A Protocol for Desktop Analysis on Master Sampling Frames for Fisheries and Aquaculture

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1

Introduction

The absence of a comprehensive master sampling frame was identified in de Graaf et al. (2011) an important obstacle in developing scientific data collection procedures for the fishery and aquaculture sectors. These sectors consist of multiple populations, and diverse variables are of interest, ranging from production to socioeconomic characteristics of fishers. Combining multiple sources of information is often necessary to develop master sampling frames that adequately target the populations and concepts of interest. Challenges in combining multiple sources of information may include incomplete data, unbalanced data structures over time or space, and measurement issues arising from differences in data collection procedures. Subjective procedures for synthesizing multiple sources of information suffer from lack of transparency and may produce systematic biases. Statistical procedures for combining multiple sources of information are better suited to data-driven decision making because they are transparent, reproducible, and allow quantification of the uncertainty in the estimators. Given the value of combining multiple sources when forming a master sampling frame for surveys of fisheries and aquaculture, a natural focus to consider for the desktop analysis is on statistical procedures for combining multiple sources.

Several types of data sources can contribute to the master sampling frame. Possible data sources for building the frame include (1) administrative data (i.e., information from registration, licensing, implementation of management programs), (2) demographic and agricultural surveys/censuses, (3) probability samples targeting fisheries specifically, and (4) maps and other geographic representations of major fishing areas. Global Strategy (2016 a, b) review sources of data for constructing frames to cover the fishery and aquaculture sectors, focusing largely on situations for developed countries. One of the objectives of the desktop analysis is to shift attention to data sources for frame construction that are appropriate for developing countries.

As discussed in more detail in Section 2, any pilot test will likely involve some combination of four basic components: (1) learning about the nature of fisheries and aquaculture in the selected test country, (2) establishing primary objectives and variables of interest for the selected test country, (3) reviewing available data sources for building a master sampling frame in the selected test country, and (4) possibly, constructing an empirical example based on one or more data sources.

In Section 3, two specific options for pilot tests are discussed. Given the important role of integrating multiple data sources in the process of building a master sampling frame, one option (Section 3.1) may be to illustrate the properties of a statistical procedure for combining multiple data sources. A different possibility (Section 3.2) is to conceptually step through the process of developing a master sampling plan for the selected test case. The desktop analysis will not involve collection of primary data, an activity requiring resources beyond the project time-line and budget. The outcome of the desktop analysis may identify gaps in existing data sources and recommendations for revisions to the data collection systems in the test country.

This pilot test protocol is a synthesis of initial "brainstorming" of desktop analysis options, discussions with FAO, and revisions to preliminary ideas based on recommendations received at the Expert Meeting in Rome (May, 2017). Section 2 covers basic aspects of any pilot test in generality. In Section 3, two relatively specific options for the pilot test are discussed. Section 4 reviews data collection for fisheries in possible test countries. Finally, discussion topics from the Expert Meeting that will play a role in formulating the details of the desktop analysis are presented.

2

Basic Elements of a Desktop Analysis

After decisions are taken on test country, many options for a pilot test will include elements from the following four components: (1) learning about the nature of fisheries and aquaculture in the selected test country, (2) defining primary objectives and variables of interest for the selected test country, (3) reviewing available data sources in the selected test country, and (4) optionally, constructing an empirical example based on one or more data sources. The empirical example may illustrate the properties of a statistical procedure for combining multiple data sources. Primary resources for the first two components include published documentation and possibly communication with experts. Data may be used to construct an empirical example.

2.1. BACKGROUND: UNDERSTANDING THE NATURE OF FISHERIES AND AQUACULTURE IN TEST COUNTRY

Understanding the basic structure of the fishing and aquaculture industries is a prerequisite for formulating the objectives of the official statistics program. The first stage of the desktop analysis will involve research into the basic nature of fisheries and aquaculture in the selected test country. This will result in a brief description of the important components of the fishery and aquaculture sectors and a discussion of any prominent issues facing the fishery and aquaculture industries in the test country.

The description of the important components of the fishery and aquaculture sectors will include but not be limited to these attributes:

- Current estimates of the contribution of fishing/aquaculture to GDP
- Current estimates of the contribution of fishing/aquaculture to employment
- Geography of fishing/aquaculture
    - Marine: dominant components of marine fishing and aquaculture
    - Inland: major lakes or rivers
- Targeted species
- Disposition of fish
    - Commercial: sale at market, export at sea, general export, sale to processors
    - Subsistence: fishing for consumption
- Size of boat or facility
- Type of gear
- Socioeconomic attributes of fishers
    - Age, education, etc.

The overview of the fishery and aquaculture sectors will also include a discussion of any important issues facing the industry or new developments in management programs that could impact official statistics. Challenges facing the industry can motivate parameters of interest. Government regulation or subsidy programs can provide administrative data for use in sampling frames or estimators. Topics that may be addressed in this section include but are not limited to the following:

- Possible challenges facing the fishing industry
    - Illegal fishing from vessels without a license
    - Declining stock, perhaps associated with reductions in CPUE over time

- Existing government programs to regulate or manage the fishing industry
    - Total allowable catches
    - Assistance programs to encourage sustainable practices
    - Assistance programs to increase yield
    - Emerging co-management of community fisheries
- Existing government programs to check for compliance with regulations
    - Observer programs (on-board, on land, or aerial) to check for compliance with bycatch laws or other forms of illegal fishing

2.2. FORMULATING THE OBJECTIVES: PARAMETERS, TARGET POPULATIONS, AND VARIABLES

The characteristics of the fishery and aquaculture industries motivate parameters of interest. In defining parameters, it is important to specify the relevant reference target populations and population units. Indicators need to be defined as explicit functions of measurable quantities, which are the variables measured in the survey. In this stage of the desktop analysis, how the general context described in Section 2.1 translates into the objectives of a statistical problem is explained.

The list below identifies important concepts related to defining objectives for a survey of fisheries and aquaculture. The reader is referred to Global Strategy (2016; a & b) for further discussion:

- Parameters for surveys of fisheries and aquaculture divide into three groups: production-related parameters, biological and environmental parameters, and socioeconomic parameters.
- Target populations: The target population is the collection of all population elements of interest, where population elements are the units in the population whose characteristics are of interest. The relevant unit depends on the specific context.
- The variables are the characteristics of the population elements that are recorded. One or more variables may be used to define a parameter. When defining variables, it is important to consider nuances associated with the measurement process. For instance, catch may be measured in terms of weight or number of fish, and conversion factors from

processing units or local units (i.e., baskets, cartons, ground weight) to standard units can be important.

The variables in the FAO annual Fisheries Yearbook constitute an important set of variables. These variables relate to fishery fleet, type of aquaculture, production by species (Tonnes), value by species (price per kilogram), and demographics. Demographic variables include sex and whether they work part-time or full-time. The list below specifies variables in the FAO Fisheries Yearbook in somewhat more detail:

- Fishing fleet: number of vessels, gross tonnage, and power (Kw) broken down by categories defined by size and gear type
    - Size categories (meters) 11.9, 12-17.9, 18-23.9, 24-29.9, 30-35.9, 46-49.9, 45-59.9, 60-74.9, >75
    - Types: Trawlers, purse seiners, other seiners, gill netters, trap setters, long liners, other liners, multipurpose vessels, dredgers, other fishing vessels
- Type of aquaculture: enclosure mechanism, type of water, size of facility
- Demographics: Number of males and females by working status and working domain
    - Status categories: Full time, part-time, occasional, unspecified
    - Working domains: aquaculture, inland waters fishing, marine coastal fishing, marine deep sea fishing, marine fishing, subsistence
- Disposition: marketing fresh, freezing, curing, canning, reduction, other
- Production for capture fisheries: tonnage by species
- Production for aquaculture: tonnage and price per kilogram by species

2.3. REVIEW PROPERTIES DATA SOURCES IN TEST COUNTRY

Many countries have existing survey or administrative programs that generate information related to fisheries and aquaculture. In this section, a review of the utility of existing data sources for building a master sampling frame that can support surveys designed around the objectives defined in Section 2.2 will be undertaken.

Such a review could be divided into three main components: listing the data sources, describing their properties, and analyzing possible uses of the data sources. Challenges that the test country currently faces when using existing data sources, especially for the purpose of building frames will be also discussed. This evaluation of the data sources may highlight gaps in the existing data sources. Limitations in existing data may motivate suggestions for ways to improve an existing data source or recommendations for initiating a new data collection program.

Important categories of data sources are listed below. Further details can be found in Global Strategy (2016, a & b).

- Administrative data
    - Examples include information from registration, licensing, implementation of management programs
- Demographic and agricultural surveys/censuses
- Surveys or censuses targeting fisheries and aquaculture operations specifically
- Maps and other geographic representations of major fishing areas, docks, or landing sites
- Subjective information from local experts
- Environmental data related to salinity, temperature, etc.

The properties of the data sources relative to measurement and selection errors that they are likely to embody will be analysed. An important non-sampling error from the perspective of the frame is coverage error. Measurement errors, such as incorrect recall or reporting bias, have implications for the frame because the choice of the frame often determines a particular data collection process.

In addition to describing the data sets and their properties, possible ways to use the data will be evaluated. Some data sets may support use of direct survey estimators that are derived under the framework of selecting a probability sample from a finite population. Other data sets may require model-based procedures, which may utilize a Bayesian paradigm for inference.

2.4. EMPIRICAL EXAMPLE

A desktop analysis may also include an empirical example. Given the need to combine multiple data sources to develop a comprehensive master sampling

frame, focus can be made for this empirical example on the statistical properties of one or more of the data combination methods. The empirical example will likely involve simulated data in addition to real data. Use of simulation is not only practical but also enhances the generalizability of the empirical study because the properties of the procedure across a range of parameter values can be examined. One way to link the empirical example to the test country of interest, is to relate the empirical example to the data sets discussed in Section 2.3 and the objectives identified in Sections 2.1 and 2.2. Possible issues to consider in the context of developing an empirical example are as follows:

- One challenge in combining multiple sources of information in the context of a developing country is that programs change over time, leading to unbalanced data structures and incomplete data. One option for an empirical study involves examining methods for combining multiple but incomplete data sources. In the context of a measurement error model, a situation in which the mechanism that leads to the missing data is correlated with the true but unobserved value of interest might be considered.
- Aquaculture data are traditionally collected through an agricultural survey, possibly as a second-phase of data collection. Two possible questions to explore through an empirical example are as follows: (1) Is using an agricultural survey as the basis for collection of information on aquaculture is adequate? (2) What are possible benefits and challenges associated with directly sampling aquaculture facilities?
- It could be considered to developing an empirical example to investigate the possible uses for environmental variables in building the master sampling frame. Questions to explore in the context of the selected test country are how environmental variables may play a role in frame construction, sample design, and estimation. Data related to environmental variables would be needed to support this type of empirical example.
- Many monitoring programs are ultimately interested in measuring change over time. Few survey designs for fisheries and aquaculture in the literature explicitly address the objective of estimating change. Through an empirical example based on a framework for a selected test country, issues associated with building a master sampling frame that explicitly address an objective of estimation for change over time might be explored.
- One option for a desktop analysis would be to assist a country (in a consulting fashion) to develop and maintain a usable Fisheries

Information Management System. For instance, Namibia has a database for storing several sources of information on fisheries and aquaculture but apparently lacks resources required to use the database (Uahengo, 2013). This sentiment is echoed in the comments related to data collection for fisheries in Asia discussed in Section 3 below. This option relates to a consulting project that MRAG Americas completed that attempted to create a generic Fisheries Information Management System that would apply broadly across a range of conditions (MRAG, 1999).

- The desktop analysis could also be aligned with on-going projects of FAO or other institutions. Specific projects of the FAO Fisheries Department that have been mentioned relate to data collection for fisheries in Oman and Angola. This idea is revisited in Section 5 and has been discussed in more detail with FAO Fisheries Department during the Expert Meeting.

The process of completing steps 2.1-2.3 can also inform the choice of an empirical example. For instance, steps 2.1-2.3 may identify a particularly salient issue for a specific test country. The empirical example may then address that issue. The discussion topics in Section 4 are also relevant for guiding the specific details of an empirical example.

This section reviews components of a pilot test in generality. Discussions at the Expert Meeting helped to decide on relevant options. The next section presents two possible forms for the pilot test.

3

Specific Options for the Pilot Test

In this section, two relatively specific options for a desktop analysis are discussed. The first involves a data analysis related to combining multiple sources of information. The second conceptually steps through a proposed process of developing a master sampling plan. After the Expert Meeting in Rome (May, 2017), it was decided to pursue the second option described in Section 3.2 below.

3.1. EXPLORE THE INTEGRATION COMPONENT OF A MASTER SAMPLING FRAME

Given that multiple sources are needed for surveys of fisheries, the "integration" component of the master sampling frame concept is particularly important. The integration component relates to frame construction, maintenance, sample design, and estimation. The integration piece may be as simple as adding production estimates based on surveys of disjoint populations. In more complex settings, integration component may involve conducting a large survey based on a frame that is inexpensive to use coupled with a smaller survey based on a more expensive method. For instance, a large household survey that obtains a cheap measurement of production-related characteristics may be used in combination with a more expensive direct measurement. The use of a validation study to verify administrative data is another example of the integration component of the master sampling frame.

The illustration in below demonstrates a model-based procedure for combining multiple estimators. The connection between the illustration below and a master sampling frame lies in the integration component of the master sampling frame. Different frames will generate different estimators. The statistical office should use statistical procedures, rather than subjective

procedures, to combine these multiple estimators. The illustration below demonstrates the feasibility of applying a model-based approach to integration of data from a developing country. In the example presented below, the data arise from surveys that use three different frames and consequently three different data collection procedures. Because of limited resources for constructing the example, the results are admittedly dissatisfying. In the pilot test, an effort will be made to work with subject-area experts to obtain the information needed to construct a more satisfying example. Section 3.1.1 explains the motivation in more detail. Section 3.1.2 provides an illustration using data for the Lower Mekong River Basin.

3.1.1. MOTIVATION AND DESCRIPTION

Developing a comprehensive master sampling frame for fishery and aquaculture sectors requires combining multiple sources of information. Combining data sources in a subjective fashion is undesirable because of lack of transparency and reproducibility as well as the possibility of introducing bias. Using statistical models to combine multiple sources of information is preferable because methods are reproducible, transparent, and furnish estimates of the uncertainty in the estimators.

A common class of statistical models for combining multiple sources of information is referred to as "multi-factor models" or "measurement error models." These models represent the underlying quantity of interest as an unobserved parameter to predict. In the model, the multiple data sources are viewed as imperfect measurements of the parameter of interest with different measurement error properties.

Identifying the parameters of the model requires assumptions about the properties of the estimators and the parameters of interest. Global Strategy (2015) and Fuller (1987, Ch. 1) define these sets of assumptions in the context of statistical models Two common sets of assumptions are described conceptually below:

- Two data sources are available. One data source is assumed unbiased. The variance of the unbiased data source for estimating the true parameter of interest is known. The unbiased data source is often obtained from a sample survey, and the variance is based on the survey design.
- Three data sources are available. One data source is assumed unbiased. None of the estimators have known variances. An assumption that the

third data source is related to the true parameter but has measurement errors that are uncorrelated with the errors in the other two sources (often called the instrumental variable assumption) allows identification of parameters.

In developing countries, obtaining data sources that satisfy the assumptions above may be infeasible. For instance, a sample survey may not exist for the year of interest. An assumption that one of the estimates is unbiased may be difficult to justify. Estimates of variances may be unavailable. When these assumptions are not satisfied, parameters of traditional models are not identifiable, and traditional estimation procedures are not applicable.

One approach to facilitating inference for non-identifiable models is to place proper prior distributions on non-identifiable parameters. This idea used in the context of missing data in Nandram and Woo (2015). In the context of a developing country, information from a subjective reporting system may inform the prior distributions for non-identifiable parameters.

This desktop analysis could explore the following three questions:

1. Can a fully identified statistical model be specified to combine multiple existing data sources for a developing country? Can the model be used to obtain a reasonable estimate and corresponding 95% confidence interval?
2. If assumptions required for model identification are difficult to justify, can inference be done after assigning prior distributions for non-identifiable parameters? What is the increase in standard errors that results from relaxing the model assumptions?
3. Can subjective reporting systems provide information about non-identifiable parameters?
4. Given challenges arising in steps 1-3, what recommendations could be made for future data collections?

3.1.2. ILLUSTRATION FOR LOWER MEKONG RIVER BASIN

MRC (2010) presents estimates of production for the Lower Mekong River Basin based on four sources. θ is considered to be the true production and let $\hat{\theta}_i$ be the estimate of θ based on source i, where $i = 1$ for the national estimate, $i = 2$ for the wetland productivity survey, $i = 3$ for the consumption-based survey, and $i = 4$ for the catch assessment survey. The wetland productivity survey actually produces three estimates based on three scenarios, and the estimate based on the medium productivity scenario is adopted for this

analysis. Table 1 gives the production estimates based on the four sources. The data are described in more detail in Section 4.1.1 below.

Because the national estimate is thought to be an underestimate, let's assume that

$$E[\hat{\theta}_1] = \theta + b_1,$$

where $b_1 < 0$. Let's assume that the other three sources of information are unbiased for θ; that is,

$$E[\hat{\theta}_i] = \theta,$$

for $i = 2, 3, 4$. For simplicity and identifiability, let's assume

$$V\{\hat{\theta}_i \,|\theta\} = \sigma^2,$$

for $i = 1,2,3,4$. A further assumption is that all estimators are normally distributed and mutually uncorrelated.

To complete the model specification, let's specify prior distributions for θ, b_1, and σ^2. Because that production is non-negative, the prior distribution for θ is uniform on $(0,10)$, where the units for θ are millions of tonnes. The prior for b_1 is uniform on the interval $(-10, 0)$. The prior for σ^2 is uniform on the interval $(0, 100)$.

Table 1: Estimates of catch in the Lower Mekong River Basin based on national estimates submitted to the FAO, a wetland productivity survey, a survey of household consumption, and a catch assessment survey.

Source	Millions of Tonnes
FAO	0.75
Wetland Productivity	1.10
Consumption	2.10
Catch Assessment	2.60

The model was fit using JAGS (Plummer, 2003). Table 3 shows the 95% credible intervals for the three model parameters. The posterior distributions are diffuse because only four data points was available. The posterior mean for production is 2.2 million tonnes, and the posterior standard deviation is 1.0. A 95% credible interval for production is [0.57, 4.48] million tonnes, which is considerably wider than the range provided in MRC (2010).

Table 2: 95% credible intervals for model parameters

Parameter	95% Credible Interval
b_1	$[-6.1, \quad -0.1]$
θ	$[0.57, \quad 4.48]$
σ^2	$[0.28, \quad 9.5]$

To enhance this illustration, more information is necessary. Assuming that the variance for $\hat{\theta}_2$ is smaller than the variance for the other sources might represent the MRC (2010) conjecture that the consumption survey is more reliable than the other sources. Consultation with experts may support informative prior distributions.

3.2. EVALUATION OF A PROCEDURE FOR DEFINING A PLAN FOR A MASTER SAMPLING FRAME

During the Expert Meeting, an idea has been developed for an approach to the desktop analysis that differs from the approach outlined in Section 3.1 and relates more closely to the final guidelines. Below, a process is outlined for determining a defensible approach to developing a master sampling frame for fisheries and aquaculture that can be applied to a variety of specific contexts. One option for the desktop analysis is to apply the process proposed below in the context of a specific country. Essentially, it is assumed that resources to develop a master sampling frame for a specific country are available. Then, individuals with expertise in the nature of fisheries in that country will be guided to step through the process outlined below. The outcome of this exercise would be a plan that could be implemented to develop a master sampling frame for the selected test country if resources were available. A benefit of this option is that the process outlined below will be included in the final guidelines, and this exercise will likely enable us to improve this proposed process. One possibility is to conduct this exercise in the context of a country where FAO has experience. Options for collaboration with ongoing projects of FAO Fisheries and Aquaculture Department are discussed in this respect in Section 5. The steps of the process are as follows:

3.2.1. IDENTIFY THE PURPOSE OF ACTIVITIES

The first step is to identify the most important objectives of the activities, where the term "activities" is used for the set of surveys or programs under consideration. Current issues facing the fishing and aquaculture industries may have implications for the primary objectives. Useful questions to keep in mind when defining the purposes of activities include, "what estimates are desired for final reports?", "what information would be useful to know for decision-

making or management?", and "is a need perceived to verify information from administrative sources?" At this stage, objectives may be relatively broad. Subsequent steps (steps 3-4) will identify precisely the target populations, variables, and measurement units.

3.2.2. EVALUATE EXISTING DATA SOURCES AND ASSESS A NEED FOR NEW ACTIVITIES

In this step, the question to be considered is whether the objectives identified require new efforts, or whether existing programs could be used or modified to provide some of the desired estimates. Data from both statistical surveys and administrative sources will be evaluated. Relevant issues to consider for administrative data relate to how well the population is covered, availability of the data to the statistical office, and possible measurement errors. For survey data, questions may relate to the frequency of data collection, possible problems ensuring that every population element has a chance to be selected, and challenges in data collection.

The quality of a data collection program for addressing the objectives may relate to whether the data collection method is direct or indirect. As in Global Strategy (2016, a), the term "direct" is used to refer to objective observations taken at the location where fishing occurs. The term, "indirect" is used to refer to information collected from administrative sources or off-site surveys, such as household or telephone interviews.

Relevant questions for this step include:

- Are all of the estimation problems identified (in step 1) amenable to incorporation into existing programs?
- Will existing programs provide direct or indirect observation of variables needed (this may need to be revisited after more detailed consideration of variables and measurement later in the process; see step 4)?
- If data from existing programs will provide only indirect observation, are small-scale verification surveys desirable (and feasible)? What should be the temporal frequency of such efforts?

3.2.3. DEFINE TARGET POPULATIONS

Given the diversity of operational units involved in fisheries and aquaculture, it appears preferrable at this point to consider a problem as consisting of multiple populations, rather than sub-populations. For example, silver carp aquaculture may involve inland ponds or raceways, as well as small mobile cage cultures in inland lakes. These are really two populations because they are comprised of quite distinct units that bear little resemblance to each other, and may well require entirely different sampling plans to provide adequate coverage. The remaining steps should be conducted for each population separately, but then again for all populations as a whole, to ensure that overall objectives can be addressed.

3.2.4. DEFINE VARIABLES OF INTEREST AND MEASUREMENT UNITS

In step 1, broad goals for estimation were established. To design a scientific data collection system, objectives need to be defined in terms of specific, quantifiable measures. This step involves specifying variables and measurement units precisely.

3.2.5. DETERMINE CONTACT METHODS

This step involves determining an approach to data collection. The appropriate contact method will depend on the available data sources as well as the budget. Adequacy of different data collection approaches for meeting the objectives defined in step 1 will be evaluated at this stage.

3.2.6. OUTLINE SAMPLE DESIGN

Ideally, the design will be specified with the aim of achieving target levels of precision for a set of estimates of interest. Use of auxiliary information to define strata or selection probabilities can improve the efficiency of the design. The sample design is closely tied to the sampling frame, discussed in step 7 below.

3.2.7. CONSTRUCT SAMPLING FRAMES

Conceptually, the sampling frame is a physical representation of the target population. Operationally, the sampling frame is the list from which a sample is selected. A sampling frame may be a spatio-temporal representation of fishing sites or a list of fishers. Often, combing multiple data sources to form

the frame is necessary to obtain adequate coverage of target populations and concepts. This step will evaluate and determine an approach to sampling frame construction that is amenable to the goals defined in steps 1—4 and the contact method determined in step 5.

3.2.8. CONSIDER POTENTIAL NONSAMPLING ERRORS

Non sampling errors are likely to arise in any survey. A sampled element may not respond. Measurement error may occur in data collection. Population elements may be inadvertently omitted from the frame (undercoverage). The survey should be designed with an effort to minimize nonsampling errors. Given appropriate auxiliary information, estimation procedures can reduce adverse effects of nonsampling errors on the accuracy or precision of estimators.

3.2.9. DEFINE ESTIMATION PROCEDURES

The estimation procedure may make use of auxiliary information available on the frame or from other data sources external to the survey. The estimation procedure may attempt to adjust for nonsampling errors arising in data collection. Complex objectives, such as estimation for domains with small sample sizes, change over time, or relationship between variables, might require relatively specialized estimation methods.

3.2.10. DEVELOP FRAMEWORK FOR STORAGE AND RETRIEVAL OF DATA AND RESULTS

Data need to be stored in a consistent format that is updated regularly. Maintaining unique identifiers for population elements is often a critical aspect of a well-functioning data management system. This is particularly important for organizing the various components of a master sampling frame. Developing a plan for data storage should be part of the overall master sampling frame process.

3.2.11. DECIDE ON A PLAN UNDER BUDGET CONSTRAINTS

A single pass through the steps above may not result in an acceptable plan. A discussion in a later step in the process may give reason to revisit an earlier step. For instance, the assessment of nonsampling errors in step 8 may cause the analysts to reconsider the contact methods determined in step 5.

Budget can also limit the available options and necessitate an iterative approach. If the process results in a plan that exceeds the allowable budget, then the objectives may need to be revised. One approach to accommodate uncertainty in the budget is to develop different plans for several possible funding levels (i.e., a low-level funding plan, medium-level funding plan, and high-level funding plan).

4

Discussion of Possible Test Countries

To complete the pilot test, resources about the nature of fisheries and fisheries data collection in the selected test country will be required. These resources may come as a combination of written documentation and communication with local experts. In preparation for writing the pilot test report, documentation describing the nature of fisheries and fisheries data collection systems for several potential test countries has been reviewed.

The review below focuses heavily on Asia for two reasons. One reason is that documentation describing data collection for fisheries exists online. The second reason is that is that reviewers of Global Strategy (2016 a,b) identified lack of content related to Southeast Asia as a weakness in the first two technical reports prepared for this project. Despite the emphasis of this section on Asian countries, thechoice of the selected Test Country has not been limited to Asia.

This section is organized by continent. In Section 4.1, data sources for fisheries and aquaculture in several countries in Southeast Asia are reviewed. Sections 4.2 and 4.3 pertain to countries in Africa and South/Central America, respectively. The choice of the countries included in this section is based heavily on the nature of the documentation found online. The material on Mozambique and South/Central America below is also in Global Strategy (2016 a) and is repeated here for ease of reference and to provide coverage of a broad range of countries in this report. The material on Southeast Asia is not covered in other Global Strategy reports.

4.1. SOUTHEAST ASIA

An important starting-point for the review is the annual Fishery Statistical Bulletin of Southeast Asia produced by the Southeast Asian Fisheries Development Center (SEAFDEC). This annual bulletin contains estimates

related to production and value for Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam. The SEAFDEC *Regional Framework for Fishery Statistics of Southeast Asia* and the introductory sections of the annual bulletins elucidate the target populations, definitions of variables, and units of measurement. Documentation describing the data sources for these bulletins is relatively sparse:

"Data and information available from various sources could be used as inputs for the Bulletin. These include the data collected through statistical surveys, from government records and semi-governmental organizations. In addition, data and information derived from new statistical techniques or small-scale surveys could also be used to provide inputs to the Bulletin."

SEAFDEC (2005) is a handbook that provides general guidelines for data collection related to fisheries and aquaculture but does not detail the specific methods that different countries use.

In an endeavour to better understand the sources of information that support statistics such as those reported in the SEAFDEC bulletins, a document produced by the group Strategies for Trawl Fisheries Bycatch Management (REBYC-II CTI) is considered and available here: http://www.rebyc-cti.org/downloads/doc_download/114-ref-06-overview-of-fisheries-data-collection-capture-fisheries-in-coastal-and-inland-small-scale-fisheries-in-cambodia. This document does not have an official title and seems to be the proceedings of the Regional Workshop on the Effective Fisheries Information Gathering in Coastal Small-Scale and Inland Fisheries for Southeast Asian Region, which took place in Bangkok, Thailand in 2013. The reader is referred to the general document as REBYC (2013) and cite specific country reports in REBYC (2013) using the name of the author of a particular report.

The reports in REBYC (2013) describe the nature of fisheries and fisheries data collection for several countries in Asia. The document includes specific reports for Cambodia, Indonesia, Thailand, and Vietnam. These reports describe the basic structure of the fishery and aquaculture sectors, discuss government interventions that may generate administrative data, provide estimates for production and selected socioeconomic characteristics, and overview the data sources that support published estimates. REBYC (2013) also includes a synthesis of issues related to data collection in a broader set of countries: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand, and Vietnam. Below, lessons learned from REBYC (2013) and related documentation are overviewed, focusing on the data

sources. Sections 4.1-4.3 discuss Cambodia, Indonesia, and Thailand, respectively. Section 4.4 is a summary of the synthesis of multiple countries provided in REBYC (2013).

4.1.1. CAMBODIA

Sensereivorth and Rady (2013) identifies two broad categories of data for fisheries and aquaculture statistics in Cambodia. One is the "Administrative Information System." The second is called "Scientific Survey" (Sensereivorth and Rady, 2013, pg. 15).

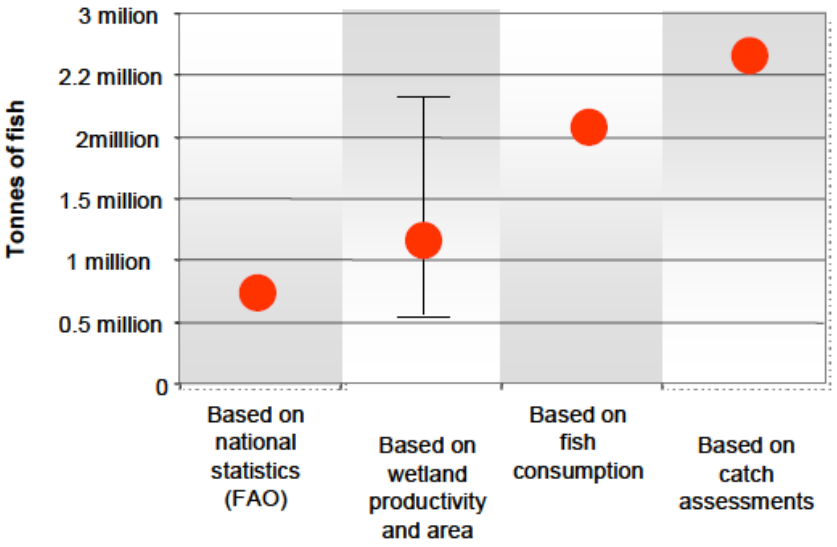
The Administrative Information System seems to be a form of a routine data collection system. This process begins at the sub-national level of the Cantonment. Trained officers for each cantonment complete a monthly logbook. The logbook has a standardized form produced by the central FiA. At a monthly meeting, the logbook data are cleaned, entered into a database, and aggregated to the national level. Sensereivorth and Rady (2013) does not define the details of the aggregation process.

In addition to the reporting system, "scientific surveys" support published estimates of production for Cambodia. A catch monitoring survey was initiated when the Mekong River Commission (MRC) began to support the fisheries sector in 1997. "The survey has been focused on catch monitoring from mobile fishing gears in main water bodies (Mekong and Tonle Sap River) and yearly observation from Dai Fishery (stationary bag-net) in the Tonle Sap River" (Sensereivorth and Rady, 2013, pg. 16).

MRC (2010) compares estimates of catch for the Lower Mekong River Basin (LMB) based on "national data" to estimates of catch based on three types of "science-based field surveys:" (1) catch assessment surveys (Van Zalinge et al., 2004), (2) wetland productivity surveys (Hortle, 2007), and (3) surveys measuring fish consumption at the household level (Hortle, 2007). The LMB includes parts of Lao PDR, Thailand, and Vietnam, in addition to Cambodia. Figure 1 below presents the estimates from the four sources provided in MRC (2010). The Wetland Productivity Study produces three estimates, based on low, medium, and high fish productivity scenarios. The upper and lower limits of the range provided for the wetland productivity study below correspond to the low and high scenarios, while the red dot corresponds to the medium productivity scenario. Coates (2002) and Barlow et al. (2008) argue that the national statistics, obtained from FAO publications, are likely underestimates because they are not based on scientific surveys (MRC, 2010). It can be noted

that MRC (2010) is not specific about the reference year, and that variations over time may contribute to differences between the estimates.

Figure 1: Estimates of fish production in lower Mekong River (includes a total from Cambodia, Lao PDR, Thailand, Vietnam) from four sources of information.



In addition to surveys targeting variables related to production, demographic surveys provide information about the socio-economic characteristics of fishers in Cambodia. Hap, Un, and Nasielski (2016) review methodology for three surveys of the socio-economic characteristics of fishers in Cambodia:

- 1998: "Socioeconomic assessment of freshwater fisheries of Cambodia"
- 2006: "Socioeconomics and values of resource in the Tonle Sap and Mekong-Bassac"
- 2009: "Economics and Livelihoods of Small-Scale Inland Fisheries in the Lower Mekong."

Sensereivorth and Rady (2013) notes the following challenges in collecting fisheries statistics in Cambodia:

- Diversity in fishing gears
- Lack of well-defined landing sites
- Small-scale fishers are not required to register according to the Law on Fisheries in Cambodia
- Cantonment officers have limited knowledge of fisheries
- Illiteracy among fishers makes data collection difficult

- High mobility of fishers during peak season
- Sale of catch to neighboring countries, particularly for large fishing boats
- Difficulty in soliciting collaboration with fishers in the process of data collection

Increasingly, government interventions in Cambodia are focusing on "fisheries co-management." This management regime results in "community fisheries," where a "community committee" maintains data related to number of fishers, number of fishing gears, catch, etc. Integrating national-level statistical production with "community management" procedures is suggested in Sensereivorth and Rady (2013) as a future direction for data collection on fisheries and aquaculture in Cambodia.

Given the extent of published literature documenting different surveys in Cambodia, Cambodia is a viable test country for this project. During the pilot test, the data sources overviewed in this section could be further researched and possibilities for combining multiple data sources using statistical models may be explored. One limitation of the estimates in the publications listed in this section is that few standard errors or confidence intervals are produced. For instance, in Figure 1, none of the estimates has a confidence interval. Similarly, the range of plausible values for fish production provided in MRC (2010) is the range of the four estimates. One aim of the research may be to provide a credible interval for fish production based a statistical model that could have generated the observed data. The preliminary illustration presented in Section 3.1 relates to the issue of standard error estimation.

4.1.2. INDONESIA

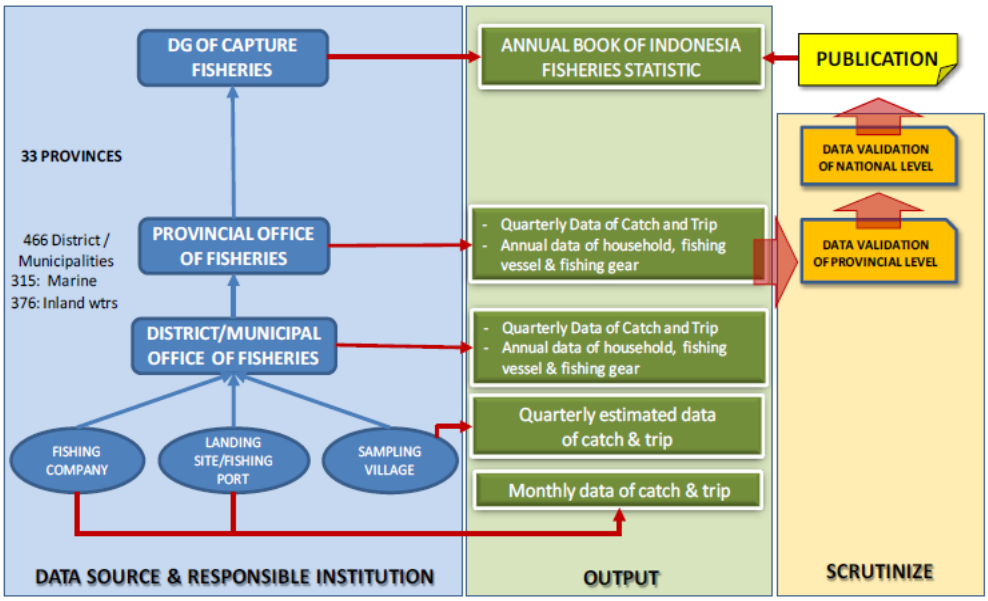
The Statistical Data Directorate of the Ministry of Marine Affairs and Fisheries in Indonesia publishes an annual report with data on catch and effort. Because of the time required for processing and validation, the report is typically published two years after the reference period. The report contains annual data on vessels, gear, and fishing households as well as quarterly data on catch and effort. (Suprapto and Anggawangsa, 2013).

The data that support the annual report arise from a routine data collection system depicted in Figure 2 from Suprapto and Anggawangsa (2013). District and province fishery officers collect monthly data on catch and effort. Every quarter, these data are aggregated to the district level. The district estimates are combined to produce estimates for Indonesia's 33 provinces, and finally the nation. (Suprapto and Anggawangsa, 2013)

Difficulties associated with the routine data collection system relate primarily to resources for implementation. Challenges and areas for improvement noted in Suprapto and Anggawangsa (2013) include human resource development, inter-agency coordination, and funding. Attempting to simplify the data collection format to reduce effort required by local officers was noted in REBYC (2013) as a possible way to further improve the system.

Indonesia has made several efforts to improve the quality of the data collected through the routine data collection system. Fishery officers have received training and technical assistance. Investments have been made in facilities and infrastructure. They developed an electronic, internet-based system called a Fisheries Statistic Information System (FSIS) for data collection and storage.

Figure 2: Schematic diagram of Indonesia's Fisheries Statistics System



In addition to the routine data collection system, Indonesia implemented a "Survey of Household Fishing Business" (SPI 2014) as a second phase of the 2013 Census of Agriculture. The SPI 2014 is described in Uluwiyah (2016). The SPI 2014 is focused primarily on fishing value and the socio-economic characteristics of Indonesia's fisheries. Information on production is also obtained.

The sample design for the SPI 2014 is a stratified two-stage design. The primary sampling unit is a census block, and the secondary sampling unit is a household within a census block. The frame for the first stage consists of all census blocks in which at least 10 fishing households were identified during

the 2013 agricultural census. The census blocks are stratified according to major fishing type. Within each selected census block, the heads of fishing households are listed and a further sample of households is selected. The document describing the design of SPI 2014 does not discuss variance estimation.

The data sources available for Indonesia suggest two possible directions for a pilot test. One direction could involve combining information from the routine data collection process with information collected from SPI 2014. For instance, routine data may be biased but, if correlated with survey responses, could be useful for small area estimation or imputation. A second approach could focus on variance estimation for SPI 2014. If the Census of Agriculture in Indonesia is not a complete enumeration, then variance estimators should reflect not only the variation due to the process of selecting the SPI 2014 from the Census but also the variation due to the first phase of selecting the sample for the Census of Agriculture. (The term "Census" traditionally refers to a complete enumeration; however, previous experience working with data from Tanzania and Namibia in the context of the FAO project described in Global Strategy (2015) is that the term "Census" is often used to describe what actually a sample survey is.)

Irianto et al. (2015) is the 2015 version of Indonesia's annual report to the Scientific Committee of the Indian Ocean Tuna Commission. Indonesian fishers target large pelagic fish, such as tuna, using long line, purse seine, and hand line. Data are collected from logbooks, a vessel monitoring system, onboard observers, and port sampling. The logbook data are mandatory, but Irianto et al. (2015) allude to issues associated with validity and a need for verification. Each vessel is required to be equipped with a vessel monitoring system before leaving the dock. Irianto et al. (2015) displays the spatial and temporal distribution of observed hooks and comments that the observed sets never extend south of 20^{o}S. Monthly coverage rates for the port sampling system range from 45—72%.

4.1.3. THAILAND

Siripech (2013), the REBYC (2013) country report for Thailand focuses on data collection for marine production and fishing effort. Marine production is classified into marine catch and aquaculture production. Marine capture fisheries are further divided into large-scale and small-scale fisheries.

Data are obtained from the following sources: "sample survey," "log book survey," "fisheries communities survey," and "the coastal aquaculture survey."

The log book survey provides information on large scale fishing gears. Sample surveys provide information on small-scale fisheries.

The survey for small-scale fisheries uses a stratified two-stage design. Fishing communities in coastal provinces are first classified into five zones, which serve as strata for the first stage. If I correctly understand Siripech (2013), the sample for the second stage is a stratified sample of fishing units, where the strata are gear types. An important challenge with respect to constructing a frame for the second stage relates to boat registration and fishing licenses. According to REBYC (2013), almost all small-scale fishermen do not register their boats. Further, when fishermen use multiple gears, they often only obtain licenses for one of the gears.

Nootmorn (2015) and Noranarttragoon (2015) describe additional monitoring programs for large-scale capture fisheries in Thailand. Nootmorn (2015) presents estimates submitted to the Scientific Committee of the Indian Ocean Tuna Commission. Noranarttragoon (2015) describes a survey program in the PrachuapKhiri Khan and Chumphon provinces to monitor trawl fisheries for bycatch.

4.1.4. SYNTHESIS SOUTH-EAST ASIA

The data collection systems reviewed in REBYC (2013) typically rely on four main data sources: (1) logbooks/routine data collections, (2) sample surveys, (3) licenses or registration, and (4) other sources of government administrative data. Typically, logbooks and routine reporting systems collect production-related variables. In some cases (i.e., Cambodia and small-scale fisheries in Thailand), catch assessment surveys provide information on production-related variables as well. Sample surveys (i.e., Indonesia SPI 2014) often collect information on socio-economic characteristics of fishers. Table 3 below is a crude summary of the data sources used in the countries reviewed in REBYC (2013).

REBYC (2013) also lists common problems associated with current data collection methods and possible mechanisms for improvement. Below, themes in these problems and solutions that are common to many of the countries reviewed in REBYC (2013) are listed.

Table 3: Summary of Data Sources discussed in REBYC (2013)

	Logbook/routine data collection	Licenses/registration	Sample surveys (includes ag. survey/census)	Other government admin. records
Brunei Darussalam	X	X	X	X
Cambodia	X	X	X	
Indonesia	X		X	
Lao PDR	X		X	
Malaysia	X		X	
Myanmar			X	
Philippines	X	X	X	X
Thailand	X	X	X	
Vietnam				

Problems in current data collections:

- Lack of cooperation from fishers; non-compliance
- Incomplete registration and licensing
- Out-dated administrative records
- Insufficient funding
    - High costs of sample surveys, particularly interviews
- Diversity of small-scale fisheries in terms of gears used and complexity of the ecosystem
- Small-scale fisheries geographically dispersed and mobile
    - Wide area of coverage – "many ports to cover"
- Insufficient human resources
    - High turn-over rate among data collection officers
    - Lack of training and supervision
- Lack of standardization
    - Differences in timing and definitions
    - Different local officers use different data collection forms for routine data collection

Possible solutions:

- Utilize more sample surveys
- Raise awareness about importance of fishery statistics
    - In particular, communicate importance of fishery statistics to individuals engaged in co-management in community fisheries
- Improve inter-agency communication
- Simplify data collection so that processes are easier to understand and less time consuming
- Use data from voluntary data collections
- Examine compatibility between logbook questionnaire and actual fishing practices
- Develop electronic data collection and storage systems
- Conduct fishery censuses to obtain updated frames
- Establish clear and standardized data collection procedures.

4.2. AFRICA

Data collection efforts for fisheries and aquaculture are briefly discussed in Namibia and Mozambique. Namibia is selected because extensive documentation is available online and a subset of data related to aquaculture has been obtained from the FAO project discussed in Global Strategy (2015). The material for Mozambique is taken from Global Strategy (2016 a).

4.2.1. NAMIBIA

The fish production industry in Namibia consists predominantly of large-scale marine capture fisheries, aquaculture operations, and small-scale inland fisheries. Artisanal fishing in marine environments is impractical in many parts of the country because of the strength of Benguela Current. Small-scale inland fishing takes place predominantly in northern regions, where communal agriculture is predominant. (Uahengo, 2013)

Following independence in 1990, the government of Namibia initiated several management strategies to support Namibian fishers who were previously disadvantaged by discriminatory laws. “The fisheries management system in Namibia is based on property rights and non-transferable quota allocations. Fishing vessels must be licensed and the licensing system is primarily for monitoring and statistical purposes” (Uahengo, 2013). For details about the structure of major fishing fleets, see Uahengo (2013).

The 2010/2011 report of the Ministry of Fisheries and Marine Resources (MFMR, 2011) in Namibia presents estimates related to value and production for the fisheries and aquaculture sectors. The report describes major target species and gives thorough information about relevant variables of interest and available data sources.

Several administrative programs provide potential sources of information related to large-scale fishing and aquaculture in Namibia. Namibia has sea, air, and coastal surveillance programs to guard against illegal marine fishing activities. Namibia also deploys onshore inspectors to monitor harbors and processing plants. Inland fisheries patrols are responsible for enforcing legislation that applies to small-scale inland capture fisheries, predominantly in the northern regions of Caprivi, Karas, Kavango, and Oshana. Vessel licensing systems generate administrative data. Log sheets are used to collect data from Namibia's tuna fishing fleet. Regulatory, licensing, and assistance programs for Namibia's emerging aquaculture sector are potential sources of administrative data (Iitembu, 2005).

Namibia has survey programs that focus largely on inland fisheries and communal aquaculture. The "Fish Market Survey," "Lake Liambezi fisheries survey," and "Zambezi fisheries survey" collect data related to small-scale inland fisheries in the northern regions (MFMR, 2011). Simasiku, Weyl, Kopij, and Mafwila (2017) provides an analysis of data collected from the Lake Liambezi survey. The 2013/2014 Agricultural Census in Namibia collected data related to aquaculture operations.

Uahengo (2013) identifies several problems associated with data collection and management for fisheries statistics in Namibia. Despite the existence of a quota system, "major gaps in the reporting and cataloging of marine fish landings exist." The data collection process is considered "cumbersome," and "the pathway for validation is complicated and not linear." Delivery of landings data is often delayed, and under-reporting is a concern. Although a fisheries information management exists, staff members lack sufficient training to use the system.

4.2.2. MOZAMBIQUE

Volstad et al. (2014) describe the methodology and results of a probability-based survey to estimate catch and effort in small-scale fisheries in Mozambique. The contact method is an access point survey. The frame is defined by the two-dimensional array consisting of landing sites and days. The landing sites are stratified by size, based on the number of registered fishing

units. Days are also stratified into months. The sample is a multi-stage sample. The primary sampling unit (PSU) is an intersection of a fishing location and a day. For each selected PSU, a census of the number of active and passive fishing units by gear type is conducted. A random sample of at least two passive units is selected from each PSU. For each sampled catch, total weight by species and number of fish is recorded. Size composition is obtained for a "limited number of species." Socioeconomic and meteorological data are also collected. The sample design and estimation procedures are applications of the types of procedures discussed in Section 5. Because some landing sites in the frame are inaccessible, the potential for selection bias exists. Using auxiliary information for all landing sites, weighting adjustments are used to account for the possibility of bias due to undercoverage.

Mozambique also has a Tuna fishing fleet that reports to the Scientific Committee of the Indian Ocean Tuna Commission (de Sousa, 2012). The reports submitted to the Scientific Committee of the Indian Ocean Tuna Commission describe the structure of the fishing fleets, focusing on longline targeting tuna. They provide estimates of catch, bycatch, and effort. They explain the use of logbooks, vessel monitoring systems, onboard observers, and dockside sampling schemes to collect data.

4.3. SOUTH AND CENTRAL AMERICA

Salas et al. (2007) focuses on small-scale coastal marine fisheries in Latin America and the Caribbean. They identify unifying characteristics of these fisheries and challenges in developing effective monitoring and management plans. The information is obtained from discussions at the first "CoastFish" conference as well as a literature review. Identifying characteristics of the fisheries include use of multiple gears, targeting multiple species, low capital, high labor, remote landing sites, large numbers of migrant and seasonal workers, and weak power among fishers. Traditionally, research in this region focused on biological and environmental aspects of the fisheries instead of socioeconomic attributes of the fishers. Challenges in conducting fisheries assessments include data of questionable reliability, changes in data collection and management programs over time, technical and financial limitations, and the abundant and highly dispersed nature of small pelagic resources. Figure 3 below, taken from Salas et al. (2007), summarizes the types of variables collected in the Latin American and Caribbean countries studied in this article.

Figure 3: Items covered in fisheries assessments in countries studied in Salas et al. (2007)

Summary of some fisheries assessment tools in use in Latin America and the Caribbean as reported by CoastFish participants and from bibliographic information

Tool	Argentina	Barbados	Mexico	Cuba	Venezuela	Colombia	Costa Rica	Brazil	Uruguay	Dominican Republic	Puerto Rico	Ecuador	Nicaragua
Data													
Catch statistics	x	x	x	x	x	x	x	x	x	x	x	x	x
Fishing effort statistics	x	x	x	x	x	x	x	x			x	x	
Size frequency	x		x	x	x	x	x	x		x	x	x	x
Spatial data			x	x	x				x				
Gears			x	x	x	x							
Biological surveys	x		x	x		x	x		x		x	x	
Observer program	x		x										
Sampling at landing	x		x	x	x							x	x
Number of fishers	x		x	x	x	x				x			
Number of permits	x		x	x				x					
Bio-ecological													
Growth	x	x	x	x	x	x	x	x	x	x	x	x	x
Mortality	x	x	x	x	x	x	x	x	x		x	x	x
Recruitment		x	x	x	x	x	x	x	x	x	x		
Larval studies			x	x						x			
Feeding	x		x	x									
Reproduction	x		x	x	x	x	x			x		x	
Trophic models			x			x							
Life history	x			x			x						
Spatial analysis			x	x		x			x	x			
Selectivity			x	x		x	x						
Production models			x	x		x	x				x		
Virtual population analysis	x	x	x	x	x		x	x				x	
GLM			x								x		
Time series				x			x				x		
Yield per recruit	x		x	x	x	x					x		
Stock assessment		x	x	x							x	x	
Oceanography	x		x	x		x				x			
Environmental issues	x		x	x	x								
Parasitology	x		x	x									
Fleet/fishing effort analysis			x	x		x			x				
CPUE trend analysis	x	x	x	x	x		x				x		
Fishing effort standarditation	x		x	x	x						x		
Socio-cultural													
Fishers perception		x	x					x	x				x
Participatory research		x	x	x									x
Institutional arrangements		x	x					x					
Social profile of fishers	x		x										
Migration		x	x										
Traditional knowledge		x						x					
Economic													
Cost/benefit analysis		x	x	x	x					x		x	
Ocuppational structure	x	x	x	x	x	x					x		
Economic assessment	x		x	x	x	x							
Uncertainty				x									
Bioeconomic models		x	x	x	x			x	x				
Market	x		x	x								x	

4.3.1. EASTERN PACIFIC OCEAN

Rendon et al. (2013) describe the use of onboard observers to monitor bycatch of sea turtles in artisanal fisheries in the Eastern Pacific Ocean (9 countries from Mexico to Peru). The observer program is "the largest regional artisanal fisheries conservation program in Latin America." One objective of the program is to monitor the effectiveness of using circle hooks in fishing lines as a way to reduce turtle bycatch. Observers receive training in how to collect data and interact with marine sea turtles. Information on vessel characteristics, gear type, identification of caught species, and interactions with non-target species are recorded using standard forms.

4.3.2. AMAZON

Bayley and Petrere (1989) discuss the assessment and management of Amazon fisheries. They advocate the use of household surveys to collect data on fish consumption and argue that this can be a useful tool for predicting yield when access point surveys are too costly. Bayley and Petrere (1986) explain, "interviewing fishermen at the multitude of separate landing points and making total boat counts with any useful level of accuracy is beyond the resources of the countries concerned [Brazil, Peru, Columbia]. Conversely, well-designed household surveys can estimate yields from dispersed fisheries as well as

additional information such as effort by gear and man-hours, species composition, and proportion of consumption caught or purchased." They describe attributes of major commercial fisheries, including total catch and effort, using government data that had been checked for discrepancies.

5

Discussion Topics

After discussions at the Expert Meeting in Rome (May, 2017), it is decided to pursue the approach to the desktop analysis discussed in Section 3.2. The discussion below aims to help hone the specifics of that approach and identify a test country. This discussion is based on Global Strategy (2016 a), Global Strategy (2016 b), the discussion of possible test countries in Section 4 of this report, and the Expert Meeting held in Rome in May, 2017. The discussion topics have implications for the pilot test and the final guidelines.

5.1. USING THE OPPORTUNITY OF EXISTING PROJECTS OF FAO FISHERIES AND AQUACULTURE DEPARTMENT

One possible approach is to coordinate efforts with on-going FAO Fisheries and Aquaculture Department (FAO/FD) projects. This has the benefit of leveraging expertise from the FAO/FD. If the research project collaborates with FAO/FD, the outcome of the pilot test also has potential to provide useful information for the FAO/FD projects involved. The list below summarizes potential opportunities for collaboration with the FAO/FD discussed during the Expert Meeting.

- Angola – Exchanges with FAO/FD revealed that fishery surveys being conducted in Angola in collaboration with FAO are in preliminary stages, so the situation may be well-suited to the project discussed in Section 3.2 above.
- Oman – An FAO/FD document describing the FAO-sponsored survey in the Sultanate of Oman suggests possible collaboration in the area of either (1) combining multiple sources of information in estimation or (2) developing survey designs that address the objective of estimation for change over time. Further, Oman maintains multiple data sources on fisheries, so the situation may be well suited to a project related to integrating different data sources when developing a master sampling

frame. The multiple data sources for Oman may also provide an avenue for testing a proposed idea of using a graphical model to describe relationships between data sets.

5.2. ROLE OF THE GUIDELINES ON MASTER SAMPLING FRAMES FOR FISHERIES AND AQUACULTURE IN IMPROVING FAO FISHERIES STATISTICS

A topic that was discussed at the Expert Meeting relates to where the guidelines for master sampling frames for fisheries and aquaculture fit with related guidelines of the Global Strategy and FAO/FD already published or are in preparation. These include guidelines for socioeconomic assessments published by FAO/FD and guidelines for how to inquire about fisheries in a census-based framework recently published by the Global Strategy. Similarly, the Global Strategy published guidelines on master sampling frames for agriculture. One interesting point from this discussion was also possible applicability of ideas in the Global Strategy guidelines for enumeration of nomadic livestock (http://gsars.org/en/guidelines-for-the-enumeration-of-nomadic-and-semi-nomadic-transhumant-livestock/) to estimation for nomadic fishers.

Another related topic for discussion is how the project fits with the quality of worldwide fishery statistics periodically published by FAO/FD. The FAO/FD publishes an annual Fisheries Yearbook. One conjecture in MRC (2010) is that countries currently underreport production when submitting estimates to the FAO. One perspective on the ultimate aim of the work is to help countries supply the FAO with more reliable data about fishery and aquaculture statistics.

5.3. COMMUNITY-BASED CO-MANAGEMENT

The research suggests that community-based co-management strategies are becoming increasingly common. One comment in the country report for Cambodia is that individuals involved in community-based co-management strategies should recognize the importance of official statistics. Likewise, those involved in producing statistics should be aware of the implications of changes in management regimes for data collection and data sources. One topic to discuss is the extent to which the work should relate to community-based co-management of fisheries.

5.4. SYNTHESIS OF OTHER TOPICS DUSCUSSED DURING THE EXPERT MEETING

The Expert Meeting on developing master sampling frames for fisheries and aquaculture covered numerous discussion topics. Below, are summarized major themes. In some cases, it is explained how a discussion topic might impact the pilot test and final guidelines.

5.4.1. NEGLECTED POPULATIONS: INLAND FISHERIES, NOMADIC FISHERIES, AND AQUACULTURE

The fishery and aquaculture sectors are composed of multiple, diverse populations. Marine fisheries have probably received the most attention by both government monitoring programs and scientific literature. Recreational fisheries have also received attention in scientific literature; however, these types of fisheries are outside the scope of this project (not in IACS code A). Three important populations for this project that have been neglected in the literature are (1) inland fisheries, (2) nomadic fisheries, and (3) aquaculture. The consultants at the expert meeting advised us to make an effort to address issues specific to these neglected population in the pilot test and/or the final guidelines.

5.4.2. REMAIN AWARE OF THE SITUATION IN DEVELOPING COUNTRIES

When writing the guidelines, fisheries experts advised to remain aware that the main target audience is a statistical department of the ministry in charge of fisheries of a developing country. Characteristics of developing countries generate unique challenges associated with frame construction, sample design, and measurement. For instance, one presentation at the Expert Meeting illustrated that a frame based on villages can be appropriate and showed that harvesting procedures make catch difficult to measure and disaggregate by species. Similarly, the presentation on a landing site survey in Cameroon demonstrated the difficulty in constructing a frame that includes landing sites located in the middle of the ocean. Scientific principles, such as probability sampling and accounting for non-sampling errors, transfer to such situations. An application of these concepts in a developing country will need to respect the specific issues arising in a particular situation. The aim of the guidelines is to convey scientific methods in a way that relates to the target audience. In this direction, specific examples for developing countries may be included in the guidelines.

5.4.3. USE ADMINISTRATIVE DATA WHERE POSSIBLE, AND CONSIDER VALIDATION STUDIES FOR VERIFICATION

Government programs often generate administrative data related to fishery and aquaculture sectors. Examples include logbooks, subsidy programs, vessel monitoring systems, registration, exports/imports, and taxation. In the interest of saving costs and avoiding duplication of efforts, administrative data should be used where possible. When using administrative data, however, it is important to remain aware that the nature of the administrative process can lead to both coverage and measurement errors. An interesting example discussed in the Expert Meeting is the case of Brazil, where government assistance programs cause severe over-coverage in administrative registers of fishers. Verification studies are useful tools for checking the quality of administrative data. Use of administrative data in combination with verification studies seems a valuable approach to propose in the guidelines.

5.4.4. CONCEPT OF A MASTER SAMPLING FRAME

The Expert Meeting included discussions related to defining the concept of a master sampling frame for surveys of fisheries and aquaculture. A relatively descriptive definition of a master sampling frame is a permanent collection of structures for implementing surveys over time. Because the fishery and aquaculture sectors consist of multiple populations, the master sampling frame will necessarily be comprised of several individual frames. The case studies presented at the Expert Meeting for Korea and the European Union demonstrate the value of using different frames for different objectives.

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