Determining the Status of Fish Stocks in Data-Poor Environments and Multispecies Fisheries

GSI Policy Brief

Maren Headley

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Head Office

111 Lombard Avenue, Suite 325
Winnipeg, Manitoba
Canada R3B 0T4

Tel: +1 (204) 958-7700
Website: www.iisd.org
Twitter: @IISD_news

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Global Subsidies Initiative

International Environment House 2,
9 chemin de Balexert
1219 Châtelaine
Geneva, Switzerland
Canada R3B 0T4

Tel: +1 (204) 958-7700
Website: www.iisd.org/gsi
Twitter: @globalsubsidies

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Acronyms

BRP	biological reference points
CPUE	catch per unit of effort
EDF	Environmental Defense Fund
FAO	Food and Agriculture Organization of the United Nations
FISHE	Framework for Integrated Stock and Habitat Evaluation
IUU	illegal, unreported and unregulated
LRP	limit reference point
MEY	maximum economic yield
MPA	marine protected area
MSY	maximum sustainable yield
PSA	Productivity-Susceptibility Analysis
TNC	The Nature Conservancy
TRP	target reference point
WTO	World Trade Organization

1.0 Introduction

Negotiations at the World Trade Organization (WTO) on subsidies to the fishing industry intensified in 2019 and early 2020 in a bid to reach an agreement on a set of comprehensive and effective rules on the issue, before being slowed down as a result of the global COVID-19 pandemic. The negotiations currently revolve around three key substantive obligations: a prohibition on subsidies to illegal, unreported, and unregulated fishing; a prohibition on subsidies to fish stocks that are already overfished; and a more general prohibition on subsidies that contribute to overcapacity and overfishing.

The question of how data-poor and multispecies stocks can be assessed is relevant to the WTO fisheries subsidies negotiations in several ways. The question arises most directly in the context of the proposed prohibition on subsidies to overfished stocks. There are several options listed for the identification of an overfished stock in the latest publicly available compilation negotiating text of the WTO fisheries subsidies negotiations (WTO, 2018). These include references to national or regional decisions and options for an objective definition. The options for an objective definition generally refer to a fish stock being overfished if "the stock is at such a low level that mortality from fishing needs to be [restricted] to allow the stock to rebuild to a level that produces maximum sustainable yield or [alternative] reference points" (WTO, 2018). One question is therefore what reference points could be considered "alternative reference points" in the context of an objective definition of an overfished stock.

The question of data-poor fisheries also arises in the context of discussions about how to discipline subsidies that might have a negative effect on specific stocks or that might contribute to overcapacity and overfishing. A further idea that has emerged recently in the negotiations is that subsidies should be prohibited if certain factors are present in the context of an overfished stock. These factors could include the lack of recovery of a stock or continuous reductions in the level of the stock. It should be noted that, by specifying these two factors, the need for a negative effect test to trigger the prohibition would be eliminated.

A key concern in the negotiations is how these rules governing subsidies to fishing could be applied by governments with little access to data about the state of their stocks. This brief provides an overview of methods for assessing fish stock status in data-poor and multispecies fisheries, with the aim of informing these areas of discussion.

2.0 Overview of Methods for Assessing Fish Stock Status

A fish stock can be defined within a biological or management context. NOAA Fisheries (2012) refers to a "biological" fish stock as "a group of fish of the same species that live in the same geographic area and mix enough to breed with each other when mature." A management stock, on the other hand, "may refer to a biological stock, or a multispecies complex that is managed as a single unit" (NOAA Fisheries, 2012).

The usual way to determine stock status and identify an overfished stock is to conduct a stock assessment. "Stock assessment involves the use of various statistical and mathematical calculations to make quantitative predictions about the reactions of fish populations to alternative management choices" (Hilborn & Walters, 1992). It is important to note that stock assessments should be conducted regularly to update stock status, which is influenced by several variables: environmental and oceanographic conditions, variable fishing behaviours, spatial and temporal changes in the productivity of the resource, and dynamic market and economic conditions.

Conducting a classic stock assessment involves the following steps: (i) determining the questions to be answered, (ii) choosing and building an appropriate model or models, (iii) designing and implementing an appropriate data collection system, (iv) collecting the required data, (v) running the assessment, (vi) interpreting the assessment results, and (vii) providing scientific advice to decision-makers.

The types of data and information utilized in a stock assessment can be placed in two categories: fishery-dependent data and fishery-independent data. Fishery-dependent data include catch and effort data, which refers to the amount of fish removed from the stock and the effort spent to get the catch (e.g., number of traps, boats, and hooks used or hours spent fishing). Sources for fishery-dependent data include monitoring at landing sites, logbooks, and onboard observers. Fishery-independent data typically include measures or estimates of the abundance of a stock, which refers to the number of fish in the stock or their weight (NOAA Fisheries, 2012). Fishery-independent data can be collected through statistically designed surveys conducted by research vessels that sample fish throughout the stock's range (NOAA Fisheries, 2012). These surveys are usually repeated annually to account for changes over time (NOAA Fisheries, 2012). Biological data and information can also be collected as part of fishery-dependent and fishery-independent data collection systems and include length, sex, age of fish, fish growth rates, natural mortality, reproductive rates, and movement patterns.

Indicators and reference points can be used to assess the status of a fishery. Indicators measure various fishery attributes, whereas reference points are predetermined values of an indicator that allow the analysis of the fishery in relation to these values (The Nature Conservancy [TNC], 2020). Indicators can be described as:

> Quantitative and qualitative empirical indicators (e.g., mean size of fish in the catch), statistically derived indicators using a model (e.g., biomass estimated using a stock assessment model), proxy indicators for biomass (e.g., catch rates or density estimates) and fishing mortality (e.g., spawning potential ratios or length composition of the

catch), or indirect indicators (e.g., increased travel time as an indication of declining local stocks). (TNC, 2020)

Reference points can either be described as target reference points or limit reference points. A target reference point (TRP) is "a numerical value (or range of values) that corresponds to a desirable condition; management should be geared toward achieving or maintaining this target" (McDonald et al., 2017). A limit reference point (LRP) is "a numerical value that specifies a condition at which the fishery is operating beyond a measure of acceptable risk (e.g., severe overfishing), and that management action should be taken to improve fishery performance or population levels" (McDonald et al., 2017).

For fisheries management purposes, it is also important to consider which types of data are available or obtainable while taking into account the social, ecological, and economic aspects of the fishery, as these factors influence which indicators and reference points are appropriate (TNC, 2020).

Stock status can be defined in a range of ways, including overfished, approaching overfished, under-exploited, and rebuilding. Measurements of a fish stock's biomass can be used to establish whether a stock is already in an overfished condition, while measurements of fishing mortality can be used to establish whether overfishing is taking place. Overfishing occurs when the fishing mortality rate exceeds a specific threshold—which is to say, the stock is being depleted too quickly even though the stock size may still be fairly large. When the stock size falls below a specific threshold, either in terms of numbers or biomass of fish, the stock is considered to be overfished. It is important to note that "overfished" refers to the state of a stock on which overfishing has occurred. However, while a stock may be overfished, overfishing may not be occurring. Therefore stocks that are overfished can be managed for low enough fishing pressure to allow the stock to rebuild to a level to support maximum sustainable yield (Caddy & Mahon, 1995).

Many, but by no means all, fisheries are managed using biological reference points (BRPs). A BRP is usually derived from a combination of several components of stock dynamics, including growth, recruitment, and mortality. BRPs provide fisheries managers with information on (i) the status of a stock and (ii) the impacts of fishing on a stock (Caddy, 2004; Caddy & Mahon, 1995).

Maximum sustainable yield (MSY) is one of the most common BRPs used in fisheries management. MSY has been defined by the Food and Agriculture Organization of the United Nations as "the highest theoretical equilibrium yield that can be continuously taken (on average) from a stock under existing (average) environmental conditions without significantly affecting the reproduction process" (FAO, 2020). Two very common BRPs are derived from it: "the biomass at which the population can produce the MSY (BMSY) and the fishing mortality needed to achieve MSY (FMSY)" (Musick & Bonfil, 2005). In this case, the concept of MSY is used as a reference point for two different indicators: biomass and fishing mortality. Some other examples of BRPs are those established in relation to other indicators—total biomass, spawning stock biomass, and fishing mortality rates.

Although MSY is the most commonly applied reference point in fisheries management, there is also increasing interest in the application of the maximum economic yield (MEY) as an alternative target (Pascoe et al., 2014). MEY is an example of an economic reference point: it represents the amount of fishing effort and catch that maximizes economic profits over time (Grafton et al., 2010). However, estimating MEY requires an understanding of both the key economic and biological variables of the fishery and the use of bioeconomic models; it is thus more resource-intensive than purely biologically based reference points.

This variety of options has a number of implications for the negotiations at the WTO. The first is that, if a stock's overfished condition can be established using "alternative reference points" in addition to points based on MSY, this would enable the discipline to be implemented using the reference points that might be chosen by member governments, including target or limit reference points for a wide variety of indicators. This means that an appropriately flexible definition of overfished stocks can help the discipline be applied in many different fisheries management contexts. It also means that members can choose different ways of measuring whether specific factors (such as lack of recovery or a continuous decline) were present in an overfished stock and, therefore, whether the subsidy prohibition should apply. Lastly, members have a variety of options for establishing whether too much fishing effort is being exerted, which could also help them implement new rules on subsidies that contribute to overcapacity and overfishing.

The use of BRP like MSY or economic reference points like MEY, or their proxies, require enough data to have been collected to be able to make comparisons over time. Not all fisheries, however, have this amount of data available. This thus raises the question of how the status of stocks in really data-poor fisheries can be established and how a subsidy discipline might be applied in these contexts.

2.1 What Methods Can Be Used to Establish the Status of Stocks in Data-Poor Fisheries?

More than 80% of global catches occur in fisheries that lack the necessary data, resources, and infrastructure to conduct quantitative model-based stock assessments to estimate a time series of biomass and fishing mortality relative to their reference points (Costello et al., 2012). In addition to being data-intensive, the application of conventional model-based assessments to data-limited fisheries is often not appropriate since many fisheries are also characterized by highly variable production, spatial heterogeneities (e.g., sedentary or low-mobility species) or large numbers of interacting species and gear (e.g., tropical multispecies fisheries) (Dowling, Smith, Knuckey et al., 2008; Dowling, Smith, & Smith, 2008). Some of the key uncertainties in data-poor fisheries include limited information on the dynamics of the fish stocks and fishing fleets (Dowling et al., 2015). Data-poor stocks or species can also occur in an otherwise data-rich or data-moderate fishery.

Developing countries face particular challenges in assessing stocks. Many of the fisheries in developing countries are multi-gear, multispecies, and data-limited for many stocks. Conventional stock assessment methods that are data-intensive and based on single-species models without consideration of ecosystem interactions are not well suited to assessing tropical fisheries. There is also a high cost associated with data collection and surveys to conduct conventional stock assessments—and developing countries usually have limited human resources available for data collection. As a result, making informed management decisions based on scientific advice in data-limited, tropical multispecies fisheries is challenging. However, there is a variety of data-limited methods that enable quantitative metrics of fishery status to be compared against management reference points.

A number of approaches to estimating the status of data-limited stocks have been developed, and data-limited assessment methods are increasingly being used for management purposes. An overview of the various data-limited assessment methods is presented in Annex 1. There is a wide range of methods that can be used to assess stock status. While some of these methods require quantitative data and modelling, others do not, relying instead on the use of expert judgment applied to relatively simple information gathered (e.g., changes in gear type or manner of deployment). Different methods use different indicators. One can draw a distinction between empirical indicators, which are "those measured more or less directly from monitoring data (e.g., survey biomass estimates, catch rates (CPUE), mean length of fish in the catch, catch levels, etc.)," and model-derived indicators that "are usually estimates of either abundance (e.g., biomass B or depletion D) or exploitation rate (e.g., fishing mortality rate F)" (Dowling et al., 2015).

If fishing mortality or biomass cannot be explicitly estimated, proxies can be used based on the type and quality of data that are available (FAO, 1996). "Proxies that may index F [fishing mortality] include truncated age distributions and small or decreasing mean size in landings or measures of fishing effort; those indexing biomass include low commercial catch per unit effort (CPUE) and low or markedly declining research survey indices. For example, overfishing could be specified as a ratio of current commercial or research CPUE compared to the CPUE of some historic period when the stock was lightly exploited" (FAO, 1996). In the case of MEY, where economic information is not available, a default value of 1.2 times the biomass that achieves MSY (BMSY) could be used as a proxy for the TRP, where BMSY is also estimated through data-limited methods if necessary (Department of Agriculture Fisheries and Forestry, 2007).

While no single generic solution exists to evaluate the status of stocks when data is limited, there are simple stock-specific methods that address this challenge (Dowling et al., 2018). The overall success of management depends on the reliability of the stock status estimate, which could be compromised by the application of inappropriate data-limited methods. In applying these methods, it is therefore important to consider the capacity of the existing fishery's management framework, including the types of data collected as well as the ecological aspects of the fishery resources (Dowling et al., 2018). When applying a subsidy rule, governments might want to be more careful regarding stocks on which they have less reliable data. They should design their implementing legislation to stop subsidizing fishing of data-poor stocks (or data-poor multispecies fisheries) if some key indicators were to begin to show downward trends.

Some of the possible indicators (both empirical/model-free and model-based) that could be used in fisheries management are provided in Table 1, along with the required data, applicability at the species level, and examples of target and limit reference points. It is important to acknowledge here that most of the options in Table 1 require some amount of data (option three being perhaps the simplest requirement). Some fisheries have little or no data at all. Applying a subsidy prohibition that depends on some knowledge of the status of stocks or degree of fishing effort in these circumstances might, then, need to be based on managers' best professional judgments, informed by such data as is present, for some length of time, as more data is collected.

Table 1. Methods for assessing data-poor fisheries: Indicators, data needs, applicability, example TRPs and LRPs

Indicator	Data needs	Single-species/ multispecies/ ecosystem management	TRP	LRP
1. Fishing mortality (F) (model-based)	Fishery-dependent length data, life-history information	Single	F_{Tar}=0.75 M	F_{Lim}=2 M*
2. MPA density ratio (DR) for target species (model-based)	Fishery-independent surveys	Single/multi	DR_{Tar}=0.4	DR_{Lim}=0.2 (single stocks)
3. Previous season's total landings (model-free)	Catch data	Single/multi/ ecosystem	Previous season's total landings stable or decreasing from running average	Previous season's total landings increasing rapidly from running average (without knowledge of effort)
4. CPUE (model-free)	Catch and effort data	Single/multi	CPUE increasing from running average	CPUE decreasing rapidly from running average
5. Fraction mature (Lmat) (model-free)	Fishery-dependent length data, life-history information	Single	$Lmat_{Tar}$=100%	$Lmat_{Lim}$=80%

Source: Adapted from McDonald et al., 2017.

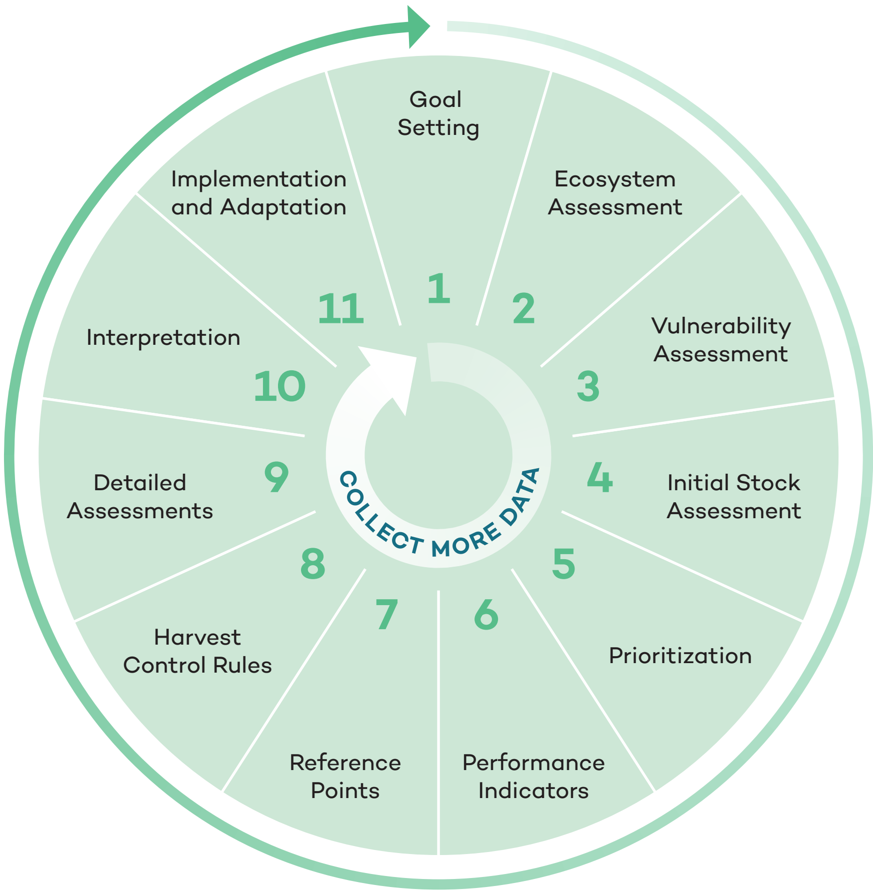
**Note: M = Natural Mortality*

In recent years, there has been a focus on the development of tools to assess and manage data-poor fisheries using data-limited methods and indicators (empirical/model-free and model-based).[1] An example of a tool that could be used to define management regulations based on

[1] For further examples of tools that can be used in the management of data-poor fisheries and support available, see the Pew Charitable Trusts issue brief, *The Link Between Effective Fisheries Management and Ending Harmful Subsidies* at https://www.pewtrusts.org/en/research-and-analysis/issue-briefs/2019/04/the-link-between-effective-fisheries-management-and-ending-harmful-subsidies

science even in resource- and data-limited conditions is the Framework for Integrated Stock and Habitat Evaluation (FISHE) (Environmental Defense Fund [EDF], 2016). Another tool that can be used is FishPath, which offers a comprehensive engagement process for fisheries managers and practitioners to navigate the universe of possible management strategies and select context-appropriate options for the fishery of interest.[2] FISHE is used in this paper as the main example. FISHE uses various methods and inputs from stakeholders and consists of an 11-step process (Figure 1).

Figure 1. The FISHE framework



Source: EDF, 2016.

The EDF describes the FISHE framework as follows:

> The eleven-step FISHE process starts with (1) goal setting, then helps stakeholders (2) estimate ecosystem health, (3) assess species vulnerability and (4) depletion, (5) prioritize target species based on these preliminary assessments, (6) select appropriate indicators of fishery sustainability that can be quantified using the available data and data-limited analytical tools, (7) identify reference points for each indicator, (8) work with stakeholders to determine harvest control rules to ensure the appropriate response to assessment results will be enacted, (9) select and apply data-limited stock assessments using information from multiple independent data streams in order to

[2] FishPath Conservation Gateway: https://www.conservationgateway.org/ConservationPractices/Marine/SustainableFisheries/Documents/FishPath%20FactSheet%20Final_03_02_16%20(1).pdf

reduce uncertainty, (10) evaluate the resulting indicator values against the reference points and interpret the results together, and (11) choose management actions aimed at achieving the stated goals. The process is repeated each year (at least) to determine the status of the fishery and to help managers and stakeholders decide whether management changes are necessary or not. (EDF, 2016)

It is important to highlight that, even in data-limited situations, "hidden" fisheries data may already exist on which judgements about a fishery's status can begin to be built. "Hidden" data refers to data collected for purposes other than fisheries management; for example, fish density estimates obtained during underwater visual surveys focused on reef health (EDF, 2016). A comparison of total fish density estimates to thresholds for reef health can contribute to informing an ecosystem assessment and determining the impacts of fishing (Step 2) (EDF, 2016). Fish density estimates by species can also be used to determine stock status once there is a time series from the start of the fishery (Step 4). Comparisons of fish density estimates in marine reserves versus densities in fishing grounds that have similar habitats can also be used to determine stock status (Step 4). Export records for commercially important species such as lobster and conch can also be used as proxies for catch once domestic consumption is accounted for (EDF, 2016).

If there are no data available for the fishery, a Productivity-Susceptibility Analysis (PSA) (Step 3) can be conducted using knowledge from fishers and local experts and available information on life-history traits of the species (e.g., maximum size). The PSA results in a vulnerability score for each species that is analyzed.

In order to conduct initial stock assessments for Step 4, various methods require varying amounts and types of data, which can be characterized as biological data, ecosystem data, fishery-dependent data, fishery-independent data, and data from inside no-take zones/marine protected areas (e.g., CPUE, length frequencies, fish densities) (EDF, 2016).

FISHE has a method matrix that organizes various methods for each step and indicates the types of data necessary to complete the assessment/analysis. Several methods should be used to determine whether the results are consistent (EDF, 2016). A summary of the various methods by step and the types of data required is provided in Annex 2.

In situations where no data exist, a data collection program should be set up. Relevant data would include size at maturity, maximum length, length composition of the catch, and total catch and CPUE trends (EDF, 2016). Ideally, data collected over a number of years are needed to determine stock status; however, one year of data can be used to estimate indicators for length, fishing mortality, spawning potential ratio, and seasonal fluctuations in catch (EDF, 2016). These indicators, when compared against reference points, can be used by managers to inform and promote adaptive fisheries management (Steps 6, 7, and 8–11) (EDF, 2016). When data-limited methods are used, it is extremely important that these indicators are carefully interpreted, especially given the fact that there can be a lot of inter-annual variation in fish populations.

2.2 What Methods Can Be Used to Establish the Status of Multispecies Fisheries?

FISHE also allows for the assessment and management of multispecies fisheries. This is particularly relevant for tropical countries where multiple species are simultaneously captured by the same gear. In multispecies fisheries, there is a risk of serial depletion, which refers to the depletion of individual stocks, one after another. Stocks caught within multispecies fisheries and considered to be vulnerable to depletion are called "weak stocks." These "weak stocks" can make the management of multispecies fisheries complex since the protection of these stocks from overfishing often limits fishing opportunities on target stocks and thereby reduces the economic potential of the fishery (EDF, 2016). Additionally, species in a multispecies fishery also interact with each other at the ecosystem level. This can have a significant effect on management outcomes—for example, if all the stocks and their interactions are not taken into account, there could be accidental overfishing or a reduction in total system productivity. Serial depletion can result in fishery collapse as well as ecosystem collapse (EDF, 2016).

FISHE addresses the issue of multispecies fisheries through the organization and prioritization of species into management "baskets" or "tiers." A representative species can be chosen from each basket for additional assessments and definitions of management strategies, which are applied to all species in the basket (EDF, 2016). In order to determine if the target species are overfished, the data-limited methods described in Step 4 can be applied to the selective representative species from the management "basket" or "tier."

In terms of managing multispecies fisheries, if a stock is found to be "weak," there are various measures that could be implemented, including closed seasons, which can protect "weak" stocks if they are timed appropriately; closed areas, which can also protect "weak" stocks if they are sufficiently large and contain habitat suitable for "weak" stocks; and sharing information on where "weak" stocks are concentrated so that fishers can avoid them and reduce catches. In addition, it may be possible to make certain changes to the way that the fishery operates and/or to the management measures implemented to help avoid serial depletion (EDF, 2016). For example, fishers could adjust their fishing practices or gear such that "weak" stocks are caught separately instead of together with stronger stocks (EDF, 2016). These management measures could be complemented with changes in subsidies provided to fleets fishing "weak" stocks in the fishery to help to moderate the level of effort exerted.

In addition to FISHE, other tools can be used to evaluate different management options in multispecies fisheries contexts. An example is the Mizer model (Scott et al., 2014). This model projects species' size distributions, abundance, and yield by accounting for both fish population growth and predator–prey and other interspecies interactions. It also provides a format for evaluating trade-offs between ecological and socioeconomic outcomes under different multispecies management scenarios, such as closed areas, fishing mortality limits on individual stocks, and fishing mortality limits on baskets of species (Blanchard et al., 2014).

These data-limited tools and options mean that there are ways that WTO members can manage data-poor and multispecies fisheries, even when the amount of data available about the fishery is limited. They also mean that subsidy rules could be implemented in ways that support these management frameworks. How this could be done is explored in more detail below.

3.0 Relevance of Data-Limited Assessment Methods for a Fisheries Subsidies Agreement

3.1 What Alternative Reference Points Could Be Used in the Context of Data-Poor Fisheries?

Most reference points are calculated from the results of model-based stock assessments, but it is also possible to set empirical or data-based reference points for indicators. Examples of empirical indicators include CPUE, mean length, and weight distribution of the catch; in very data-poor fisheries, it could include catch or effort levels or local ecological knowledge about trends over time (McDonald et al., 2017). For fisheries management purposes, trends or running averages of these types of indicators can be calculated from historical time series of data and then proxy reference points can be set for these indicators based on patterns over time (McDonald et al., 2017).

In implementing a subsidy rule, WTO members could use a wide range of "alternative reference points" in order to establish when a stock was overfished or when overfishing is occurring. Some alternative reference points might require data of the chosen indicator to have been collected over time. In data-poor situations, proxies can be used to establish reference points using indicators for which at least some data is available, for instance, information based on fishers' knowledge.

3.2 What Methods Could Governments Use to Trigger the Prohibition of a Subsidy on a Data-Poor or Multispecies Fishery?

There are several options being discussed in the WTO negotiations that would identify when subsidies should be prohibited for fishing. Discussions about a prohibition on subsidies to fishing an overfished stock have most recently focused on two situations related to the stock: lack of recovery of the stock or continuous reduction in the level of the stock. Therefore, the prohibition would be triggered only when certain situations related to an overfished stock are present, and this would eliminate the need for a negative effects test. An ongoing question is how this kind of a discipline could apply in the context of a data-poor or multispecies fishery.

A possible method that governments could use to identify when a subsidy should be prohibited for overfished, data-poor, or multispecies fisheries is the implementation of an adaptive management framework such as FISHE. Adaptive management frameworks allow adjustments to catch or effort in the future based on past observations using harvest control rules. In the context of a subsidy rule, the real value of an adaptive management framework is that it could allow members to implement subsidy prohibitions as part of management responses to information about the state of the stock developed through the framework. For multispecies fisheries, for example, governments could incorporate economic policy responses like stopping subsidies to fishers to reduce effort levels if "weak" stocks were showing signs of stress. In data-poor fisheries, assessments of the presence of factors like ongoing decline could be made based on the information that is available about the fishery, including local fishers' knowledge. Again, it is important to note that adaptive management frameworks take time to be fully developed, but a subsidy rule could begin to be implemented based on information that is already available about a fishery.

4.0 Conclusion

Developing countries face particular challenges in assessing stocks since many of them are multi-gear, multispecies, and data-limited. Conventional stock assessment methods that are data-intensive and based on single-species models without consideration of ecosystem interactions are not well suited to assessing tropical fisheries. There is also a high cost associated with data collection and surveys to conduct conventional stock assessments, and developing countries usually have limited human resources available for data collection.

In recent years, there has been a focus on the development of tools to assess and manage data-poor fisheries using data-limited methods and indicators (model-free and model-based). FISHE is an example of a tool that could be used to define management regulations based on science, even in resource and data-limited conditions. FISHE also addresses the issue of multispecies fisheries through organization and prioritization of species into management "baskets" or "tiers." A representative species is chosen from each basket for additional assessments and definitions of management strategies, which are applied for all species in the basket.

In terms of establishing stock status, most reference points are calculated from the results of conventional stock assessments (e.g., MSY) or a bioeconomic assessment (e.g., MEY). However, it is also possible to set empirical or data-based reference points for which the indicators can be directly measured in data-limited situations. These can include reference points for indicators that do not require complex sets of data (such as levels of CPUE or the fraction of mature specimens of a species that are caught).

In the context of the WTO negotiations, a rule based on a definition of an overfished stock that refers to alternative reference points provides members with considerable flexibility to choose those reference points. Members could implement the subsidy rule on the basis of proxies for reference points, which could be chosen on the basis of the data that was available for their fisheries.

Methods like FISHE could provide a framework in which governments could include economic policy decisions, like stopping subsidies if a "weak" stock in a multispecies fishery were showing signs of stress. Where data is extremely limited, decisions about the status of stocks and the amount of fishing effort might, at first, need to be made on the basis of managers' best professional judgment, informed by local fishers' knowledge—but these decisions would be informed by data as they were collected and as the management framework was developed.

These same methods could also be used to measure levels of fishing effort (as well as stock status) in data-poor and multispecies fisheries, which could help members to implement other possible subsidy prohibitions, such as rules on subsidies that contribute to overcapacity and overfishing.

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Annex 1. Overview of Data-Limited Assessment Methods

Input-based category	Data-limited assessment method	Types of indicators[3]
Expert judgment	Move directly to harvest control measures	Knowledge-based
	Discourse/expert judgment	Knowledge-based
	Data exploration via plotting and descriptive statistics	Empirical
	Analysis of changes in the spatial distribution of fishing effort	Empirical
	Analysis of changes in the spatial distribution of catch	Empirical
	Analysis of changes in gear type or manner of deployment	Empirical
Empirical reference points	Size-based sequential trigger system	Empirical
	Sequential effort triggers	Empirical
	Sequential catch triggers	Empirical
Risk analysis/ vulnerability	Comprehensive assessment of risk to ecosystems (CARE)	Empirical
	Ecosystem threshold analysis	Empirical
	RAPFISH (multi-dimensional scaling)	Empirical
	Productivity–Susceptibility Analysis (PSA) to estimate risk of overfishing	Empirical
	Ecological risk assessment for the effects of fishing (ERAEF)	Empirical
	Sustainability assessment for fishing effects (SAFE)	Empirical
Abundance indicators	Analysis of changes in species composition	Empirical
	Use of biomass surveys to inform management	Empirical
	Single-indicator analysis using standardized catch per unit effort (CPUE)	Empirical
	Linear regression to recent time series of CPUE	Empirical

3 Minimum set of indicators required for the associated data-limited assessment method.

Input-based category	Data-limited assessment method	Types of indicators[3]
Marine protected area (MPA)	Analysis of ratio of density inside and outside MPAs	Model-based
	Analysis of length/size-specific catch-rate indicators for fish sampled inside and outside of MPAs and per recruit	Model-based
Catch only	Optimized catch-only method (OCOM)	Model-based
	Boosted regression tree (BRT) model for stock depletion using catch data	Model-based
	Only reliable catch series (ORCS)	Model-based
	Depletion-corrected average catch (DCAC)	Model-based
	Depletion-based stock reduction analysis (DB-SRA)	Model-based
	Simple stock synthesis (SSS)	Model-based
	Stochastic stock reduction analysis (stochastic SRA)	Model-based
	Catch-MSY/CMSY	Model-based
	Feasible stock trajectories	Model-based
Population dynamics model	Depletion analysis	Model-based
	Production model	Model-based
	Statistical catch-age analysis (SCAA)	Model-based
Size/age-based	Analysis of size relative to size at maturity	Empirical
	Analysis of changes in mean length/ weight or length/weight percentiles	Empirical
	Analysis of sustainability indicators based on length-based reference points (LBRP)	Empirical
	Catch curve analysis	Model-based
	Length-based spawning potential ratio (LB-SPR)	Model-based
	Mortality estimates from length data in non-equilibrium situations	Model-based
	Length-based Integrated Mixed Effects (LIME)	Model-based

Input-based category	Data-limited assessment method	Types of indicators[3]
Multiple indicators	Hierarchical decision trees	Empirical
	Traffic lights	Empirical
	Cumulative Sum (CUSUM) Control Charts	Empirical
	Sequential trigger framework involving catch and/or effort, CPUE, size, sex ratio, etc.	Empirical

Note: Empirical/model-free indicators are based on directly-measured properties. Model-based indicators are model outputs (Dowling et al., 2018). Knowledge-based indicators depend on expert knowledge and judgement about historical catch levels.

Source: Dowling et al., 2018.

Annex 2. Examples of Methods and the Types of Data Required From the FISHE Method Matrix

	Step 2	Step 3	Step 4	Step 4	Step 4	Step 9
Type of Data	**Ecosystem Risk Assessment for the Effects of Fishing**	**Productivity and Susceptibility Analysis**	**MPA Density Ratio**	**Length-Based Reference Point**	**Mean Length**	**Catch-Maximum Sustainable Yield**
Biological						
Common life-history characteristics		*	*	*	*	*
Natural mortality		+		+	*	
Fecundity curves				+		
Von Bertalanffy parameters		+		+	*	
Carrying capacity						*
Age length				*		
Ecosystem data						
Knowledge about the makeup of the ecosystem	*	+				
Fishery-Dependent Data						
Knowledge about how the fishery interacts with stocks	*	*		*	*	
Catch						*
Length frequencies				* > 1 year	*	
Estimated stock size						* First & final year
Fishery selectivity				+	*	

Type of Data	Step 2 Ecosystem Risk Assessment for the Effects of Fishing	Step 3 Productivity and Susceptibility Analysis	Step 4 MPA Density Ratio	Step 4 Length-Based Reference Point	Step 4 Mean Length	Step 9 Catch-Maximum Sustainable Yield
Fishery-Independent Data						
Scientific survey: length frequencies			+ 1 or more years			
Scientific survey: fish densities			* 1 or more years			
Scientific survey: catch per unit effort			+			
Inside No-Take Zones/Marine Protected Areas						
Catch per unit effort			+ 1 or more years			
Length frequencies			+		+	
Fish densities			* 1 or more years			

* represents data that is necessary to conduct the method
+ represents data that can be used to answer additional questions

Source: EDF, 2016.

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IISD Head Office

111 Lombard Avenue, Suite 325
Winnipeg, Manitoba
Canada R3B 0T4

Tel: +1 (204) 958-7700
Website: www.iisd.org
Twitter: @IISD_news

Global Subsidies Initiative

International Environment House 2
9 chemin de Balexert, 1219 Châtelaine
Geneva, Switzerland

Tel: +41 22 917-8683
Website: www.iisd.org/gsi
Twitter: @globalsubsidies