulos, 2002).

When a population is heterogeneous, dividing the population into sub-populations called strata can help to increase the precision of estimates. Stratification is an important feature of fisheries sampling programs. Stratification reduces the errors in sampling estimates through the reduction of data variability. The principle of stratification is to divide the population in such a way that the elements within a stratum are as similar as possible. In a stratification design, every element of the population exists within a stratum and no element exists in two stratums at once. The strata should not overlap, and all strata should be sampled. The strata should be sampled separately with the estimates from each stratum combined to produce one estimate for the whole population. Different gear types of an artisanal fishery can be considered as different strata. The major objective of stratification is to reduce the variability of sampled data making it more reliable. This will reduce the number of samples needed and consequently make the sampling program less costly. However, it must be noted that over-stratification can increase the cost of a sample program. This is because with the creation of a new strata the cost increases since all strata must be sampled. When simple random sampling is applied to each stratum, the sampling design is called stratified random sampling (Cadima, et al., 2005; Graaf, et al., 2015; Stamatopoulos, 2002).

When sampling, the key question to be answered is, how many samples are needed? This question can be answered by using the relation between relative error and sample size (Graaf, et al., 2015). The number of samples needed is derived from the formula:

$$n = \left[\frac{{}^{t}n - 1^{s}}{\varepsilon\bar{x}}\right]^{2}$$

where:

${}^{t}n$ - 1^{s}	t-fractiles
s	sample standard deviation
$\bar{x}$	sample mean
ε	tolerated relative error

Because *n* and t are related, *n* cannot be calculated but must be estimated by calculating the relative error from a range of sample sizes and selecting the sample size where ε is closest to the tolerated value of ε. Population size has limited influence on the required sample size. The idea that one needs to sample a particular percentage of the fleet causing sample size to increase with population size is a misconception. Rather sample size is influenced more so by variability in the samples. If variability is high, larger sample sizes are needed. If variability is low, smaller sample sizes are needed. Hence, the percentage of the population that needs sampling is irrelevant and stratification to reduce variability is important (Graaf, et al., 2015; Graaf, Stamatopoulos, & Jarrett, 2017). An increase in sample size increases the accuracy of estimates. However, this relationship is not linear. For instance, the accuracy of estimates from a sample that is 50% of the population is not 50% but rather very near to 100%. Small samples sizes can produce estimates with high accuracy once the samples are representative of the population (Stamatopoulos, 2002). Hence beyond a particular sample size the increase in accuracy is negligible while the costs of sampling increase significantly.

When it comes to sample size, managers must determine what to do when they can only take a certain number of samples due to limited staff and budget (Graaf, et al., 2015). In this regard, two different allocation schemes are available to managers, proportional allocation and optimal (Neyman) allocation. In proportional allocation, samples are distribution among strata by taking only into consideration the proportion of different sampling units within the strata. For instance, if we are looking to sample catches from canoes landing at different landing sites. With a limited number of samples that can be taken sampling will be distributed among landing sites proportional to the number of canoes landing there. This can be represented as:

$$Sample\ size = max.no.samples\frac{no.canoes\ in\ stratum}{total\ no.canoes}$$

In Neyman or "optimum stratified sampling equation" sample size is determined by the size of the stratum and the standard deviation of the collected data. In Neyman (optimal) sampling the sample size per stratum should be large when the stratum is large and the standard deviation is large. In Neyman allocation the sample size is proportional to the number of vessels and standard deviation in each stratum (Graaf, et al., 2015). The overall aim of Neyman allocation is to reduce the variance in all of the samples. It does not focus on reducing the variance in individual samples. Neyman allocation uses the absolute values of the variance expressed through the standard deviation.

In sampling of fisheries catches where sometimes large differences in the absolute values of the mean exist and where the aim is to obtain high precision in the estimates of each stratum, Neyman allocation is probably not the most appropriate method (Graaf, et al., 2015). It could be more correct to use the coefficient of variation (standard deviation/mean) within each stratum to allocate the samples to different strata (Graaf, et al., 2015). In this case, the allocated sample size is proportional to the coefficient of variation within a stratum (Graaf, et al., 2015).

4 PROBLEM STATEMENT

There are two problems being addressed by this study. Firstly, there is a need to appraise the sampling methods provided in the FAO handbook 'Sample-based fishery surveys: A technical handbook' (Stamatopoulos, 2002). It is important that these sampling methods be appraised using data coming from fully-censused fisheries so that accurate comparisons and conclusions can be made. Secondly, there is a need to evaluate the catch and effort data collection, management and processing system of Saint Vincent and the Grenadines.

The commercial domestic fisheries of Saint Vincent and the Grenadines involve the commercial targeting of over 100 species of finfish, shellfish and mammals. With the decline in agriculture over the past two decades, the slow increase in tourism's contribution to the economy and an exclusive economic zone that is 27,500 km^2 (CRFM, 2017) as well as high seas fisheries, the fisheries sector is the most lucrative option available in developing the nation's economy. The policy and management objectives above show that the fisheries sector is highly valued as a mechanism for food security and economic development (SVGFD, 2014). However, stock assessments on commercial fisheries species are necessary if fisheries are to be regulated so that will contribute significantly to the economy. Unfortunately, due to financial constraints complete scientific assessments on the status of the stocks of these species does not take place on a regular basis. Before stock assessments can take place on these commercial species, it is also important that the catch and effort data on which these assessments will be based be collected in as accurate a manner as possible because this will affect the accuracy of the stock assessments. Hence, the need exists for the catch and effort data collection and management process for the commercial marine fisheries to be evaluated to determine how valuable the data collected will be in the production of stock assessments.

5 RESEARCH OBJECTIVES

The objectives of this research are:

1. To appraise the sampling and estimation procedures found in the FAO manual, Sample-based fishery surveys: A technical handbook (FAO, 2002) against known values from census data taken in the Icelandic hook and line (jigger) fleet.

2. To evaluate the catch and effort data collection and catch and effort estimation strategy utilised by the Fisheries Division for the commercial domestic fisheries in Saint Vincent and the Grenadines so that accurately collected and estimated catch and effort data will be available to generate stock assessments and other fisheries statistics.

3. To evaluate the data management strategy for catch and effort data in the domestic fisheries of Saint Vincent and the Grenadines.

6 METHODOLOGY

6.1 Study area and scope

An appraisal of the FAO sampling guidelines was done using data from 2010 to 2016 for the Icelandic jigger fleet. This data was collected from all landing sites in Iceland (figure 4). For the evaluation of the data collection and data management process for the domestic marine fisheries of Saint Vincent and the Grenadines, the proposed study area consists of the whole of Saint Vincent and the Grenadines. Catch and effort data from 1994 to 2016 was used to evaluate the data collection system and data management system.

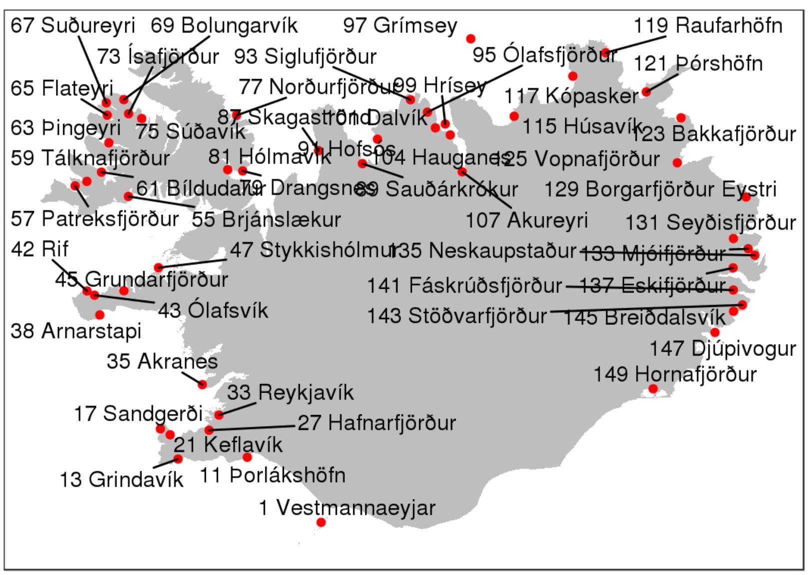

Figure 4. Landing sites for the Icelandic jigger fleet.

6.2 The use of Microsoft Excel and R

Microsoft Excel and R Studio were used for data cleaning, tidying, transformation, analyses and the creation of outputs. These programs are commonly used by data users to do the same globally (Grolemund & Wickham, 2017). Microsoft Excel and R Studio were used to check Catch and effort data obtained from the Fisheries Division in Saint Vincent and the Grenadines for errors and inconsistencies. The same was done for data from the Icelandic jigger fleet. Along with standard graphs and tables, calendar heatmaps were generated in R Studio to provide a better way to visualise daily data and sample days.

6.3 Appraisal of FAO sample-based fishery sampling guidelines

R Studio was used to explore fisheries harbours, trip and catch data from the 2010 to 2016 Iceland jigger fleet to determine what information was available and the manner in which it was stored. The data was explored and checked for potential errors or any inconsistencies that may impact the quality of the study. R Studio was then used to perform exploratory analyses on the census data in order to understand the nature of the hook fishery in space and time and to understand the general distribution of catch per trip. Various analyses were then conducted on the data to appraise concepts and recommendations in FAO sample-based fishery sampling guidelines such as variability, sample size, stratification, and sample allocation. This included investigating the required sample sizes for acceptable accuracy and the effects of applying different sampling schemes to sampled data.

Random samples were taken from all 2016 trips in the Icelandic jigger fleet. Stratification was not taken into consideration when selecting the samples. These samples were used to estimate the CPUE (catch per trip) which was then used to compute the total catch by the following formula:

Catch (2016) = CPUE (of sample) * Effort (from census)

Repeated sampling was conducted on the census data to estimate the mean coefficient of variance produced under different sampling strategies (random, proportional and Neyman).

Attempts were made to design a sampling programme for this fishery however the seasonal nature of the fishery made this inappropriate.

To generate monthly statistics, 100 random samples were taken from mackerel trips and trips containing other species for the Icelandic jigger fleet for the month of August 2016. The confidence interval was estimated using:

$$\bar{m} = \pm t_n - 1 \frac{s}{\sqrt{n}}$$

Where:

$\overline{m}$ is the mean

n is the sample size

s is the standard deviation in the sample

$t_n - 1$ is the Student t-statistics at a desired confidence level (if *n* is large it approaches 1.96).

The standard error is:

$$se = \frac{s}{\sqrt{n}}$$

The sampling error is:

$$\varepsilon = t_n - 1\frac{s}{\sqrt{n}}$$

The above equations apply in a strict sense only if the population size is infinite. In the case of the Icelandic jigger fishery for the month of August the population size must be treated as finite. Hence a finite population correction factor (fpc) is needed. The finite population correction factor (fpc) is:

$$fpc = \sqrt{\frac{N-n}{N-1}}$$

The finite population correction factor is applied to the sampling error:

$$\varepsilon_{fin} = \varepsilon\, fpc$$

The full equation for the confidence interval of a finite population is:

$$\overline{m} = \pm t_n - 1\frac{s}{\sqrt{n}}\sqrt{\frac{N-n}{N-1}}$$

The confidence interval then is:

lower = $\overline{m}$ - ε

upper = $\overline{m}$ + ε

In sampling-based fishery surveys, one often expresses desirable accuracy as wanting to be sure to a particular percentage that the true mean deviates no more than a particular percentage from the estimated mean e.g. one expressing a desirable accuracy of wanting to be 95% sure that the true mean deviates no more than 10% from the estimated mean. The percentage deviation from the mean is often expressed as relative error. The relative error is:

$$\varepsilon r = \frac{\varepsilon}{\bar{m}}$$

The relative error is often expressed as a percentage. Sample size can be estimated using the following formula (Graaf, et al., 2015):

$$n_0 = \left(\frac{t_n - 1^s}{\varepsilon_r \bar{m}}\right) 2$$

Where

$t_n - 1$: t-fractiles, a value that is dependent on *n*

s: sample standard deviation

$\bar{m}$: sample mean

ε_r : maximum relative error expressed as a proportion

The equation above assumes that the population is infinite. For finite populations the fpc factor is applied and the equation becomes:

$$n \quad = \left(\frac{n_0 N}{n_0 + (N - 1)}\right)$$

6.4 Data collection, tidying and cleaning for Saint Vincent and the Grenadines data

Catch and effort data from 1994 to 2016 for the commercial domestic fisheries in Saint Vincent and the Grenadines was collected and analysed for potential mistakes, inaccuracies and inconsistencies in data recording. Two main programs were used to facilitate this process, Microsoft Office Excel and R Studio. Procedures were generated in Microsoft Excel and R for generating efficient reporting procedures of standard statistics from these data.

6.5 Analysis of the data collection and estimation process for Saint Vincent and the Grenadines

The catch and effort data collection, catch and effort estimation processes utilized by the Fisheries Division for the commercial domestic fisheries in Saint Vincent and the Grenadines were analysed for their strengths and weaknesses. The catch and effort data collection, catch and effort estimation processes utilized by the Fisheries Division for the commercial domestic fisheries was evaluated based on FAO guidelines for sample-based fisheries (Stamatopoulos, 2002; Graaf, et al., 2015). Solutions for reducing any weaknesses discovered in these processes was recommended.

Data for 2016 were extracted from the dataset provided and analyses were run in R Studio and Microsoft Excel. Catch statistics were generated from the SVGFD 2016 catch and effort data in order to analyse the accuracy and precision of the samples collected using currently sampling protocol. To provide a better picture of what occurs at landing sites the SVGFD January 2016 catch and effort data was also segregated and analysed. This assisted in providing a more detailed picture of what is taking place. Additionally, statistics were generated in R Studio to facilitate the proportional reallocation of samplings by landing site.

6.6 Analysis of data management procedures for Saint Vincent and the Grenadines data

The method used to store and manage data by the Fisheries Division for the commercial domestic fisheries in Saint Vincent and the Grenadines was evaluated for its strengths and weaknesses. The evaluation was done through a review of the electronic data files obtained from the Fisheries Division. Analyses were also performed in R to assist with the review.

7 RESULTS

7.1 The Icelandic census data for the jigger (hook and line) fishery

The Icelandic hook and line fishery is performed by small fibreglass vessels less than 15 meters in length (during part of the year these vessels also use long-line gear that are not considered in this study). A fishing trip normally does not exceed more than a day.

The annual landings of the jigger fleet have ranged between 10 thousand to 25 thousand tonnes (figure 5). The fishery has traditionally targeted cod, with saithe as bycatch but in recent years a targeted mackerel fishery has developed. Although the latter uses hooks the gear-setup is different than in the targeted cod fishery. The mackerel fishery can solely be described as a clean fishery with only 0.3% catch of other species while in the targeted cod fishery around 11.4% is other species (Table 4).

The fishery is highly seasonal, with the highest catches in the cod fishery in 2016 occurring over the months of May to September but that of the mackerel being limited to the months of August and September (Figure 5). The landings from the cod fishery are widely distributed along the Icelandic coast, while the landings of mackerel being limited to the southwest coast (Figure 6).

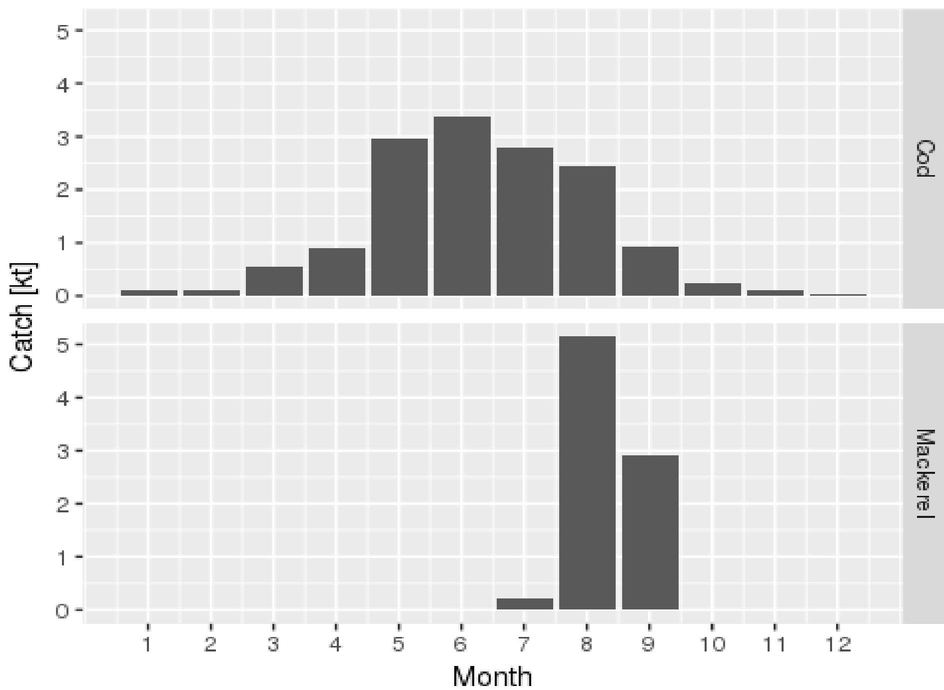

Figure 5. Catch by month of the Icelandic jigger fishery for the year 2016 split by the fishery targeting cod and mackerel.

Table 4. Proportion of species caught in the targeted cod and mackerel fishery in 2016.

Species caught	Percentage in catch	
	Cod Trips	Mackerel Trips
Cod	88.6	0.2
Mackerel	0.0	99.7
Saithe	9.8	0.1
Other	1.6	0.0

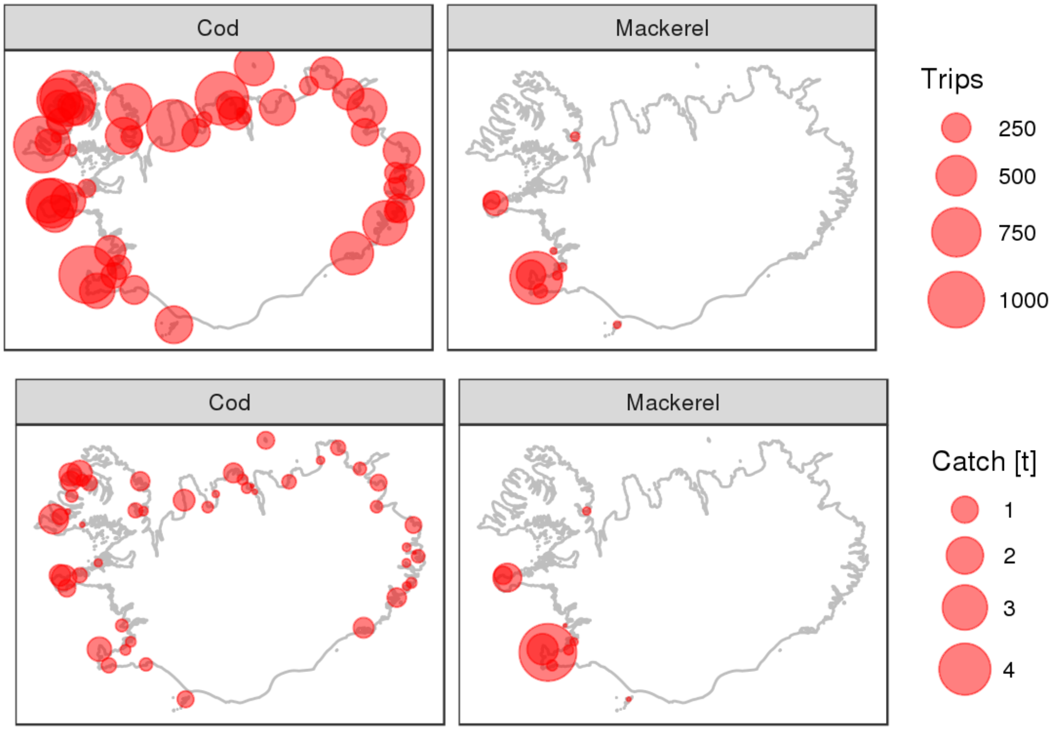

Figure 6. Distribution of landings and catches of mackerel and cod of the jigger fishery by landing sites in 2016.

The distribution of the catch per trip shows that in the cod fishery catches are infrequently above 1 tonne while the catch per trip in the mackerel fishery shows much higher variability, with catches up to 10 tonnes not uncommon (Figure 7 and Table 5). In general, the number of trips in the mackerel fishery are relatively few compared with the cod fishery, but the mean catch is 7 times higher. Hence the total landings in the mackerel fishery are only about 40% lower than in the cod fishery.

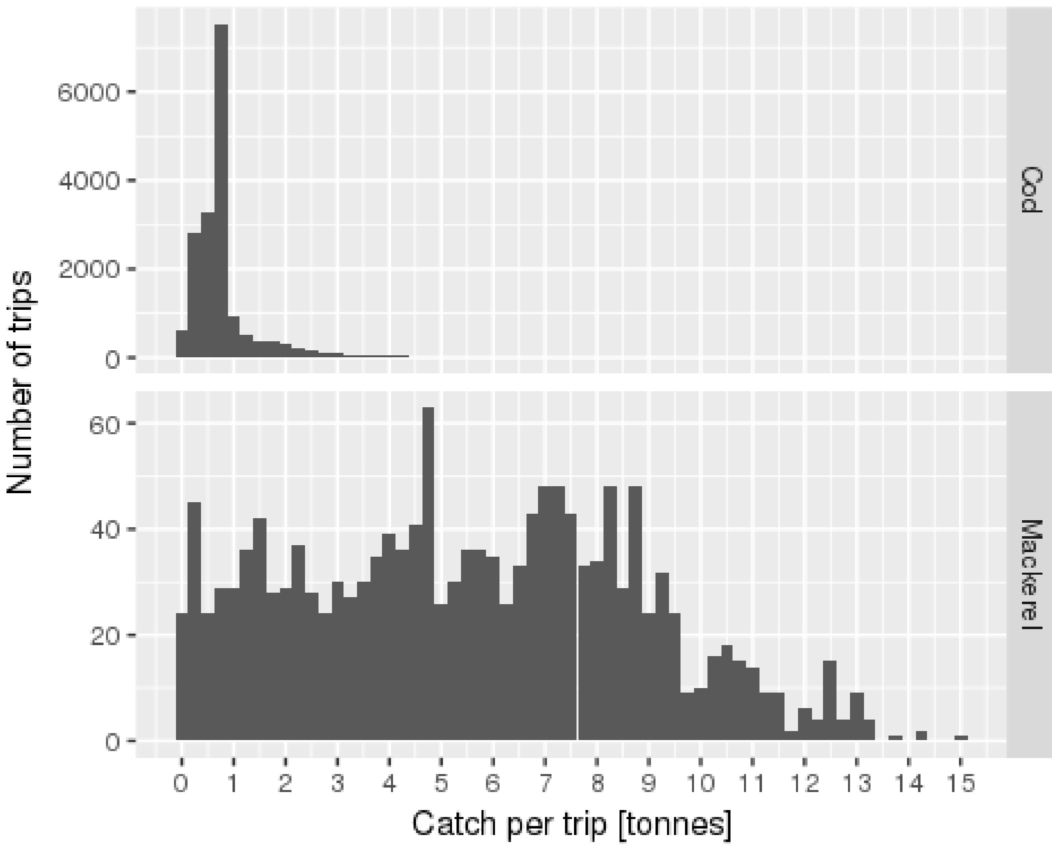

Figure 7. Distribution of the catch per trip for the cod and mackerel jigger fishery in 2016.

Table 5. Variability in catch per trip in the Icelandic jigger fishery in 2016.

Type of trip	**No. of trips**	**Total catch in 2016 (tonnes)**	**Mean catch per trip (tonnes)**	**Standard deviation**	**Variance**
With mackerel	1500	8290	5.53	3.25	10.6
No mackerel	17626	14561	0.826	0.727	0.528
All trips	19126	22852	1.19	1.71	2.91

Variability in the catch per trip in the cod fishery (Figure 8) show that the variability in the catch are relatively lower in the summer months compared with other months in the year. This is partly a reflection of management measures during an Olympic-style summer fishery targeting cod, where a maximum cap on a catch per trip is set.

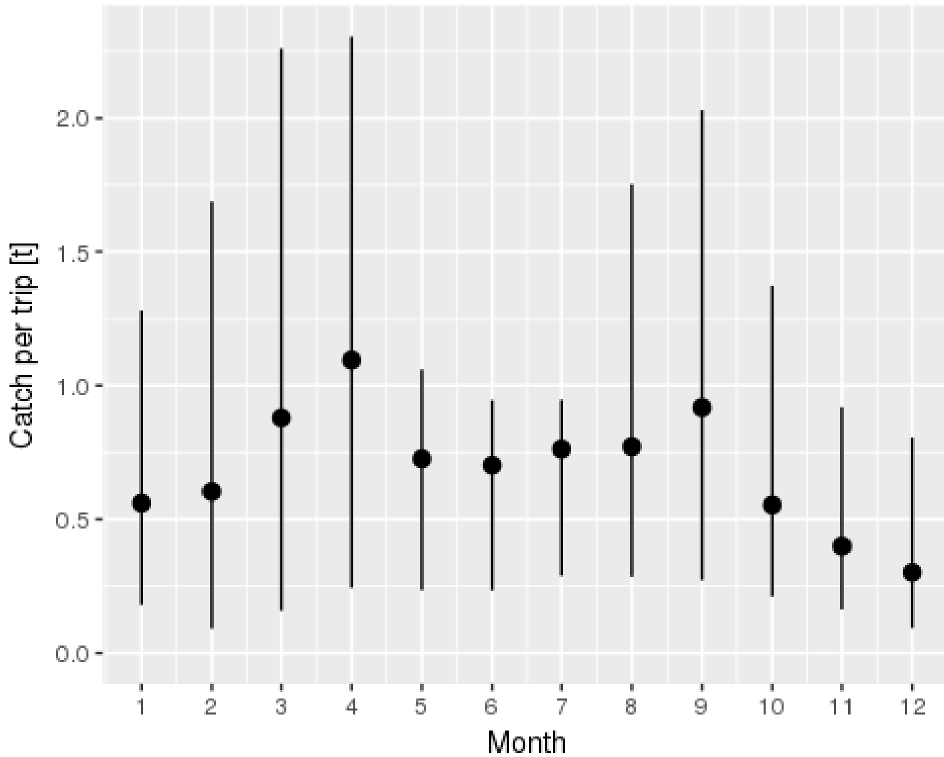

Figure 8. Median and 80% distribution of catch per trip in the cod fishery by month.

Because of the observed difference in the variance of catch per trip in the mackerel and cod fishery (Figure 5 and Table 5) the FAO guidelines suggest that a stratification of the two fisheries would increase the precision in the estimates in the catch per trip and subsequently total landings.

This was tested by taking a single draw of 1000 catches per trips from the 2016 census data (emulating sampling of catches) using no stratification in the calculation, proportional stratification based on the number of trips in each fishery and Neyman (optimal) allocation where number of trips is weighted by the variance of the estimated catch per trip. In each case the mean catch per trip was estimated along with associated statistics (Table 6).

Table 6. How variance in catch per trip affects sampling design.

Sampling strategy	**Target species**	**Number of samples**	**Mean catch per trip (tonnes)**	**Variance**	**Standard deviation**	**Coefficient of Variation**
Unstratified	All	1000	1.100	2.033	1.426	4.10
Proportional	Cod	922	0.816	0.462	0.679	2.74
Proportional	Mackerel	78	5.319	8.635	2.938	6.26
Neyman	Cod	724	0.816	0.526	0.725	3.30
Neyman	Mackerel	276	5.387	9.043	3.007	3.36

Table 6 demonstrates how variance in catch per trip affects sampling design. If variances are not taken into consideration (proportional allocation) relatively few mackerel trips would be sampled resulting in a relatively high coefficient of variation. On the other hand, sampling based on Neyman (optimal) allocation results in more samples being allocated to the mackerel fishery resulting in low coefficient of variation for that fishery at the cost of some increase in the sampling of the cod fishery.

The estimates of the catch per trip based on these 1000 samples were raised and summarised to total annual landings using the census effort data (Table 7). In general, the standard error and coefficient of variation was lower when using stratification, the Neyman (optimal) allocation producing marginally higher precision. The effect of sample size, using repeated sampling of the census data illustrates the general effect of stratification on the precision in the estimates (Figure 9). The overall pattern is that the coefficient of variation decreases with increasing sample size. For a given level of precision (here expressed as cv) the samples size needed decreases substantially when moving from unstratified sampling to proportional and ultimately Neyman (optimal) sampling allocation.

Table 7. Using unstratified, Proportional and Neyman (optimal) allocation of samples to generate an annual estimate of catch for the Icelandic jigger fishery.

Annual catch from Cencus data (tonnes)	**Lower confidence limit**	**Estimated catch (tonnes)**	**Upper confidence limit**	**Error**	**Standard error**	**Coefficient of variance**	**Allocation method**
	19.4	21.0	22.7	1.69	0.862	0.0410	Unstratified
22.9	21.1	22.4	23.6	1.25	0.636	0.0284	Proportional
	21.4	22.5	23.5	1.07	0.547	0.0243	Neyman

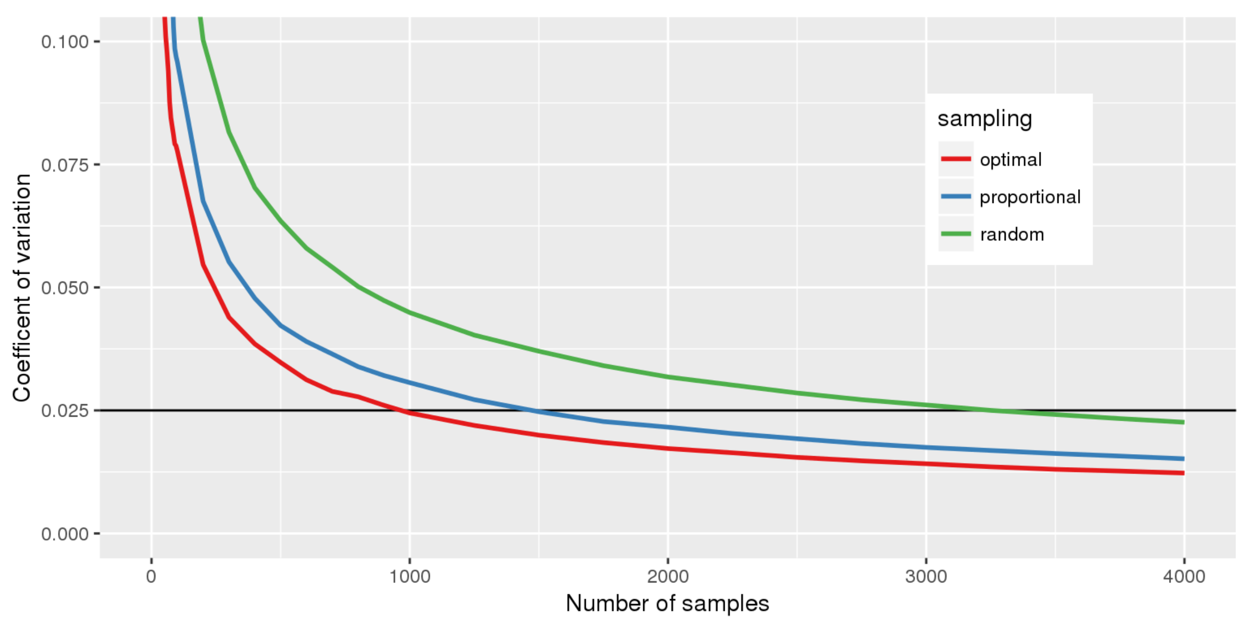

Figure 9. The number of samples needed using different sampling strategies to obtain a tolerance level of 2.5 % (coefficient of variation of 0.025).

7.1.1 Stratification by month and fishery

If the management objective is to obtain accurate estimates of total landings by month the time step has to be set as primary strata. The seasonal variability in the variance of the catch per trip in the cod fishery would though on statistical grounds suggest fewer strata. If the objective is also to obtain accurate monthly statistics on the cod and mackerel fishery separately one would categorize that as secondary strata.

The primary objective here, instead of allocating a prefixed number of samples to strata is to estimate minimum sampling size within each minor stratum (month and fishery) for a given level of precision. When no data is available one needs to set-up a pilot study to estimate the variability in the catches. Here a pilot study was emulated using 100 randomly sampled trips for each month and fishery (only August and September for the mackerel fishery) (Table 8).

Table 8. The minimum number of samples needed per month for the mackerel and cod (other) fisheries at the 10% (n10) and 5% (n05) tolerance level.

Month	**Target**	**n[1]**	**m[2]**	**sd[3]**	**N[4]**	**n10**	**n05**
1	Cod	100	0.718	0.593	166	103	144
2	Cod	100	0.695	0.623	151	102	135
3	Cod	100	0.939	0.781	513	177	347
4	Cod	100	1.307	0.828	729	130	336
5	Cod	100	0.840	0.623	3922	203	698
6	Cod	100	0.722	0.481	4528	167	596
7	Cod	100	0.733	0.388	3536	108	388
8	Mackerel	100	5.694	2.871	867	91	272
8	Cod	100	0.822	0.787	2642	314	921
9	Cod	100	4.874	3.207	558	130	305
9	Mackerel	100	1.151	0.934	850	197	464
10	Cod	100	0.672	0.505	317	131	233
11	Cod	100	0.471	0.315	215	97	165
12	Cod	100	0.372	0.331	57	49	55

[1]The number of samples taken to investigate the number of samples needed for 5% and 10% tolerance levels.
[2]The mean catch per trip (tonnes) based on the 100 pilot samples.
[3]Standard deviation based on the 100 pilot samples.
[4]The number of trips (from census data).

Results from the pilot study show that the higher the tolerance level the higher the number of samples required (Table 8).

Following the pilot study to investigate variability and generate sample monthly sizes it is now possible to estimate mean catch per month (Table 9). To double test the algorithm and investigate how many times the estimated catch deviates by more than 10% from the true mean, random sampling was simulated 500 times for the month of August. In each draw the number of samples taken were 90 for mackerel and 258 for the targeted cod fishery. For each random sampling CPUE (the sample mean) and CPUE (the census mean) was calculated (Figure 7).

Table 9. Mean catch per month for mackerel and cod based on sample size using a 10% tolerance level.

Month	Target	n	m	sd
1	Cod	103	0.680	0.544
2	Cod	102	0.799	0.796
3	Cod	177	1.040	0.844
4	Cod	130	1.192	0.864
5	Cod	203	0.737	0.471
6	Cod	167	0.768	0.747
7	Cod	108	0.726	0.435
8	Mackerel	91	5.768	3.302
8	Cod	314	0.945	0.921
9	Mackerel	130	5.328	3.403
9	Cod	197	1.120	0.856
10	Cod	131	0.767	0.591
11	Cod	97	0.527	0.439
12	Cod	49	0.396	0.311

n: number of trips.
m: mean catch.
sd: standard deviation.

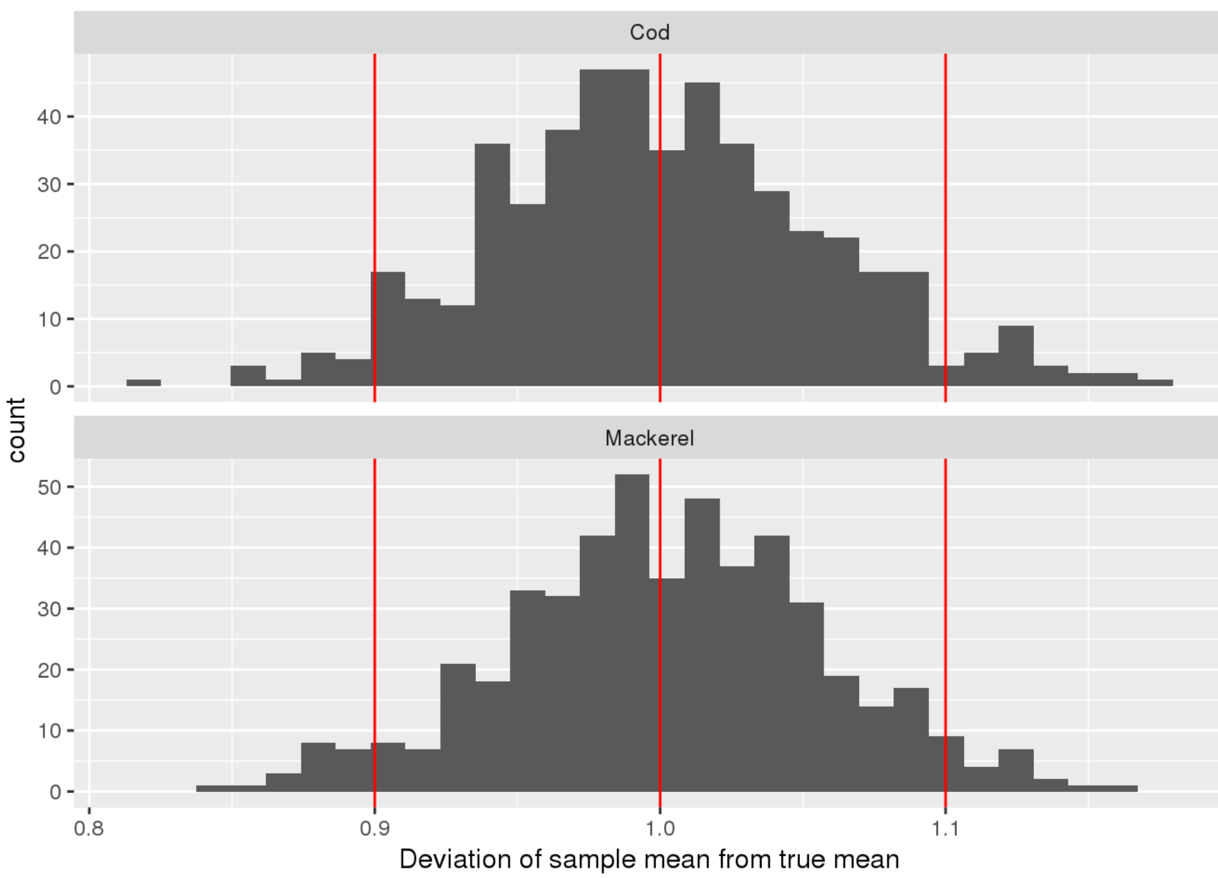

Figure 10. Deviation of the sample mean for the true mean.

Figure 10 shows the ratio of the sample mean over the true mean. In a number of cases, the estimated mean is more than 10% ‘away’ from the true mean. It is expected that in 95% of the cases, the sample mean would be within those tolerance limits, however, only 93% and 94.6% of the simulation for mackerel fell within the expected range. The sample sizes in the pilot study was increased and the study was repeated (Figure 11).

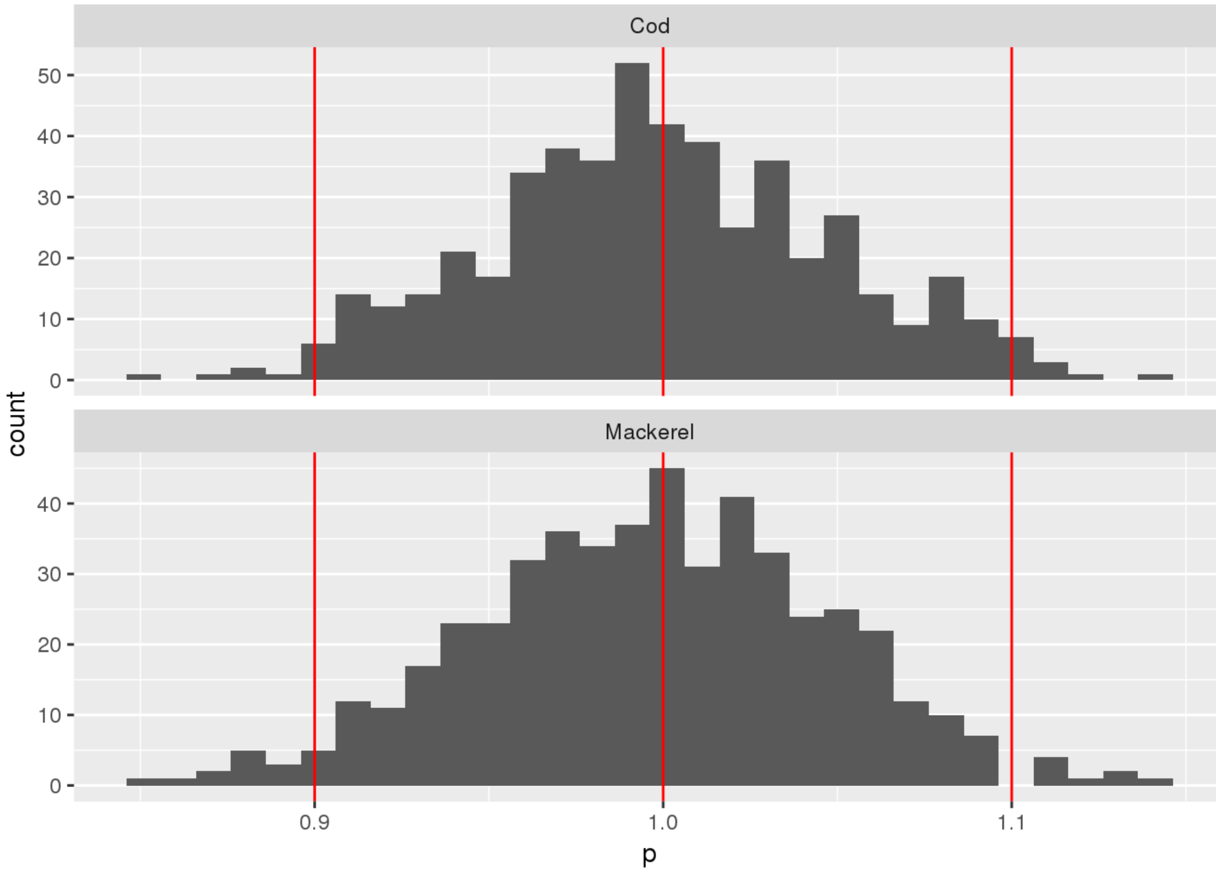

Figure 11. Deviation of the sample mean from the true mean after sample sizes were increased and pilot study repeated.

Table 10. Estimating total catch per month for mackerel and cod in the Icelandic jigger fishery (2016).

Month	Target	N[1]	Catch[2]	n[3]	m[4]	sd[5]	catch[6]	se[7]	cv.se[8]	Error[9]	lower[10]	upper[11]	r[12]
1	Cod	166	111.903	103	0.680	0.544	112.911	0.054	0.079	17.654	95.256	130.565	0.991
2	Cod	151	116.656	102	0.799	0.796	120.708	0.079	0.099	23.594	97.114	144.302	0.966
3	Cod	513	551.534	177	1.040	0.844	533.419	0.063	0.061	64.242	469.177	597.661	1.034
4	Cod	729	897.523	130	1.192	0.864	868.873	0.076	0.064	109.245	759.628	978.118	1.033

5	Cod	3922	2962.705	203	0.737	0.471	2889.297	0.033	0.045	255.625	2633.672	3144.921	1.025
6	Cod	13	11.276	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6	Cod	4528	3394.791	167	0.768	0.747	3478.345	0.058	0.075	516.732	2961.612	3995.077	0.976
7	Mackerel	51	202.717	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7	Cod	3536	2800.876	108	0.726	0.435	2567.071	0.042	0.058	293.471	2273.599	2860.542	1.091
8	Mackerel	867	5148.572	91	5.768	3.302	5000.961	0.346	0.060	596.277	4404.684	5597.238	1.030
8	Cod	2642	2433.767	314	0.945	0.921	2497.220	0.052	0.055	270.329	2226.891	2767.549	0.975
9	Mackerel	558	2919.830	130	5.328	3.403	2973.294	0.298	0.056	329.547	2643.747	3302.842	0.982
9	Cod	850	931.329	197	1.120	0.856	952.203	0.061	0.054	102.225	849.978	1054.428	0.978
10	Mackerel	11	7.884	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10	Cod	317	227.949	131	0.767	0.591	243.245	0.052	0.067	32.392	210.854	275.637	0.937
11	Cod	215	108.547	97	0.527	0.439	113.352	0.045	0.085	19.030	94.322	132.381	0.958
12	Cod	57	23.735	49	0.396	0.311	22.580	0.044	0.112	5.084	17.496	27.664	1.051

[1]N: Effort, number of trips per month
[2]Catch : Census catch
[3]n: Number of samples taken
[4]m: Mean catch per unit effort (tonnes)
[5]sd: Standard deviation of the sample
[6]catch: Estimated catch (tonnes)
[7]se: Standard error of the mean
[8]cv.se: The coefficent of variation of the mean
[9]error: The sample error at 95% confidence level
[11]lower: The lower confidence bound of the catch
[12]upper: The upper confidence bound of the catch
[13]r: The ratio of census catch (Catch) vs the estimated catch (catch).

Using the mean catch per month and the effort (number of trips per month) it was possible to estimate the total catch per month (Table 10). Generally, the estimated catch was within 10% of the true catch, i.e. the ratio was within 0.90<= r <= 1.10 (the criterion used when the number of samples were decided). This was not the case in every month because there is 5% probability that the true catch will lie outside the +/- of the estimated catch (1 in every 10 cases) i.e., it can be expected in 1 out of every 10 cases that the estimates lies outside the stated tolerance level, so this can be expected to happen at minimum in one month over the whole year.

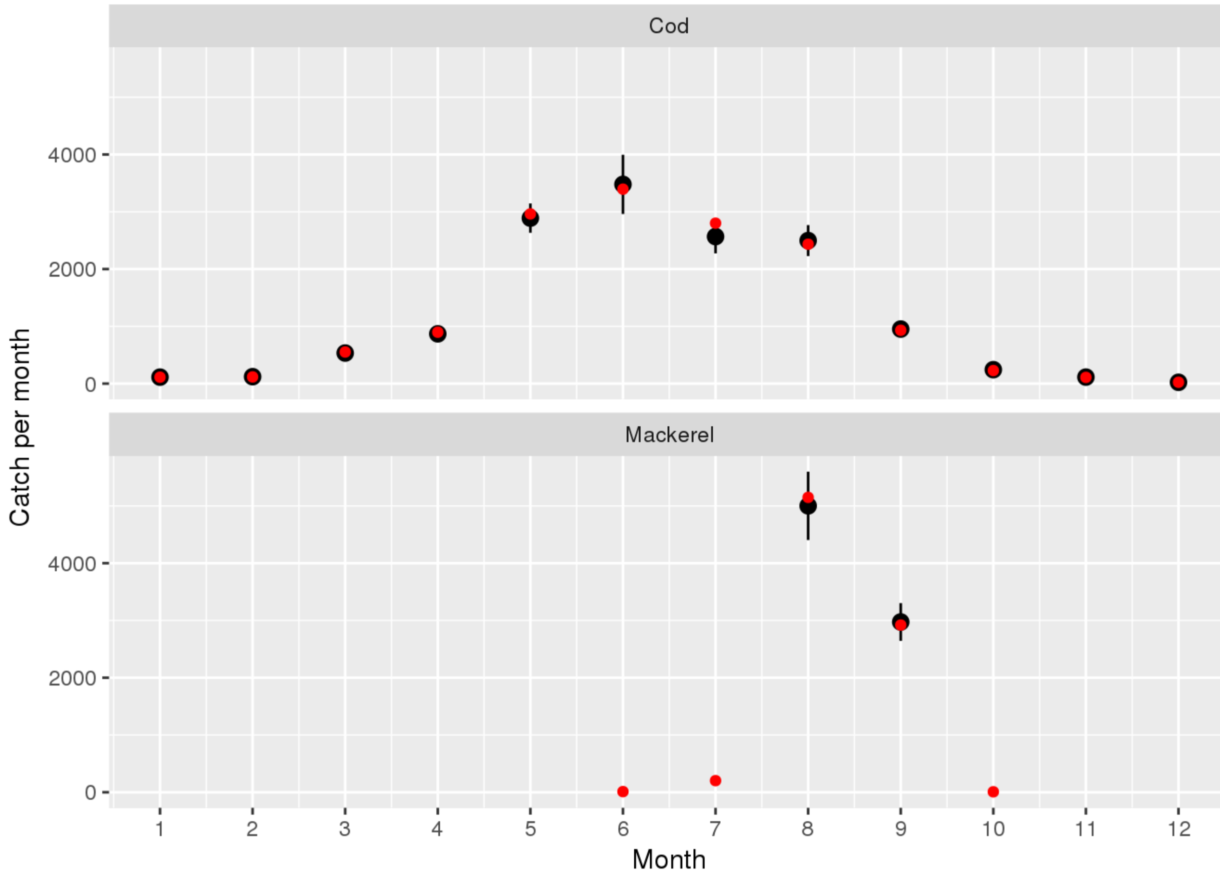

Figure 12. Monthly census catc h (red dot) and estimated catch and 95% confidence interval (black dot and vertical bar) for the Icelandic jigger fishery in 2016.

7.2 An analysis of the data collection and estimation process of Saint Vincent and the Grenadines

Documentation on the process and procedures involved in the collection of catch and effort data is very limited and written instructions are not provided to data collectors to aid them in the data collection process (*pers comm* with members of staff of the SVGFD). Disparities were found in the information provided by the Fisheries Division concerning the method it uses to obtain monthly estimates. The Fisheries Division indicated that the estimate for any site is obtained from multiplying the sample weight by the number of days in a month divided by the number of days sampled (SVGFD, 2014). It was indicated that this is because every day is considered a fishing day. However, subsequently, the SVGFD from informal conversation with the author indicated that the estimate for any site is obtained from multiplying the sample weight by the number of days fished divided by the number of days sampled. An investigation of the data shows the latter to be true. For instance, the sample weight of wahoo (*Acanthocybium solandri*) obtained at Calliaqua on the 28th December from Bernie Wright was 16lbs. This value was raised to a monthly landings value of 60.8lbs by multiplying the sample weight (16lbs) by the number of active fishing days (19) divided by the number of days sampled (5):

Monthly estimates from a sample = 16 x (19/5)

While the value of the total catch for a species is calculated by the SVGFD under same principles as that put forward by the FAO. That is, the sample sale price of a landed species multiplied by the estimated catch for that species, there is a difference. While the FAO manual indicates that the first sale price of the species should be used (i.e. the price as sold by the fishers), the price being used by the SVGFD is the price per pound as being sold by fish vendors after it has been sold to them by the fishers. The estimated total value of landings is calculated by the FAO and SVGFD by adding up all estimated values by species.

The reported sampling days and trips sampled in the Saint Vincent and the Grenadines domestic fisheries were low for the landing sites in 2016 (Table 11). The standard deviation and coefficient of variance for catches at the landing sites were relatively high (Table 12). For the entire year no trips were sampled in Fancy even though 28 sampling days were allocated to this site (Table 11). Sampling days do not seem to be allocated to different landing sites based on their designation (i.e. primary sites receiving more days and tertiary sites receiving the least). For instance, Kingstown the leading landing site had 41 sampling days reported for the entire year, while Rose Bank a secondary landing site had 67 sampling days reported and Owia a tertiary landing site had 83 sampling days reported (Table 11). The number of sampling days allocated to the landing sites were not allocated evenly throughout the year for all landing sites (Figure 13). Also, the percentage of sampling days with landings varied between landing sites (Figure 14). The total number of trips per landing site per month was also found (Figure 15).

In 2016 only 7 of the 23 landing sites had a mean of 2 or more trips occurring on a sampling day (Table 11). Kingstown had the highest number of trips sampled per day with 4.5 (Table 11). Other than Fancy where no trips were recorded in 28 sampling days, the landing site with the lowest mean number of trips per sampling day was Buccament Bay with 0.1 (Table 11). Additional statistics comparing samples on a gear by gear basis were also obtained (Table 13). High variation in catches was found for gears such as scuba and harpoon. The heaviest catch per trip were by harpooning and seining. The lowest catches per trip were trips where hand lining and bottom lining were the gears used.

Table 11. Sampling statistics derived from the 2016 catch and effort data for Saint Vincent and the Grenadines.

Landing site	**Reported sampling days**	**No. of trips sampled**	**Mean no. of trips sampled per day**
Kingstown	41	185	4.51
Rose Bank	67	227	3.39
Calliaqua	50	154	3.08
Paget Farm	96	262	2.73
Owia	83	184	2.22
Barrouallie	76	163	2.14
Port Elizabeth	1	2	2
Biabou	48	91	1.9
Clare Valley	44	54	1.23
Aston	104	115	1.11
Clifton	102	88	0.86

Indian Bay	35	25	0.71
Lowman's Bay	28	15	0.54
Fitz Hughes	31	15	0.48
Layou	43	20	0.47
Questelles	30	13	0.43
Petit Bordel	29	12	0.41
Campden Park	26	8	0.31
Dark View	29	5	0.17
Sandy Bay	45	6	0.13
Buccament Bay	52	5	0.1
Fancy	28	0	0

Table 12. Catch statistics for landing sites in Saint Vincent and the Grenadines Domestic Fisheries in 2016 (see Appendix 2 for values in lbs).

Landing site	**Mean catch (kg) per trip**	**Maximum catch (kg) per trip**	**Standard Deviation**	**Coefficient of variation**	**Standard error**	**Relative error**
Clare Valley	7.578615	136.0776	19.06583	1.141237	2.594546	0.342
Layou	16.24404	149.6854	38.08449	1.063673	8.515736	0.524
Barrouallie	79.61356	1587.572	185.1154	1.054601	14.49952	0.182
Questelles	31.92607	226.796	68.90698	0.978852	19.11119	0.599
Petit Bordel	33.98175	181.4368	53.52703	0.714407	15.45207	0.455
Paget Farm	58.00036	937.1211	85.55879	0.669048	5.285708	0.091
Lowman's Bay	30.33034	158.7572	40.79153	0.623689	10.53241	0.347
Fitz Hughes	72.09074	204.1164	77.9389	0.490333	20.12361	0.279
Rose Bank	6.167037	44.90561	6.150708	0.452231	0.408233	0.066
Dark View	10.1151	25.40115	9.882862	0.443159	4.4198	0.437
Port Elizabeth	35.60697	57.60618	31.11142	0.396439	21.99921	0.618
Kingstown	88.32525	408.2328	75.71403	0.388728	5.566481	0.063
Calliaqua	27.44322	143.7887	23.33595	0.385553	1.880592	0.069
Campden Park	3.147021	7.711064	2.59001	0.373306	0.915802	0.291
Buccament	90.7184	181.4368	71.07061	0.355163	31.78365	0.35
Chateaubelair	79.3219	204.1164	58.49114	0.334297	9.248287	0.117
Biabou	31.48745	104.3262	22.5916	0.325225	2.368204	0.075
Owia	18.06249	127.0058	12.88156	0.323411	0.949822	0.053
Clifton	16.73119	38.55532	8.455408	0.229064	0.901287	0.054
Ashton	16.50304	40.82328	8.293023	0.228157	0.773374	0.047
Indian Bay	9.2941	16.32931	3.36157	0.1642	0.672223	0.072
Sandy Bay	9.14759	11.3398	1.890118	0.093894	0.77156	0.084

Table 13. Catch statistics for different gears in the domestic fisheries sector of Saint Vincent and the Grenadines for the year 2016 (see Appendix 3 for values in lbs).

Gear	**No. of samples**	**Mean catch (lbs)**	**Maximum catch (lbs)**	**Standard deviation**	**Coefficient of variation**	**Standard error**	**Relative standard error**
Scuba	141	68.49239	937.1211	112.9444	0.748427	9.525432	0.139
Harpoon	31	263.9905	1587.572	337.926	0.580598	60.78133	0.23
Hand line	596	10.79549	94.80073	11.15836	0.471736	0.458128	0.0424
Trolling	390	31.11641	228.1568	29.75564	0.433634	1.505925	0.0484
Gill net	7	93.43995	181.4368	74.84268	0.36242	28.21342	0.302
Spear gun	118	22.31673	145.1494	17.2365	0.350627	1.587572	0.0712
Palang	80	31.16177	143.7887	23.22391	0.337926	2.599082	0.0833
Beach seine	125	143.7887	544.3104	93.89354	0.295288	8.391452	0.0582

Fish pot	181	35.69769	95.25432	21.59098	0.274877	1.605716	0.045
Bottom line	12	16.7829	45.3592	9.842946	0.265805	2.839486	0.169
Total	**1681**						

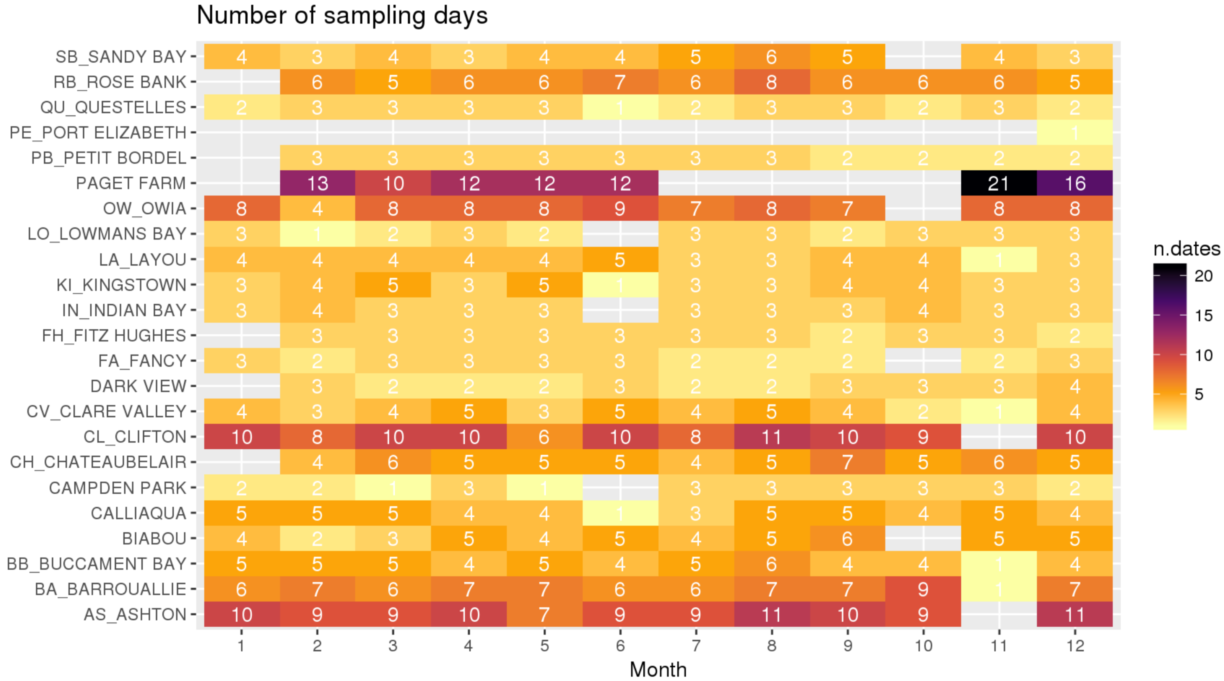

Figure 13. The number of sampling days allocated to fish landing sites in Saint Vincent and the Grenadines in 2016.

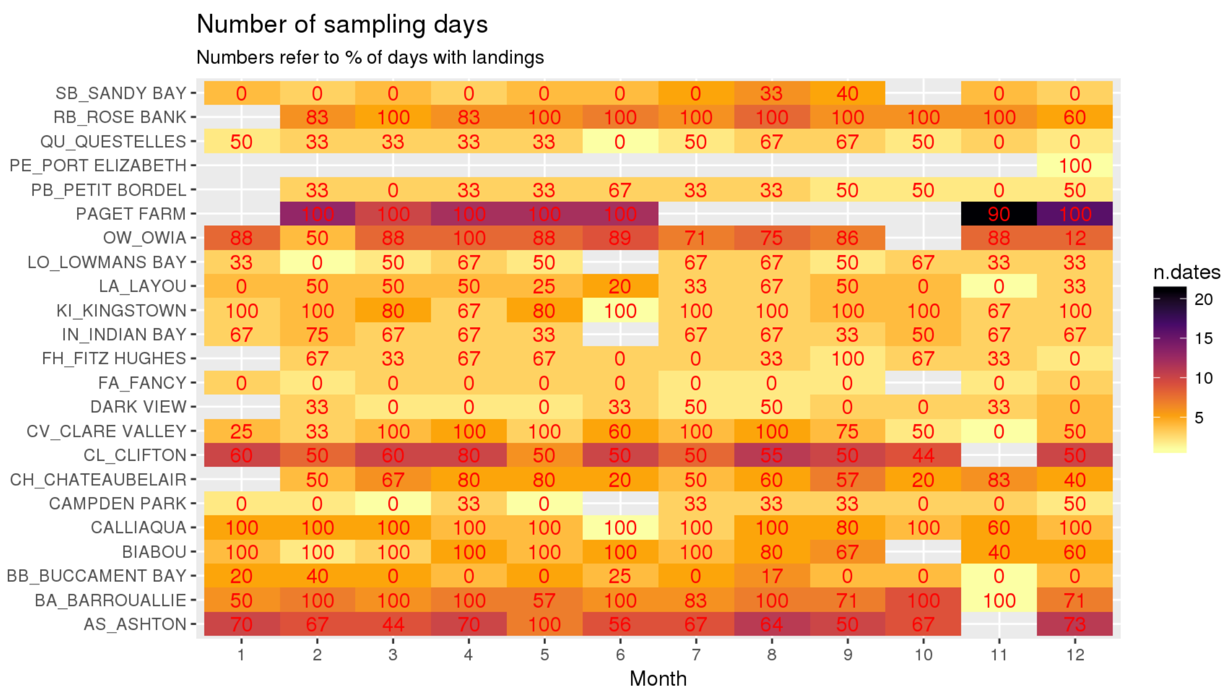

Figure 14. The percentage of sampling days with landings for fish landing sites in Saint Vincent and the Grenadines for 2016.

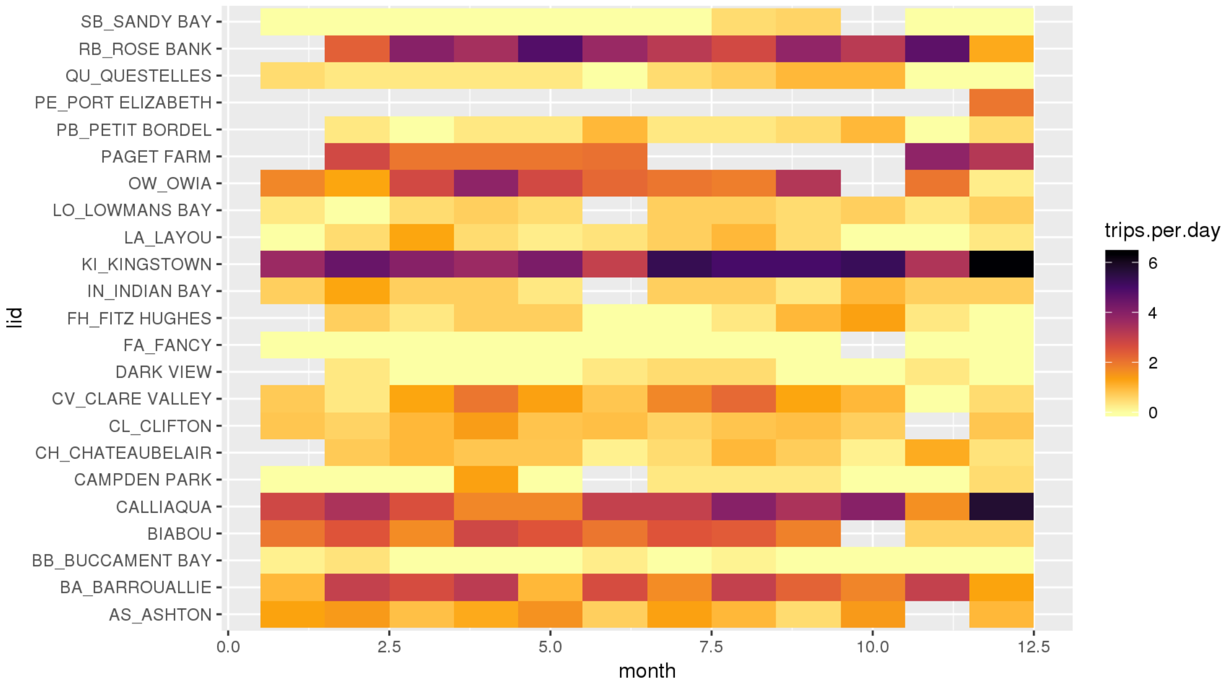

Figure 15. The total number of trips per day for each month for fish landing sites in Saint Vincent and the Grenadines for 2016.

January 2016 catch and effort data for was used as an example to generate monthly statistics (Table 14). Statistics were generated to facilitate the proportional reallocation of samplings by landing site (Table 15).

Table 14. Sampling statistics for different landing sites in Saint Vincent and the Grenadines (January 2016).

Landing site	**Reported sampling days**	**No. of trips sampled**	**Mean no. of trips sampled per day**
Kingstown	3	10	3.33
Calliaqua	5	10	2
Owia	8	11	1.375
Biabou	4	5	1.25
Barrouallie	6	6	1
Clare Valley	4	3	0.75
Indian Bay	3	2	0.67
Aston	10	6	0.6
Clifton	10	6	0.6
Questelles	2	1	0.5
Lowman’s Bay	3	1	0.33
Buccament Bay	5	1	0.2

Table 15. Proportional reallocation of sampling for fish landing sites in Saint Vincent and the Grenadines.

Landing site	No. of recorded sampling days	No. of trips sampled	Mean number of trips per sampling day	Estimated number of trips per year	p[1]	n[2]	d[3]
Kingstown	41	185	4.51	1077.89	0.15	257	0.72
Rose Bank	67	227	3.39	810.21	0.11	193	1.18
Calliaqua	50	154	3.08	736.12	0.10	176	0.88
Paget Farm	96	262	2.73	652.47	0.09	156	1.68
Owia	83	184	2.22	530.58	0.07	127	1.45
Barrouallie	76	163	2.14	511.46	0.07	122	0.34
Port Elizabeth	1	2	2.00	478.00	0.07	114	0.02
Biabou	48	91	1.90	454.10	0.06	108	0.84
Clare Valley	44	54	1.23	293.97	0.04	70	0.77
Ashton	104	115	1.11	265.29	0.04	63	1.83
Clifton	102	88	0.86	205.54	0.03	49	1.80
Indian Bay	35	25	0.71	169.69	0.02	40	0.62
Chateaubelair	57	40	0.70	167.30	0.02	40	1.00
Lowman's Bay	28	15	0.54	129.06	0.02	31	0.48
Fitz Hughes	31	15	0.48	114.72	0.02	27	0.56
Layou	43	20	0.47	112.33	0.02	27	0.74
Questelles	30	13	0.43	102.77	0.01	25	0.52
Petit Bordel	29	12	0.41	97.99	0.01	23	0.52
Campden Park	26	8	0.31	74.09	0.01	18	0.44
Dark View	29	5	0.17	40.63	0.01	10	0.50
Sandy Bay	45	6	0.13	31.07	0	7	0.86
Buccament Bay	52	5	0.10	23.90	0	6	0.83
Fancy	28	0	0	0	0	0	NA

[1] p is the proportion of annual estimated trips per landing site.
[2] n is the number of samples per site if allocated based on proportional reallocation of samples.
[3] d represents how much over (>1) or undersampling (<1) was done in 2016.

The proportional allocation of samples is based on the catch reported at the different landing sites (Table 15). Landing sites are allocated sampling based on the proportion of catches landed there. Landing sites with more catches should be sampled more etc. Table 15 shows how the annual sampling should be allocated based on proportional allocation. Kingstown the main landing site had the highest proportion of trips and if the sampling days from 2016 were used as a standard should have the most trips sampled (257). Following Kingstown with the highest proportion of sampling is Rosebank (193), Calliaqua (176) and Paget Farm (156). Barrouallie the only primary landing site other than Kingstown should have the 6th largest amount of trips sampled (122). While Owia the main landing site on the east coast of Saint Vincent should have the 5th largest amount of trips sampled (127). In 2016 only 2 trips were sampled in Port Elizabeth (in one day). The reallocation exercise shows that ideally 114 trips should be sampled in Port Elizabeth. If 2 trips per day is taken as the norm, this means that to obtain this number ideally 57 sampling days are needed annually for Port Elizabeth. The number of sampling that should be allocated to Chateaubelair did not change indicating that the amount of sampling allocated to Chateaubelair in 2016 is proportional to the relative amount of trips recorded there. Twenty-eight sampling days were reported for Fancy in 2016, however, no trips were sampled here. Based on the proportional reallocation analysis no trips should be sampled here, i.e. it should receive no sampling days.

An alternative approach for the allocation of sampling days is the use of the optimal (Neyman) allocation (Table 16). In Neyman allocation the standard deviation of the catch per unit effort (catch per trip) for each landing site is taken into account. The results of the Neyman reallocation shows that the landing site that should have the highest proportion of sampling is Barrouallie (471) followed by Kingstown (406). The next highest proportion of sampling was allocated to Paget Farm (278). After this the proportion allocated does not vary a lot among landing sites (Table 26). Forty-five trips were sampled in Sandy Bay in 6 sampling days in 2016. Based on Neyman reallocation no trips should be sampled in Sandy Bay. Other sites where the analysis indicates sampling should be reduced significantly are: Dark view, Campden Park, Indian Bay, Clifton and Ashton. Landing sites where a strong increase in sampling should occur based on the Neyman analysis are: Barrouallie, Kingstown, Paget Farm and Port Elizabeth. Both the Proportional allocation analysis and the Neyman analysis show that a very strong increase in sampling is required at Port Elizabeth.

Table 16. Neyman (optimal) reallocation of catch and effort data sampling for fish landing sites in Saint Vincent and the Grenadines.

Landing site	**No. of recorded sampling days**	**No. of trips sampled**	**Mean number of trips per sampling day**	**Estimated number of trips per year**	**Sd.cpue[1]**	**p[2]**	**n[3]**	**d[3]**
Kingstown	41	185	4.51	1077.89	75.71358	0.24	406	0.46
Rose Bank	67	227	3.39	810.21	6.150708	0.01	25	9.08
Calliaqua	50	154	3.08	736.12	23.33731	0.05	86	1.79
Paget Farm	96	262	2.73	652.47	85.56106	0.16	278	0.94
Owia	83	184	2.22	530.58	12.88201	0.02	34	5.41
Barrouallie	76	163	2.14	511.46	185.1154	0.28	471	0.35
Port Elizabeth	1	2	2.00	478.00	31.11188	0.04	74	0.03
Biabou	48	91	1.90	454.10	22.59342	0.03	51	1.78
Clare Valley	44	54	1.23	293.97	19.06447	0.02	28	1.93
Ashton	104	115	1.11	265.29	8.291662	0.01	11	10.45
Clifton	102	88	0.86	205.54	8.454955	0.01	9	9.78
Indian Bay	35	25	0.71	169.69	3.361117	0	3	8.33
Chateaubelair	57	40	0.70	167.30	58.49069	0.03	49	0.82
Lowman's Bay	28	15	0.54	129.06	40.79153	0.02	26	0.58
Fitz Hughes	31	15	0.48	114.72	77.94071	0.03	45	0.33
Layou	43	20	0.47	112.33	38.08358	0.01	21	0.95
Questelles	30	13	0.43	102.77	68.90516	0.02	35	0.37
Petit Bordel	29	12	0.41	97.99	53.52839	0.02	26	0.46
Campden Park	26	8	0.31	74.09	2.59001	0	1	8.00
Dark View	29	5	0.17	40.63	9.88377	0	2	2.50
Sandy Bay	45	6	0.13	31.07	1.891479	0	0	Inf
Buccament Bay	52	5	0.10	23.90	71.06879	0.01	8	0.62
Fancy	28	0	0	0	NA	NA	NA	NA

[1]Sd.cpue represents the standard deviation of the catch per unit effort (catch per trip).
[2]p is the proportion of annual estimated trips per landing site.
[3]n is the number of samples if based on optimal (Neyman) reallocation of samples.
[4]d represents how much over (>1) or undersampling (<1) that was done in 2016.

7.3 An assessment of the fisheries catch and effort data management system of Saint Vincent and the Grenadines

The assessment conducted on the fisheries catch and effort data management system of SVGFD has found that very useful data was being collected and stored. This included: the name of the data collector; the date, month and year; the site; the vessel name when available; the vessel registration number when available; the name of the captain; the area fished; the crew size; the cost of fuel used; the quantity of bait used; the estimated time of departure of the vessel; the estimated time of arrival of the vessel; the hours fished; the gear used; the species caught; the market category of the species caught, the landed weight, the landed condition of the fish, the price per pound for all species caught, the landed value for each species, the estimated monthly weight of all species caught; and the estimated month value for each species caught (see Appendix 1). The excel data sheets used to store the catch and effort data are also being constructed in a standardised manner. However, documentation on the process and procedures involved in the collection, storage and management of catch and effort data was limited (*pers comm* with Fisheries Division staff) and the management of the data does not appear to be highly organised.

A central database for the storage of catch and effort data is presently non-existent. Catch and effort data is stored by years in separate Microsoft Excel files that are in turn contained within separate folders organised by years and containing other files with catch and export related data for that particular year. The catch and effort data forms (see Appendix 1) are stored in the folder Catch and effort data. Within this folder the catch and effort data forms are located in the Microsoft Excel file catch and effort data Jan – Dec and the name of the particular year. Within this file catch and effort data for each month is stored in separate sheets. There are two sheets for each month. One sheet contains the sampling and estimation data (see Appendix 1) while the other contains information from the first sheet organised in a pivot table.

The current spreadsheet design is prone to many errors. For instance, errors were found in the writing of formulas and the naming of months. Errors in the writing of formulas lead to the erroneous estimation of catches at different landing sites. Errors in the writing of formulas came from miscounting the number of sampling days and hence dividing the number of fishing days by the wrong number when raising the sampled catch to an estimated monthly catch.

Also, the lack of a trip identification number rendered reading of the data form more difficult. Additionally, it was observed that while fish were landed in different conditions (whole, gutted and headed), this was not factored in when producing estimates of total fish landed per month. Regardless of the landed condition of the sample, the same formula was used to generate estimates. In other words, no weight conversion is being done. Importantly, vessel identification was missing from most of the data entries.

8 LIMITATIONS AND WEAKNESSES OF THE STUDY

It is important to note that while this author works at the Fisheries Division of Saint Vincent and the Grenadines, he is not a member of the Data Unit and he has not had significant interaction with the catch and effort data and the procedures by which it is obtained, stored, managed and released to end users prior to this study. A key weakness of the study was that it was conducted without a full complement of information as would have been desired by the author. Key information from the Fisheries Division in Saint Vincent and the Grenadines was not provided. For instance, information on frame surveys conducted by the Division was not provided. Some information had to be obtained via informal communication with some members of staff of the division.

Another major limitation is that a design for sampling effort of the Icelandic jigger fishery was not undertaken due to the limited scope of the study.

9 DISCUSSION

9.1 The Icelandic census data for the jigger fleet

An objective of this study is to use the census data for the Icelandic jigger fleet to appraise different FAO sampling techniques for the estimation of mean catch per trip. Hence, it was necessary to develop an understanding of the fishery and the census data provided. This was done by looking at the trends and patterns within the fishery. Information on Icelandic fisheries are collected in a census so in reality no sampling is necessary. The situations discussed are hypothetical and provided insight into the sampling program that exists in Saint Vincent and the Grenadines and the strategies that can be utilised to improve this program if necessary.

Landings from mackerel trips contributed strongly to variability in the catches (Figure 7). Where there is high variability in landings, increasing the sample size should increase the precision and accuracy of catch estimation. The high standard deviation in catches for mackerel trips compared to cod is an indication that the jigger fishery should be stratified into mackerel trips and cod trips for sampling purposes (see Section 3). This will reduce variability in collected samples leading to a reduction in required sampled size (figure 9).

The jigger fishery data was used to compare random, proportional and Neyman (optimal) sampling allocation strategies. In countries with relatively poor economies such as Saint Vincent and the Grenadines it is very important that the available resource base be utilised as efficiently as possible. Appraising these methods and considering which is the most viable option to apply to the Saint Vincent and the Grenadines sampling program is very important. Under Neyman (optimal) allocation more samples were allocated to the mackerel fishery compared to the cod fishery. This has to do with the higher standard deviation of the mackerel catches compared to catches for cod (see Section 3). This underscores the importance of variability when it comes to determining sample size. These results are an important indication that when allocating sample days in Saint Vincent and the Grenadines the standard deviation and variability in the data should be taken into consideration. This can cause a significant difference in the manner in which samples are allocated and the reliability of the resultant estimates.

An investigation to verify this (Table 7) shows that Neyman (optimal) allocation was the best method producing an annual catch for the Icelandic 2016 data. This method produced an estimate closest to the annual catch from the Icelandic census data and the standard error and coefficient of variance for this method was the lowest. Both Neyman and Proportional allocation were better at producing an annual estimated catch compared to allocating samples to the targeted strata (mackerel trips and cod trips) randomly (Table 7). For a desired coefficient of variation, the number of samples required under Neyman (optimal) sampling allocation was less (Table 7 and Figure 9) than the others. In situations where this holds true (where variations in mean catch among strata is not too large), the Neyman (optimal) allocation will lead to a reduction in the cost of sampling and a more efficient use of available resources. Of the three approaches investigated, random sampling allocation requires the most samples and will be the costliest (Figure 9). For instance, to obtain a coefficient of variation of 0.025 (tolerance level of 2.5%) over 3 times more samples were required when samples were allocated randomly than when they were allocated using Neyman (optimal) allocation (Figure 9).

A sampling design to mimic the sampling program in Saint Vincent and the Grenadines using the Icelandic census data was somewhat emulated. The objective of the design was to provide the best estimate of the total catches by month and fisheries using the 2016 census data to estimate the number of samples needed per month per fishery to obtain a 5% or 10% tolerance level for 2016.

The above study highlighted some important consideration in relation to Saint Vincent and the Grenadines sampling program. For that program to be properly evaluated the objectives need to be laid out a priori by the managers. These include: what are basic units upon which reported catch is desired and or needed? For example an objective to get accurate estimates of catch and effort by landing sites per month would require a different sampling design than if the objective is to obtain those statistics by only month and major gear type. The same applies if the statistics required are only annual statistics. In general, more strata required will increase the number of needed samples. What level of precision is desired in the statistics per stratum? In general, the higher the required precision the higher the number of samples needed. Where a budget limits the number of samples that can be taken, proper allocation of samples by strata can increase the accuracy and precision in the estimates.

9.2 An analysis of the data collection and estimation process of Saint Vincent and the Grenadines

Due to the wide geographic spread of fishing activities in Saint Vincent and the Grenadines and the artisanal nature of the domestic fisheries sector a sampling protocol is the most appropriate method of collecting catch and effort data from fishers. However, in the 2016 data disparities were found between the sampling and estimation procedures the Fisheries Division indicated it used and the actual method used. For instance, the Fisheries Division indicated that sampling days are allocated to different landing sites based on their stratification as primary, secondary and tertiary. However, a look at the number of sampling days by site recorded in the 2016 data revealed no such pattern (Table 11 and Figure 15). Also, disparities were found between the method the

Fisheries Division indicated it used to obtain monthly estimates from samples and the actual method used. This can confuse end users of the data as well as members of staff of the Division who may not be familiar with the actual procedure being used. This is compounded by the fact that documentation on the data collection and management system is limited. Documentation of the data collection system is important (Graaf, et al., 2015) The lack of documentation affects continuity, can confuse trainees and make their comprehension of the system more difficult. Insufficient documentation on the data collection procedures of the Saint Vincent Fisheries Division can lead to the confusion of end users such as researchers who may be attempting to answer important questions. For instance, when the author requested information from the Data Unit on the procedures being used to collect and estimate catch and effort data, it was indicated to him by the Fisheries Division that the procedures are the same as for Saint Lucia where documentation already exists. However, upon investigation it was discovered that while the data collection and estimation procedures for the two countries are similar, they are not the same. For instance, in Saint Lucia the data collector is required to capture information from every other returning vessel on sampling days while in Saint Vincent and the Grenadines a full census is done on sampling days (*pers comm.* with members of staff of the SVGFD).

Disparities were also noticed between the guidelines put forward by the FAO and the estimation procedures being used by the SVGFD. One such disparity comes from the method used by the SVGFD to price the fish being sampled. Fishes sampled are priced according to the prices used by vendors. However, the FAO guidelines indicate that the first sale price (i.e. the fishers' price) should be used. This is important should large gaps develop between the selling prices of secondary sellers and fishers. The vendor's price is reflective of additional costs such as stall rental and ice for storage and may no longer be representative of the value of the actual fish. Also, because there can be more than one type of secondary seller (e.g. vendors, fish markets, exporters and traders) there are greater inconsistencies in the sale price among secondary sellers than among fishers. The fisher's price is more likely to be consistent across landing sites and be more immune to inflation and value addition making it a more reliable estimate of the direct and relative value of fishery resources in time and space.

The method and the system used to allocate sampling days to different landing sites needs reviewing. High levels of variability in the catch according to landing site was found for the 2016 catch and effort data. This is an indication that there is low precision in the estimates derived. By looking at the number of trips sampled at each landing site for January 2016 (Table 14) the low sample sizes appear to be contributing significantly to the high variability. The low sample sizes are due to the number of days assigned to each landing site as well as the low number of trips per day. If the total number of days assigned to the landing sites cannot be changed due to financial or other reasons related to the logistics of the system, then a reallocation of sampling days to the various sites should be considered. This will aid in maximising the efficiency of sampling and help in the assignment of more sampling days to sites of higher priority.

One solution to reduce the errors involved due to the high variability of the catch data is to introduce further stratification into the sampling design (Graaf, et al., 2015). The main objective of stratification is to reduce the variability in the sampled data, thereby, improving the reliability of the data collection. An increase in the reliability of the data leads to a reduction in the sample size required to provide reliable statistics, leading to a reduction in the cost of the sampling programme (Graaf, et al., 2015).

It may be worthwhile for the SVG Fisheries Division to consider restructuring the sampling program and base the sampling allocation on gear type rather than catch rates at different sites. However, in SVG it may not be worth it to conduct daily sampling by gear and site since the daily landings by gear will be very low and it may not be practical if there is no daily variation in gear use. In other words, as is, doing this will not lead to the collection of additional information due to the small-scale nature of the domestic fisheries sector. One can organise data collectors to collect information from particular gears regardless of the landing site, however, the logistics behind this arrangement will be difficult and expensive to organise if reliable estimates by gear are to be obtained. If it is not organised properly, this approach may make the statistics per landing site less reliable. The implementation of gear-based sampling schemes is not recommended (Graaf, Stamatopoulos, & Jarrett, 2017).

Another solution is to reallocate the number of samplings among landing sites. Two methods were investigated in this regard, the Proportional reallocation of samples among sites and the Neyman (optimal) reallocation of samples among sites. Of the two methods the Neyman (optimal) reallocation can be considered more robust due to the fact that the standard deviation of the catch per unit effort (catch per trip) for each landing site is taken into account. What the results of both methods show is that there has been oversampling and under-sampling at different landing sites. With the implementation of either of these methods the sampling system can be made more efficient and possible cost effective and more importantly more accurate and precise estimates are possible through the reallocation of sampling at different landing sites. Kingstown, the main landing site, was found to be under-sampled in 2016 by both Proportional reallocation and Neyman reallocation methods (Tables 15 and 16). This is not surprising. Kingstown is a relatively busy landing site and the number of trips per sampling day recorded there in 2016 (Tables 15 and 16) does not appear to be representative of the volume of landings that take place there. Results from both methods indicate that more sampling needs to be allocated to Port Elizabeth. In 2016 only one sampling day containing two trips was sampled in Port Elizabeth. Yet the Proportional sampling reallocation method and the Neyman sampling reallocation method indicate that 114 and 74 trips need to be sampled at this landing site respectively. However, it is possible that the trips sampled for Port Elizabeth in 2016 were due to a special event that required that site to be sampled. Due to the limited information provided by the SVGFD this possibility could not be explored further. Because no catches were recorded for Fancy in 2016 despite having 28 sampling days recorded in 2016, it may be best to cease sampling at this landing site and reallocate some of these days to other sampling sites that are being under-sampled. This suggestion is supported and factored into the results of the reallocation analyses (Tables 10 and 11). The results of the Neyman reallocation analysis indicate that no sampling should occur at Sandy Bay as well. Both analyses indicated that the number of trips being sampled at Owia could be reduced as this site was being oversampled. The three latter sites are situated relatively close to each other on the north eastern coast of Saint Vincent and the Grenadines. Therefore, the proportional reallocation and the Neyman reallocation analyses indicate that there is heavy oversampling on the north eastern section of the coastline in Saint Vincent relative to other landing sites (Tables 15 and 16). Conversely sites in Zone 2 (Barrouallie, Buccament, Clare Valley and Layou) were found to be under-sampled by the Proportional reallocation method. The same was found using the Neyman reallocation of samples with the exception of Clare Valley where it determined relatively high oversampling was occurring (Table 11).

Neyman analysis found that Barrouallie should be the landing site with the highest proportion of trips sampled. This site had the highest standard deviation in its CPUE. The high standard deviation in the CPUE here is likely due to the landing of whales in this community. Barrouallie is one of two places where whales are landed in Saint Vincent and the Grenadines. The other is the Grenadine island of Bequia. There is large variability in the catching and landing of whales. The gear utilized in the hunting of whales is harpoon. This explains the high standard deviation, coefficient of variation, standard error and relative standard error for this gear (Table 9). It may be worthwhile to treat the whale fishery in Barrouallie as a sampling stratum.

9.3 An assessment of the fisheries catch and effort data management system of Saint Vincent and the Grenadines

The lack of a database and the current storage strategy for catch and effort data at the Saint Vincent and the Grenadines Fisheries Division presents various problems. Firstly, it makes analysing the data very difficult. Organising the data in a database makes analysis in statistical programs such as R Studio, SPSS or Microsoft Excel easier and less time-consuming. For example, in order to analyse the entire year of 2016 in R Studio, twelve different data sheets representing the twelve months must first be joined. The same must be if other years are to be added to the analysis. The objectives of analyses vary, so this must be done every time a new analysis is performed. This is very time consuming and can place an unnecessary burden on persons working with this data on a regular basis e.g. members of staff of the SVGFD Data Unit. This can significantly decrease the work time available to do other projects. This is of particular importance in developing countries such as Saint Vincent and the Grenadines where the human resource base tends to be limited due to financial constraints.

The lack of a database also makes it more difficult for persons not interfacing with the data on a regular basis to find specific data or information. For instance, data and information can be hidden in sheets with titles that may not be obvious indicators of the data or information it contains. In a well-managed database, one only needs to scan the column headings of a single sheet to find what they seek. Hence, the system becomes more efficient and users will not be confused as to what data is actually available within the datasets. While this can be a benefit when it comes to data security it is a big disadvantage when it comes to data retrieval. Also, training new members of staff in the current data input and storage procedures will be more difficult creating inefficiency in the work process. Also, the data will need to be organised to make assessment of stocks easier as the Divisions develops further in the direction of increased resource assessment.

The lack of vessel identification in most of the entries also compounded the difficulty in using the data to conduct analyses. Vessels remained unidentified in many entries due to the low levels of vessel registration. Fortunately, a nationwide vessel registration programme has already been initiated.

Human error found in the excel worksheets used to store and manage data is an indication that a new worksheet design is required so that human error can be reduced. This can be done by creating worksheets that are more automated and require less manual typing.

10 RECOMMENDATIONS

10.1 Data management

Proper documentation of the system and procedures used by the Fisheries Division of Saint Vincent and the Grenadines (SVGFD) to collect, store and manage catch and effort data is needed. This is necessary for data validation and verification, ground truthing related activities, cross checking and reviewing past data and information, continuity and other related issues. A database needs to be created to store the catch and effort data. The standardised manner in which the catch and effort data is being stored among data sheets makes it easy to join the different months and years and create one database. Members of staff of the SVGFD Data Unit need training in the importance of and the creation of databases as tools for efficient data storage and management. The effort and time it will take now to get the data into a well-managed database will be much less than if the situation is allowed to continue for additional years.

The current Microsoft Excel spreadsheet used to store catch and effort data and generate estimates needs to be redesigned to make it less error-prone. The spreadsheet needs to be designed in a way to make the calculation of formulas more automatic so that errors associated with the manual input of data can be reduced. For instance, the number of sampling days can be derived from the original catch and effort data sheets using pivot tables. Using the VLOOKUP function in Microsoft Excel, this number can be extracted back to a column in the original data sheet to be used in a formula replacing the need for it to be typed manually. Once designed properly, this approach will be less error prone compared to manual typing. Every manual input of data is an opportunity for an error to occur. Where available, a conversion factor should be used to derive estimates based on the landed condition of the fish (whole, gutted, headed etc.). For species where one does not exist, then investigations can be conducted using biological data to assist in the creation of conversion factors. This will greatly improve the accuracy of the estimates. Additionally, the use of the first three columns of the spreadsheet as headers makes analysis in R Studio more difficult. These headers are not necessary. The only information they provide is that the spreadsheet is the catch and effort data entry form. This information can be noted elsewhere.

10.2 Data collection

Data Collectors need to be provided with clear unambiguous written instructions on the sampling procedures and the reasons for these procedures in order for them to perform their duties correctly. The sampling strategy being utilised by the St. Vincent and the Grenadines Fisheries Division needs to be redesigned to increase sampling of landings at landing sites. Additionally, sampling days need to be allocated using the Neyman (optimal) sampling allocation strategy. If this is not possible, at least proportional allocation is recommended in preference to the current allocation strategy that has no recognisable patterns in the way samples are being allocated.

10.2.1 Reclassification exercise

There is a need for a reclassification exercise to determine which sites should be placed into the categories of primary, secondary and tertiary. The current classification may be out-dated and needs updating.

10.2.2 Cetacean hunting in Barrouallie

The high variability cetacean catches (represented by harpoon gear) is an indication that data collection for cetaceans should be separated. Because whaling is a sensitive issue, there should be a full census for collecting information on cetacean catches. It should be made compulsory that whalers provide information on cetacean catches to the Fisheries Division

10.2.3 Census study to evaluate the accuracy and precision of estimates

The Fisheries Division should consider a case study where a complete census is attempted at a landing site for an entire month. A primary landing site should be chosen because the total landings at these sites are relatively high. This census should occur independent to the regular sampling program, allowing the comparison of estimates obtained from the sampling program with known values from this census. This study will also provide additional evidence on whether or not random, proportional or Neyman (optimal) sampling allocation is the best for sampling fisheries in Saint Vincent and the Grenadines.

Of the two sites, Barrouallie should be chosen because a significant amount of information is already being collected at Kingstown. It has been indicated that a full census already occurs at Kingstown, however, there are a couple of issues here. The information provided to the author is unclear and it is not certain if the information being collected at Kingstown is a full census of landings or just the sales data for some landings. Opportunities to clarify this were limited and hence the author was not able to clarify this issue prior to the writing of this report. However, opportunities should be available in the near future to have this issue clarified and hence have the proposal amended to suit. Another option may be to fill any gaps in the data collection at Kingstown if indeed a full census is not taking place. However, potential issues in coordination between the New Kingstown Fish Market and the Fisheries Division in the completion of this study can lead to some inconsistencies in the data collection. Secondly, the best landing facilities and strongest market are located at Kingstown making it a unique landing site where many boats that do not make the landing site at their home port land there in greater numbers compared to other landing sites. This is not a problem in itself when it comes to generating estimates but principally can be a variable that can in theory create additional variability in the catch when there is inconsistency in which boats land their catches there. In essence, it creates one more thing to worry about or potentially adds to the statistical ‘noise’ that can be misinterpreted as genuine trends in landings. From a scientific perspective, it may be worthwhile to have the monthly census in Barrouallie where there are less variables that can interfere with the objectives of the study.

An important consideration with this proposal is that if done in Barrouallie a full enumeration of the landings may still not occur because the whaling fleet in Barrouallie lands its catches at late hours. One approach to this problem is to exclude the whaling fleet from the study. Considering also the very high variability in catches from this fleet, this may be the best option. There are 5 boats in this fleet.

Alternatively, Calliaqua a secondary landing site can be chosen to do this census study. Information is also being collected here by a market facility at this location, however, this author has no information to indicate how representative of the total landings this information is. Information from the Fisheries Division indicate that Kingstown is the only landing site where a full census is supposed to take place. Accessible office facilities exist at Calliaqua and landings from boats from other home ports landing there is not an issue.

This census study should be done periodically to evaluate the accuracy and precision of estimates.

10.3 Training

In addition to the training mentioned above, SVGFD staff need additional training in statistics and estimation procedures. Good quality data is one of the foundations on which proper fisheries management is built and this study has highlighted that there are some issues that needs addressing in the data management, collection and estimation system of the SVGFD.

11 CONCLUSIONS

An evaluation was done of the catch and effort data collection and catch and effort estimation strategy of Saint Vincent and the Grenadines. Disparities were found between information the SVGFD releases concerning the methods used in the catch and effort data collection system. These disparities need to be addressed. Attempts should be made to ensure that information provided to end users concerning the nature of the data collection system be as accurate and clear as possible. Recommendations were made and additional information exists in the other chapters of the study. Hopefully this study will be reviewed, and the information contained therein utilised in future decision making at the SVGFD. There is need for a review of the sampling strategy being implemented at present. The sampling allocation strategy being currently used matches closest to a random sampling allocation strategy. This study has shown that this strategy requires a greater sample size compared to proportional and Neyman allocation when it comes producing reliable estimates. This should be taken into consideration as soon as possible and considerations made to redesign the sampling program to produce the best catch estimates in the most cost-effective manner. A central database for the management of catch and effort data is required. Fortunately, due to the manner in which the data recording spreadsheet is designed this should not be a difficult task.

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13 APPENDICES

Appendix 1

Table illustrating layout of the Saint Vincent and the Grenadines catch and effort data entry form.

ST. VINCENT AND THE GRENADINES																						
CATCH AND EFFORT DATA ENTRY FORM																						
Initial	DAY	MONTH	site	Vessel Name	Vessel Reg. No	Fisherman name	Area Fished	Crew Size	Fuel Used $	Qty Bait	ETD	ETA	Hrs. Fished	gear	Species	market_cat	land_wt	Landed Status	Price	Value	Est. Wght	Est. Value
EJ	4	JAN	KI_KINGSTOWN			Gregory Lewis	817	10	140	0	05.30am	11.58am		BSNE	SCAD,MACKEREL	MISC, FOOD FISH	400	W (Whole)	5	2000	1900	9500
EJ	4	JAN	KI_KINGSTOWN			Ulrick Hutchins	729	3	215	35	07.30am	2.41 pm	6	PALN	HIND,RED	MISC, FOOD FISH	30	W (Whole)	9	270	142.5	1282.5
EJ	4	JAN	KI_KINGSTOWN			Ulrick Hutchins	729	3	215	35	07.30am	2.41 pm	6	PALN	SNAPPER,SILK	MISC, FOOD FISH	15	W (Whole)	9	135	71.25	641.25
EJ	4	JAN	KI_KINGSTOWN			Ulrick Hutchins	729	3	215	35	07.30am	2.41 pm	6	PALN	SNAPPER,BLACKFIN	MISC, FOOD FISH	5	W (Whole)	9	45	23.75	213.75
EJ	4	JAN	KI_KINGSTOWN			Lamar Cordice	830	3	260	50	06.30am	3.14 pm	7	TROL	AMBERJACK,GREATER	MISC, FOOD FISH	16	W (Whole)	6	96	76	456
EJ	4	JAN	KI_KINGSTOWN			Lamar Cordice	830	3	260	50	06.30am	3.14 pm	7	TROL	DOLPHINFISH	MISC, FOOD FISH	28	G (Gutted)	9	252	133	1197

Appendix 2

Catch statistics for landing sites in Saint Vincent and the Grenadines Domestic Fisheries in 2016.

Landing site	Mean catch (lbs) per trip	Maximum catch (lbs) per trip	Standard Deviation	Coefficient of variation	Standard error	Relative error
Clare Valley	16.708	300	42.033	2.516	5.720	0.342
Layou	35.812	330	83.962	2.345	18.774	0.524
Barrouallie	175.518	3500	408.110	2.325	31.966	0.182
Questelles	70.385	500	151.914	2.158	42.133	0.599
Petit Bordel	74.917	400	118.007	1.575	34.066	0.455
Paget Farm	127.869	2066	188.625	1.475	11.653	0.091
Lowman's Bay	66.867	350	89.930	1.375	23.220	0.347
Fitz Hughes	158.933	450	171.826	1.081	44.365	0.279
Rose Bank	13.596	99	13.560	0.997	0.900	0.066
Dark View	22.300	56	21.788	0.977	9.744	0.437
Port Elizabeth	78.500	127	68.589	0.874	48.500	0.618
Kingstown	194.724	900	166.921	0.857	12.272	0.063
Calliaqua	60.502	317	51.447	0.850	4.146	0.069
Campden Park	6.938	17	5.710	0.823	2.019	0.291
Buccament	200	400	156.684	0.783	70.071	0.350
Chateaubelair	174.875	450	128.951	0.737	20.389	0.117
Biabou	69.418	230	49.806	0.717	5.221	0.075
Owia	39.821	280	28.399	0.713	2.094	0.053
Clifton	36.886	85	18.641	0.505	1.987	0.054
Ashton	36.383	90	18.283	0.503	1.705	0.047
Indian Bay	20.490	36	7.411	0.362	1.482	0.072
Sandy Bay	20.167	25	4.167	0.207	1.701	0.084

Appendix 3

Catch statistics for different gears in the domestic fisheries sector of Saint Vincent and the Grenadines for the year 2016.

Gear	No. of samples	Mean catch (lbs)	Maximum catch (lbs)	Standard deviation	Coefficient of variation	Standard error	Relative standard error
Scuba	141	151	2066	249	1.65	21	0.139
Harpoon	31	582	3500	745	1.28	134	0.230
Hand line	596	23.8	209	24.6	1.04	1.01	0.0424
Trolling	390	68.6	503	65.6	0.956	3.32	0.0484
Gill net	7	206	400	165	0.799	62.2	0.302
Spear gun	118	49.2	320	38.0	0.773	3.50	0.0712
Palang	80	68.7	317	51.2	0.745	5.73	0.0833
Beach seine	125	317	1200	207	0.651	18.5	0.0582
Fish pot	181	78.7	210	47.6	0.606	3.54	0.0450
Bottom line	12	37.0	100	21.7	0.586	6.26	0.169
Total	**1681**						