Redesigning of the Quarterly Municipal Fisheries Survey in the Philippines

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ABSTRACT

The Quarterly Municipal Fisheries Survey (QMFS) is a nationwide survey conducted by the Philippine Statistics Authority that generates quarterly volume and value of production by species unloaded at municipal fish landing facilities. The old design of QMFS uses stratified random sampling of traditional municipal landing centers. In the old design, there is a non-probabilistic selection of key informants (KIs) per sample landing center (LC) which indicates that not all fishing operators have the chance to be selected. Also, data collected is not based on the actual catch of the day, instead it relies on recall of the KIs for a monthly catch in each quarter for the whole LC which may indicate a bias on the recall. Moreover, the number of fishing days in a month and the total number of fishing boats in each day is not estimated in the survey. Given these limitations, there is a need to revisit the sampling design of QMFS.

After performing sampling experiments and simulations, the new sampling design for QMFS is a two-stage stratified sampling with systematic selection of landing centers in the first stage and systematic selection of boats in the second stage. The sampling rate of landing centers is 10%. If the total boats in a landing center is greater than 10, 10 boats are sampled, otherwise, all boats are sampled. The frequency of data collection is once a day per week where AM unloading is separated from PM unloading. The new sampling design provides estimates that passed the acceptable reliability measures at the provincial level.

Keywords*: Fisheries, Sampling, Two-stage Stratified Sampling*

1.0 Introduction

1.1 Background and Rationale

In the Philippines, fishery statistics are grouped into three main categories: (1) commercial fisheries, (2) municipal fisheries, and (3) aquaculture. Municipal fisheries are further subdivided into two, marine municipal and inland municipal. Collection of fisheries statistics was first done by the Bureau of Fisheries and Aquatic Resources (BFAR) of the Department of Agriculture (DA) until 1987 when the Bureau of Agriculture Statistics (BAS) was created by virtue of Executive Order 116. With the merging of BAS with the other statistical agencies in 2015 by virtue of the Republic Act No. 10625 (Philippine Statistical Act of 2013), the Philippine Statistics Authority (PSA) took over the generation of fisheries statistics through surveys. Fishery statistics is very important not only in national accounting but also in ensuring sustainability of the resources.

Marine Municipal fishing cover operations carried out without the use of a boat or the use of a boat of three (3) gross tons or less. Most regulatory agencies' attention is focused on these fisheries due to the massive number of stakeholders and the magnitude of its impact to the lives of these stakeholders as well as its effect on sustainability of the resource. As of 2019, there are 265,753 vessels registered to be municipal (i.e., less than three tons capacity), and this excludes operators that do not have boats. In the Census of Agriculture and Fisheries (CAF) 2012, a total of 646,173 marine fishing operators were enumerated, implying that about two-thirds of these fishers do not own a boat, illustrating how marginalized this sector is.

The Quarterly Municipal Fisheries Survey (QMFS) is conducted quarterly by the Philippine Statistics Authority on traditional landing centers, and from administrative records of fish unloading in Philippine Fisheries Development Authority (PFDA), Local Government Unit (LGU) and privately managed landing centers. Table 1 shows the comparison of the old and new sampling design of the QMFS.

Table 1. QMFS: Old Sampling Design vs New Sampling Design

	Old Sampling Design	**New Sampling Design**
Sampling Frame	List of municipal traditional fish landing centers (LCs)	List of municipal traditional fish LCs from Listing of Marine Fish Landing Centers conducted in 2019
Sampling Design	Stratified Random Sampling ● Stratification of LCs into 3 strata ● Stratification variable: Average Daily Unloadings (ADU)	Two-Stage Stratified Sampling ● First stage: Selection of LCs (Systematic) ● Second stage: Selection of Boats (Systematic)

	• Simple random selection of LCs per stratum	
Data Collection	Interview 5 key informants (KIs) per sample LC. KIs can be boat operator, technician, fisherman and/or trader	➢ LC sampling rate is 10% ➢ 10 sample boats if total boats is greater than 10, otherwise, complete enumeration ➢ Frequency: one day per week, separate AM and PM unloadings ➢ Sample operators can be boat operator, technician, fisherman and/or trader
Coverage	67 provinces, 31 species and others	First year: all provinces
Frequency	Quarterly	Quarterly

As observed in the old design, there is a non-probabilistic selection of KIs per sample LC which indicates that not all fishing operators have the chance to be selected. Also, data collected is not based on the actual catch of the day, instead it relies on recall of the KI for a monthly catch in each quarter for the whole LC which may indicate a bias on the recall. Moreover, the number of fishing days in a month and the total number of fishing boats in each day is not estimated in the survey. Given these limitations, there is a need to revisit the survey design of QMFS.

1.2 Objectives

The objective of the redesigning of the Quarterly Municipal Fisheries Survey (QMFS) is to determine the best sampling design that will produce reliable quarterly municipal fisheries estimates. Specifically, this study aims:

- to determine the appropriate sample selection method;
- to determine the best sampling design;
- to determine the sample rotation procedure that would also update the frame;
- to determine the estimation procedure;
- to produce reliability measures from the selected estimation procedure; and
- to determine operational implications of the redesigning that will support its implementation as a regular survey

1.3 Scope and Delimitation

This research study provided the best sampling design based on the acceptable reliability measures and implementation considerations. However, there are four types of landing centers: traditional; PFDA-managed; LGU-managed, and; privately-owned. Only the traditional landing centers are covered by surveys of PSA since PFDA-managed, LGU-managed, and privately-owned landing centers are covered by regulatory function of PFDA. Data from three other types of landing centers in the form of administrative reports are then combined with data collected by PSA from traditional landing centers to generate official statistics for fisheries.

1.4 Significance of the Study

The results of the study are beneficial primarily in updating the sampling frame for all the provinces as well as updating the sampling design to incorporate the variability in the distribution of municipal fishing boats at the landing center level. Subsequently, the update ensures that the statistics generated from the QMFS are reliable until the provincial level.

2.0 Methodology

3.1 Sampling Frame

The frame is composed of Traditional Landing Centers since other landing centers are monitored by PFDA. A total of 8,364 traditional municipal landing centers is included in the frame, these accommodate unloading of daily catch of almost 25 million kilograms. As noted in Section 1.1, landing centers are stratified into three with average daily unloading (ADU) as the stratification variable. With the reasonable number of landing centers per province (domain), stratification may work well to address heterogeneity of the landing centers. In the sampling experiments, ADU for the frame will be reconstructed from the actual data.

3.2 Sampling Experiment with Actual Landing Center Level Data

The data at the landing center level for the second quarter of 2009, fourth quarter of 2009, and first quarter of 2010 were used in the initial sampling experiment. This data however covers only three provinces (Bohol, Camarines Sur, and Misamis Occidental) for 52 traditional landing centers for a total of eight months.

3.2.1 Sampling Design

Simple random sampling is the design considered in this experiment. LCs were drawn from each of the provinces with 25%, 50% and 100% sampling rates covering the months of January to June and October to December. In a sample LC, data for the month were collected either daily, every other day, twice a week, once a week, twice a month, or once a month.

3.3 Simulation

In characterizing further various features of the proposed sampling design, sampling experiments are further conducted from simulated data based on the frame, landing center level data from three provinces, and from the time series data. The time series data are from the first quarter of 2002 until the third quarter of 2017 by province and by species.

3.3.1 Sampling Design

To address heterogeneity of landing centers, stratification, and probability proportional to size (PPS) sampling are included in the design settings. Thus, first sampling design is PPS with ADU as the size measure. Then ADU is used as a stratification variable to form three strata of landing centers. In each stratum, sample size is proportionally allocated and simple random samples of landing centers are selected.

LCs are selected considering three proportions (25%, 50%, and 100%) of samples. For each sampling proportion, frequency of data collection is set-up at: everyday (daily), every other day, once a week, twice a month, and once a month.

Production (catch) data was re-created for all landing centers using the following data generating process:

$$y_{ijkl} = \mu + M_i + LC_j + D_k + e_{ijkl}$$

where,

y_{ijkl} is the catch for month i, in landing center j for day k;

M_i is the monthly random effect;

LC_j is the random effect for the landing center;

D_k is the random effect for the days; and

e_{ijkl} is the typical error term in the model.

The variances of the random components are estimated from the landing-center level data from Bohol, Camarines Sur, and Misamis Occidental for Q2 2009, Q4 2009, and Q1 2010, while overall means are obtained from the time series data.

For each of the sampling scenarios, 200 samples were drawn, CV and relative bias were computed as average of the 200 replicates.

3.4 New Sampling Design

After determining the operational implications of the redesigning, further modifications were applied on the recommended sampling design that was later approved by the PSA Board. The new sampling design of QMFS is a two-stage stratified sampling with landing centers as the primary sampling unit and operators as the secondary sampling unit.

3.4.1 Sampling Frame

The updated listing of municipal traditional fish landing centers is compiled from a list of marine fish landing centers to create the sampling frame.

3.4.2 Data Collection

All provinces are sampled for 3 months in a quarter using the survey-based estimation. Data is collected once week and for AM and PM unloadings separately.

3.4.3 Domain

Provinces are still utilized as the domain.

3.4.4 Stratification Variable

Average daily unloadings with three strata is used for stratification. Stratum boundaries are determined based on the iterative method of adjacent means.

3.4.5 Sample Selection

Sample size is then optimally allocated to the strata using Neyman Allocation Method. Neyman allocation is one of the sample allocation methods that may be used with stratified samples. The purpose of the method is to maximize survey precision, given a fixed sample size, hence is fit for the computation of stratum sample sizes since the total sample size (10% of the total LCs) is already fixed per province.

Landing centers are selected systematically at the first stage while operators such as boat operator, technician, fisherman, and/or trader are selected systematically at the second stage. If the total number of boats is larger than 10, then 10 boats is sampled; while, if the total number of boats is less than or equal to 10, complete enumeration is done.

3.4.6 Sample Rotation Scheme

Since samples will be selected using stratified samples, sample landing centers can be rotated every year.

3.4.7 Sampling Weight

The sampling weight is computed as:

$$w_{hij} = \left(\frac{A_h}{a_h}\right)\left(\frac{N_{hi}}{n_{hi}}\right)$$

where:

w_{hij} is the weight of operator j in LC i at stratum h

A_h is the total number of LCs for the province at stratum h

a_h is the number of sample LCs for the province at stratum h

N_{hi} is the total number of municipal operators in LC i at stratum h

n_{hi} is the number of sample municipal operators in LC i at stratum h

3.4.8 Total and Variance Estimation

Total Production

The following formula is used to calculate the province's total production estimate:

$$\hat{Y} = \sum_{h=1}^{L} \widehat{Y_h}$$

Moreover, the following formula is used to calculate the stratum h production estimate:

$$\widehat{Y_h} = \sum_{i=1}^{a_h} \sum_{m=1}^{3} \frac{F_{im}}{f_{im}} \sum_{j=1}^{n_{hi}} w_{hijm} y_{hijm}$$

where:

F_{im} is the total fishing days in LC i on month m

f_{im} is the sample fishing days in LC i on month m

y_{hijm} is the volume of production for operator j in LC i on month m at stratum h

w_{hijm} is the final weight of operator j in LC i on month m at stratum h

a_h is the number of sample LCs for stratum h of the province

n_{hi} is the number of sample operators for LC i in stratum h

L is the total number of strata

Variance of the Total Production

The following formula is used to calculate the province's variance estimate:

$$\hat{V}\left(\hat{Y}\right) = \sum_{h=1}^{3} \hat{V}\left(\widehat{Y_h}\right)$$

where:

$\hat{V}\left(\widehat{Y_h}\right)$ is the variance of stratum h

Futher, the stratum variance is computed as:

$$\hat{V}\left(\widehat{Y_h}\right) = \left(1 - \frac{a_h}{A_h}\right) a_h {s_h}^2 + \frac{a_h}{A_h} \sum_{i=1}^{a} \left(1 - \frac{n_{hi}}{N_{hi}}\right) n_{hi} s_{hi}^2$$

where:

$${s_h}^2 = \frac{\sum_{i=1}^{a_h} \left(y_{hi} - \underline{y_h}\right)^2}{a_h - 1}$$

$$s_{hi}^2 = \frac{\sum_{j=1}^{n_{hi}} \left(y_{hij} - \underline{y_{hi}}\right)^2}{n_{hi} - 1}$$

y_{hi} is the estimated production for the LC i in stratum h

$\underline{y_h}$ is the mean production for stratum h of the province

$\underline{y_{hi}}$ is the mean production for LC i stratum h

a_h is the number of sample LCs for stratum h of the province

n_{hi} is the number of sample operators for LC i in stratum h

3.5.9 Measure of Precision

The following formula is used to calculate the Coefficient of Variation (CV) of the estimates produced:

$$\widehat{CV}\ (\hat{Y})\% = \frac{\sqrt{\hat{V}\ (\hat{Y})}}{\hat{Y}} * 100$$

CV less than or equal to 10% is considered precise. Hence, the estimate is considered reliable.

4.0 Results and Discussions

4.1 Selection of Best Sampling Design

4.1.1. Simulation Results and Assessment

Characteristics of the estimated monthly catch from simulated production data under different scenarios of sampling rate and data collection frequencies are summarized in Table 2. Relative bias is generally larger because of the sparsity in the data used in characterizing the parameters of the data generating process. There are small differences in relative bias and coefficient of variations between 25% and 50% sampling rates. Larger differences, however, are observed across different data collection frequencies. Daily data collection is very ideal but not logistically efficient. This would mean assignment of a data collector dedicated to a sample landing center. Once a month data collection is not reasonable either since bias and CV are too large, as this also fails to capture catch distribution influenced by lunar cycle (Poisson et al, 2010). There is a large increase in bias and CV from daily to every other day data collection. However, every other day and the less frequent once a week data collection have minimal difference in bias and CV of the estimated catch for the month.

Table 2. Results of Sampling Experiments (PPS) with Simulated Data for Municipal Fisheries (Frequency of Data Collection by Sampling Rate)

Frequency of Data Collection	**Sampling Rate**					
	0.1		**0.25**		**0.5**	
	CV(%)	**Bias (%)**	**CV(%)**	**Bias (%)**	**CV(%)**	**Bias (%)**
Everyday	3.90	3.07	2.87	1.95	4.45	1.60
Every Other Day	5.66	13.65	4.06	13.10	5.10	12.98
Once a Week	6.71	20.81	4.93	20.4	5.74	20.24
Twice a Week	6.33	17.81	4.62	17.35	5.49	17.20
Twice a Month	9.00	28.68	6.67	28.36	6.97	28.11
Once a Month	11.97	37.16	8.90	36.75	8.79	36.55

Outcomes of sampling experiments are also summarized for every domain (provinces) in Table 3. CV are generally small (lower than 10%), except for a few provinces like Camarines Norte and Surigao del Sur. Some provinces registered large CV like Ilocos Sur (74.72%), La Union (25.30%), Western Samar (23.55%), and Catanduanes (13.88%), but these are not among the top 80% producing provinces. Sparsity of the data from the frame as well as inconsistency between catch data and frame information could have triggered this inflation in CV of municipal catch estimates in these provinces.

Table 3. Results of Sampling Experiments (PPS) with Simulated Data for Municipal Fisheries (Monthly Estimates-By Province-10% Sampling Rate, Once a Week Collection)

Province	CV(%)	Bias (%)
AGUSAN DEL NORTE	10.23	14.88
BATANGAS	5.65	14.38
BOHOL	3.60	4.37
CAMARINES NORTE	20.69	38.87
CAMARINES SUR	3.27	5.41
CATANDUANES	13.88	55.83
DAVAO DEL SUR	9.81	10.12
DAVAO ORIENTAL	6.56	19.52
EASTERN SAMAR	3.56	10.05
ILOCOS SUR	74.72	18.21
ILOILO	5.25	43.75
LA UNION	25.30	25.75
LANAO DEL NORTE	6.78	16.30
LANAO DEL SUR	5.32	54.58
MASBATE	1.90	7.24
MISAMIS OCCIDENTA	6.78	7.13
NEGROS OCCIDENTAL	2.72	11.40
PALAWAN	4.80	32.30
PANGASINAN	9.31	17.86
SARANGGANI	3.77	8.53
SURIGAO DEL NORTE	2.28	8.20
SURIGAO DEL SUR	16.04	48.66
TAWI-TAWI	1.75	4.89
WESTERN SAMAR	23.55	34.61
ZAMBALES	4.49	17.01
ZAMBOANGA DEL NOR	7.33	25.09
ZAMBOANGA DEL SUR	9.48	38.63
ZAMBOANGA SIBUGAY	2.59	5.20

Quarterly catch estimates are also characterized in Table 3, similar patterns can be observed as with the monthly estimates.

Table 3. Results of Sampling Experiments (PPS) with Simulated Data for Municipal Fisheries (Quarterly Estimates-By Province-10% Sampling Rate, Once a Week Collection)

Province	Q1_CV	Q2_CV	Q4_CV	Q1_Bias	Q2_Bias	Q4_Bias

AGUSAN DEL NORTE	9.32	12.08	9.30	14.39	15.89	14.37
BATANGAS	5.38	5.79	5.77	13.44	14.71	15.00
BOHOL	2.80	3.50	4.51	4.04	4.21	4.86
CAMARINES NORTE	14.36	23.47	24.25	27.36	42.00	47.26
CAMARINES SUR	3.28	3.03	3.49	5.39	5.45	5.39
CATANDUANES	7.89	12.08	21.66	33.50	56.33	77.65
DAVAO DEL SUR	6.96	8.66	13.82	8.44	9.44	12.48
DAVAO ORIENTAL	6.16	7.65	5.88	18.96	20.79	18.80
EASTERN SAMAR	3.68	3.33	3.66	10.89	8.86	10.38
ILOCOS SUR	75.06	75.81	73.27	17.41	17.14	20.09
ILOILO	4.98	5.39	5.38	43.55	43.13	44.58
LA UNION	28.03	25.71	22.18	28.02	24.86	24.37
LANAO DEL NORTE	8.22	6.49	5.64	15.71	18.04	15.14
LANAO DEL SUR	7.87	5.40	2.69	54.32	61.99	47.43
MASBATE	2.02	2.09	1.60	6.25	7.90	7.56
MISAMIS OCCIDENTA	4.94	6.57	8.83	5.81	7.27	8.31
NEGROS OCCIDENTAL	3.18	2.80	2.17	12.61	10.68	10.90
PALAWAN	4.58	5.05	4.77	33.79	31.08	32.03
PANGASINAN	8.64	12.15	7.14	17.88	19.10	16.59
SARANGGANI	3.25	4.08	3.97	7.95	9.01	8.63
SURIGAO DEL NORTE	2.08	2.57	2.20	8.44	8.35	7.80
SURIGAO DEL SUR	9.42	27.35	11.36	34.24	76.51	35.22
TAWI-TAWI	1.91	1.90	1.44	4.97	5.26	4.45
WESTERN SAMAR	26.43	23.63	20.59	33.45	35.94	34.44
ZAMBALES	4.25	4.95	4.26	18.61	16.98	15.45
ZAMBOANGA DEL NOR	8.17	6.71	7.10	23.51	25.97	25.80
ZAMBOANGA DEL SUR	11.70	7.19	9.55	40.81	34.82	40.27
ZAMBOANGA SIBUGAY	4.36	1.31	2.11	6.58	4.27	4.75

CV and relative bias of the 200 replicates are summarized in Table 4. CV and bias are slightly higher than those in PPS. However, considering the possibly inconsistent levels of ADU in the frame, stratified design is perceived to be more robust (problems can be resolved by post-stratification) than with PPS.

Characteristics and estimates from sampling rates of 10% and 25% are not too different. Daily and every other day data collection would also be better, but the deterioration of efficiency of once a week data collection is not too far.

Table 4. Results of Sampling Experiments (Stratified) with Simulated Data for Municipal Fisheries (Frequency of Data Collection by Sampling Rate)

Frequency of Data Collection	**Sampling Rate**					
	0.1		**0.25**		**0.5**	
	CV(%)	**Bias (%)**	**CV(%)**	**Bias (%)**	**CV(%)**	**Bias (%)**

Everyday	4.67	9.7	3.64	7.49	2.95	5.88
Every Other Day	5.25	10.63	3.87	8.98	2.95	8.02
Once a Week	7.34	12.82	5.43	11.42	4.14	10.61
Twice a Week	9.31	15.2	6.86	13.78	5.24	13.03
Twice a Month	11.09	20.44	8.23	19.21	6.28	18.6
Once a Month	10.46	28.96	8.19	28.04	6.56	27.6

Considering a 10% sampling rate with once a week data collection, CV for the top 80% producing provinces are within 10% or lower, except for Lanao del Sur (12.55%). Ilocos Sur now have lower CV at 11.62% from over 74% in PPS samples, see Table 15 for details.

Table 5. Results of Sampling Experiments (Stratified) with Simulated Data for Municipal Fisheries (Monthly Estimates-By Province-10% Sampling Rate, Once a Week Collection)

Province	CV(%)	Bias(%)
AGUSAN DEL NORTE	5.20	10.78
BATANGAS	6.72	12.31
BOHOL	2.17	4.19
CAMARINES NORTE	10.63	22.76
CAMARINES SUR	3.94	6.99
CATANDUANES	9.91	30.78
DAVAO DEL SUR	5.38	9.97
DAVAO ORIENTAL	5.42	12.70
EASTERN SAMAR	5.69	13.13
ILOCOS SUR	11.62	34.87
ILOILO	5.85	26.97
LANAO DEL NORTE	5.44	10.31
LANAO DEL SUR	12.55	28.46
MASBATE	2.34	5.21
MISAMIS OCCIDENTAL	4.22	6.92
NEGROS OCCIDENTAL	3.29	10.88
PALAWAN	5.07	18.15
PANGASINAN	10.04	14.36
SARANGGANI	5.59	9.20

SURIGAO DEL NORTE	2.79	7.48
SURIGAO DEL SUR	11.03	28.76
TAWI-TAWI	3.40	6.27
ZAMBALES	5.50	16.18
ZAMBOANGA DEL NORTE	6.66	15.47
ZAMBOANGA DEL SUR	8.78	21.92
ZAMBOANGA SIBUGAY	3.17	5.55

4.1.2 Parallel Pilot Survey Results

The pilot run of redesigned QMFS is conducted in the province of Quezon, Negros Occidental and Surigao Del Norte. Province also serves as the domain of the survey. This means that species unloaded in the landing center and its measurements within the geographic area, regardless of from where and which fishing ground it was caught, are accounted for in the province.

The updated list of municipal fish landing centers serves as the sampling frame in the selection of sample landing centers. The said list was generated from the Listing of Marine Fish Landing Centers (LMFLC) which was conducted in 2019.

The selection of sample landing centers for pilot redesigned QMFS is through stratified random sampling with the average daily unloading (ADU) as the stratification variable. The sampling rate will be 10 percent of the total number of landing centers in the province.

The current and proposed designs' estimates were calculated using the results of the pilot survey. Figures 1 and 2 provide a comparison of current and proposed design for the coefficient of variation (CV) of total volume and average value of municipal fisheries in pilot provinces.

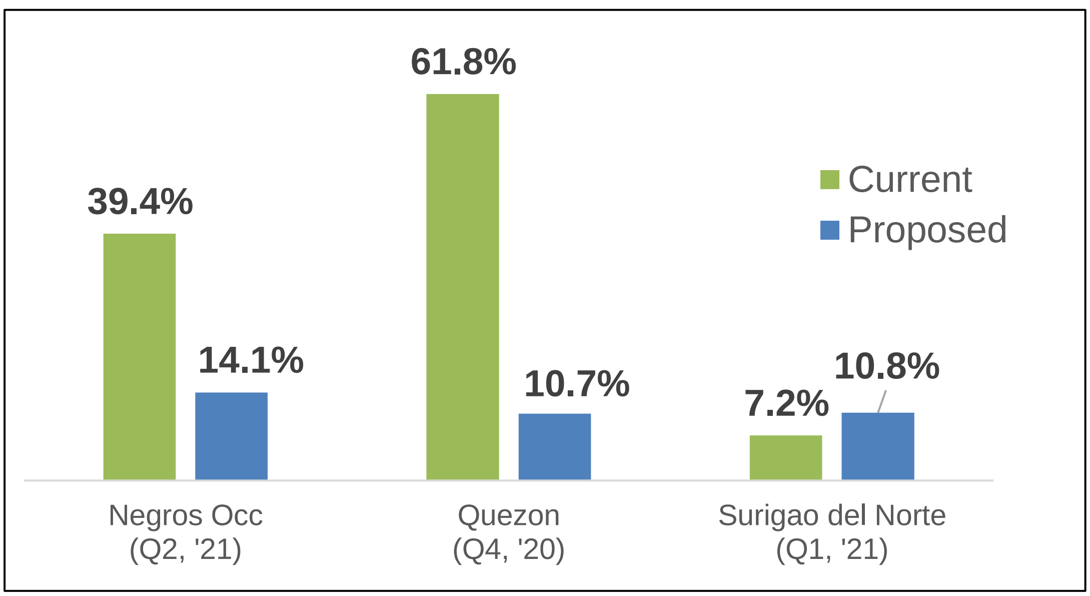

Figure 1. CV (%) of Total Volume of Production in Pilot Provinces

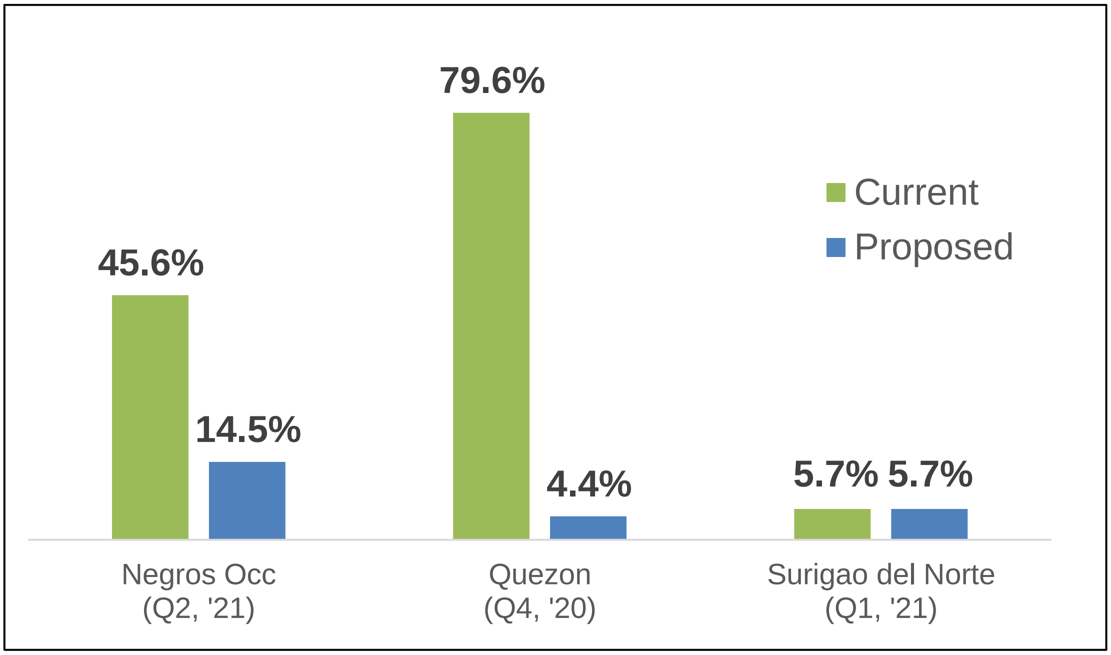

Figure 2. CV (%) of Average Price in Pilot Provinces

Generally, proposed design's coefficient of variation (CV) of total volume and average price is lower than the current design in most of the pilot provinces.

4.2 Modifications on the Best Sampling Design

During the technology transfer training of the Statistical Methodology Unit (SMU) to Fisheries Statistics Division (FSD), it was observed that for QMFS more samples are selected from the lower strata or the strata that have small values of average daily unloading. According to FSD, operationally, it is more convenient to have sample Landing Centers (LCs) per stratum that are close at hand but still considering the stratum boundaries. This is to maximize the data that will come from LCs with high values of average daily unloading. With this, SMU devised additional codes to recompute for the stratum sample sizes with the same stratum boundaries computed using *Adjacent Means*. The chosen allocation scheme used is the *Neyman allocation*.

Neyman allocation is one of the sample allocation methods that may be used with stratified samples. The purpose of the method is to maximize survey precision, given a fixed sample size, hence is fit for the computation of stratum sample sizes since the total sample size (10% of the total LCs) is already fixed per province.

5.0 Summary and Conclusions

The new sampling design for QMFS is a two-stage stratified sampling with systematic selection of landing centers in the first stage and systematic selection of boats in the second stage. The sampling rate of landing centers is 10%. If the total boats in a landing center is greater than 10, 10 boats are sampled, otherwise, sample all boats. The frequency of data collection is once a day per week where AM unloading is separated from PM unloading.

The landing centers are divided into three strata using the iterative method of Adjacent Means with average daily unloading as the size measure. The set boundaries are then used to compute for the optimum sample size per stratum using the Neyman Allocation method. Selection of boats at the second stage happens during the operation since the list of boats is not yet available.

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