

Measuring fishing capacity in tuna fisheries: Data Envelopment Analysis, industry surveys and data collection

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ABSTRACT

This paper addresses Objective B of the FAO Methodological Workshop on the Management of Tuna Fishing Capacity, which is “to determine the feasibility of, (1) routinely collecting input data for the Data Envelopment Analysis (DEA) and (2) performing industry surveys of tuna fishing capacity utilization.” Data envelopment analysis (DEA) derives a deterministic production frontier describing the most technically efficient combination of outputs, given the state of fishing technology, the fish stock and unrestricted variable inputs. Within the context of measuring fishing capacity to allow for DEA to be undertaken, it is necessary, at the very least, to obtain a data set detailing fixed inputs (fixed physical characteristics of individual vessels) to the fishery and the associated outputs (catches) of those vessels. Such data are available for the eastern and the western and central Pacific Ocean, but not for the Atlantic and Indian Oceans. The paper also addresses the potential to conduct industry surveys in order to obtain estimates of tuna fishing capacity utilization and concludes that, while it may be feasible in principle, it may be difficult in practice.

1. INTRODUCTION

This paper addresses Objective B of FAO Methodological Workshop on the Management of Tuna Fishing Capacity, which is “to determine the feasibility of, (1) routinely collecting input data for the Data Envelopment Analysis (DEA) and (2) performing industry surveys of tuna fishing capacity utilization.”

In Section 2 of the paper an overview of the concepts of capacity and capacity utilization are provided. Section 3 provides background to DEA methodology, requirements for DEA, current availability of data for major industrial tuna fisheries that are suitable for DEA and the feasibility of routinely collecting such data. Section 4 provides background information on industrial surveys of capacity utilization and the feasibility of employing such surveys to measure tuna fishing capacity utilization.

2. CAPACITY AND CAPACITY UTILIZATION

Capacity is a short-run concept, for which firms and industry face short-run constraints, such as the stock of capital or other fixed inputs, existing regulations, the state of technology and other technological constraints (Morrison 1985). Capacity is defined in terms of potential output. This potential output can be further defined and measured in accordance with either a technological-economic approach or an economic optimization approach based directly on microeconomic theory (Morrison 1985).¹ What distinguishes the two notions of capacity is how the underlying economic aspects are included to determine the capacity output.

In either approach, capacity utilization (CU) is simply actual output divided by capacity output (Morrison 1985).² In the technological-economic approach, a CU value of less than 1 implies that firms have the potential for greater production without having to incur major expenditures for new capital or equipment (Klein and Summers 1966).

This paper, Reid *et al* (2005), Squires *et al* (2003), Kirkley and Squires (1999), the 1998 FAO Technical Working Group (FAO 1998) and the 1999 FAO Technical Consultation (FAO 2000) focus on the technological-economic measures of capacity, because the paucity of cost data in most fisheries militates against estimation of cost or profit functions to derive economic measures of capacity and capacity utilization. Similarly, the technological-economic approach is the one used by the US Federal Reserve Board (Corrado and Matthey 1997) and in most other countries to monitor capacity utilisation throughout the economy.

The technological-economic capacity of a firm can be defined following Johansen's (1968, p. 52) definition of plant capacity as, "... the maximum amount that can be produced per unit of time with existing plant and equipment, provided the availability of variable factors of production is not restricted". Färe (1984) provides a formal proof and discussion of plant capacity.³

Capacity output thus represents the maximum production that fixed inputs are capable of supporting. This concept of capacity conforms to that of a full-input point on a production function, with the qualification that capacity representing a realistically sustainable maximum level of output, rather than some higher unsustainable short-term maximum (Klein and Long 1973). In practice, this approach gives maximum potential output, given full utilization of the variable inputs under normal operating conditions because the data used reflect normal operating conditions and existing market, resource stock and environmental conditions.⁴ This approach gives an endogenous output, and incorporates the firm's *ex ante* short-run optimization behaviour for the production technology, given full utilization of the variable inputs under normal operating conditions.

The definition and measurement of capacity in fishing and other natural resource industries face a unique problem because of the stock-flow production technology, in

¹ In the economics approach, capacity can be defined as the output pertaining to one of two economic optima: (1) the tangency of the short- and long-run average cost curves (Chenery 1952, Klein 1960, Friedman 1963), so that the firm is in long-run equilibrium with respect to its use of capital, or (2), the tangency of the long-run average cost curve with minimum short-run average total cost curve (Cassel 1937, Hickman 1964).

² See also Gréboval (2003).

³ For further basic discussion, see also Färe, Grosskopf, and Kokkelenberg (1989). For further discussion on the application of plant capacity to fisheries, *i.e.* the technological-economic notion of fishing capacity, see Kirkley and Squires (1999), Kirkley, Morrison Paul and Squires (2002, 2004), and Pascoe *et al.* (2003).

⁴ Klein and Long (1973, p. 744) state that, "Full capacity should be defined as an attainable level of output that can be reached under normal input conditions—without lengthening accepted working weeks, and allowing for usual vacations and for normal maintenance." The US Bureau of the Census survey uses the concept of practical capacity, defined as "the maximum level of production that this establishment could reasonably expect to obtain using a realistic employee work schedule with the machinery and equipment in place" and assuming a normal product mix and down-time for maintenance, repair and cleanup.

which inputs are applied to the renewable natural resource stock to produce a flow of output. For renewable resources, capacity measures are contingent upon the level of the resource stock. Capacity is, therefore, the maximum yield in a given period of time that can be produced, given the capital stock, regulations, current technology and state of the resource (FAO 1998, Kirkley and Squires 1999). Nonetheless, annual climate-driven ocean variability is clearly a key factor affecting fisheries. Monsoon and El Nino-Southern Oscillation events provide clear examples because the distribution and catchability of fish varies. As a consequence, and owing to annual changes in the size and species and age mix of the resource stocks, the target level and capacity output from the stock-flow production process can vary annually, and even seasonally, when there are strong seasonal effects.

An additional factor that is important to consider is the source of variations in the level of technical efficiency at which a vessel operates. Pascoe and Coglán (2002) found that differences in vessel characteristics explained about one third of the variation in technical efficiency of English Channel trawlers, and attributed the remainder to unmeasurable characteristics, such as skill of the captains and differences in technology that could not be quantified. Other studies (*e.g.* Kirkley, Squires and Strand 1998 and Squires and Kirkley 1999) have also suggested that much of the difference in efficiency among vessels may be owing to differences in skill of the captains. As such, in this study, where data permits, fishing capacity is estimated under two different measures. First, as discussed previously, it is estimated under full variable input utilization and maximum technical efficiency. Second, it is estimated under full variable input utilization, but with current levels of technical efficiency. The latter was done to try to account for variations in skill levels of the captains in deriving estimated capacity output levels; it, in effect, measures capacity utilization purged of the effects of technical efficiency.

In fisheries and other renewable resource industries, excess capacity is often defined relative to some biological or bio-socio-economic reference point, which accounts for sustainable resource use and a target resource stock size. Excess capacity, in a technological-economic approach, can be defined as the difference between capacity output and the target level of capacity output, such as maximum sustainable yield or the catch rate corresponding to the fishing mortality of an alternative harvest (FAO 1998). The target level of capacity output was defined by the 1998 FAO Technical Working Group as, "Target fishing capacity is the maximum amount of fish over a period of time (year, season) that can be produced by a fishing fleet if fully utilized while satisfying fishery management objectives designed to ensure sustainable fisheries ..." (FAO 1998, p. 11)⁵ The 1999 FAO Technical Consultation on measuring fishing capacity reached a similar conclusion (FAO 2000). The target fishing capacity catch can be specified as, for example, maximum sustainable yield (MSY) or maximum economic yield (MEY).

⁵ Fishing capacity is generally defined by FAO (1998, 2000) as follows:

Fishing capacity is the maximum amount of fish over a period of time (year, season) that can be produced by a fishing fleet if fully utilized, given the biomass and age structure of the fish stock and the present state of the technology. Fishing capacity is the ability of a vessel or fleet of vessels to catch fish, *i.e.* $Y_C = Y(E_C, S)$.

In this general definition, Y_C denotes current yield/catch, E_C denotes current effort, and S denotes stock size (biomass). Fishing capacity thus represents the maximum amount of fish caught by a fleet fully utilizing its variable economic inputs under normal operating conditions, given the fleet's capital stock (vessels gear and equipment, including fish-aggregating devices), biomass and harvesting technology. Normal operating conditions refers to those operating conditions faced by fishing vessels in the normal conditions of the periods in which they operate.

3. THE FEASIBILITY OF ROUTINELY COLLECTING INPUT DATA FOR DATA ENVELOPMENT ANALYSIS (DEA)

3.1 Data Envelopment Analysis (DEA)

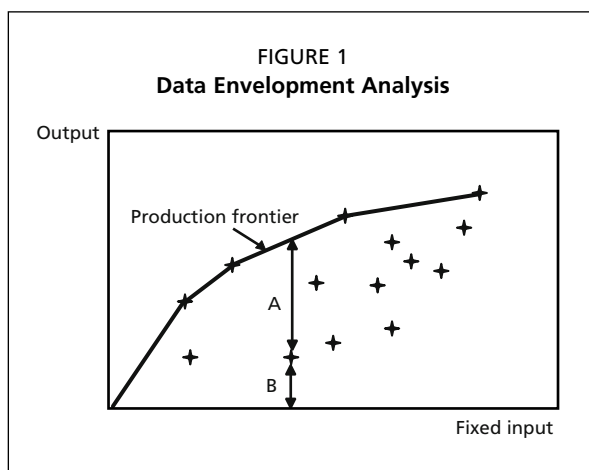
The DEA approach derives a deterministic production frontier describing the most technically efficient combination of outputs, given the state of fishing technology, the fish stock and unrestricted variable inputs. Färe (1984) introduced this methodology as a means of measuring the technological-economic concept of capacity and CU for manufacturing firms, and it was further developed by Färe, Grosskopf and Kokkelenberg (1989). Kirkley and Squires (1999) proposed DEA as a useful approach for assessing capacity in fisheries. The DEA approach distinguishes between variable and fixed factors, and allows for multiple outputs and variable returns to scale.

The DEA approach calculates capacity output, given that the variable factors are unbounded and the fixed factors, environmental parameters, such as the resource stock and oceanic conditions, and state of technology constrain output. Capacity output corresponds to the output that could be produced, given full and efficient utilisation of variable inputs and given the constraints imposed by the capacity base—the fixed factors, the state of technology, environmental conditions and resource stock. In practice, because the data reflect both technological and economic decisions made by firms, the variable inputs correspond to full and efficient utilization under normal operating conditions

The use of DEA to estimate fishing capacity output and capacity utilization is illustrated in Figure 1. DEA, using the observed landings for different-sized vessels and a measure of the capital stock or fixed inputs, such as gross registered tonnage (GRT), determines the output or landings that are the greatest for any given vessel size, assuming that variable inputs are fully utilized (variable inputs are thereby unconstrained) under normal operating conditions, where normal operating conditions are reflected in the data. DEA estimates a frontier or maximum landings curve, as determined by the best-practice vessels, which represents fishing capacity output. The landings directly on the best-practice production frontier represent full capacity utilization ($CU = 1$). When a vessel produces at less than full capacity, as represented by an output lying below the frontier in Figure 1, the capacity utilization is less than 1. In Figure 1, therefore, B represents the size of landings, A denotes the excess capacity (*vis-à-vis* observed production), $A + B$ denotes capacity output, and the ratio $A/(A + B)$ represents capacity utilization, so that $CU < 1$ in this case. The production frontier (also called the reference technology), established by the best-practice vessels (the ones on the frontier) and estimated by DEA, gives capacity output, given the fixed inputs or capacity base, the states of technology and the environment and the resource stocks, provided that the variable inputs (fishing effort) are fully utilized under normal

operating conditions. The production frontier gives technically efficient output, given the fixed inputs, states of technology and the environment, and resource stocks when the variable inputs are utilized at the observed levels. Hence, the difference between capacity output and technically efficient output is that variable inputs are fully utilized in the former and are utilized at the observed levels (which could be fully utilized) in the latter.

Alternative methods for measuring capacity and capacity utilization have been proposed, most notably duality-based measures using cost, profit or revenue functions (Morrison 1985, Squires 1987, Segerson and Squires 1990,



1993, 1995). Unlike duality-based econometric estimates such as cost, profit or revenue functions, DEA does not impose an underlying functional form. Unlike the cost, profit or revenue function approach, DEA estimates primal measures of capacity in a multiple-product environment without imposing separability assumptions on the outputs (Segerson and Squires 1990). DEA can be used when prices are difficult to define, behavioural assumptions, such as cost minimization, are difficult to justify or cost data are unavailable.

The DEA approach has limitations. First, it is a non-statistical approach, which makes statistical tests of hypotheses about structure and significance of estimates difficult to perform. Second, because DEA is non-statistical, all deviations from the frontier are assumed to be to the result of inefficiency. Third, estimates of capacity and capacity utilization may be sensitive to the particular data sample (a feature shared by the dual cost, profit or revenue function approach).

3.2 Data requirements

Within the context of measuring fishing capacity to allow for DEA to be undertaken, it is necessary, at the very least, to obtain a data set detailing fixed inputs (fixed physical characteristics of the vessels) to the fishery and the associated output (catch). The data on the physical characteristics could include, among other attributes, GRT, well capacity, engine horsepower and/or freezing capacity per day. While it is not necessary that such data be obtained at a vessel level it is necessary that the data be disaggregated to a reasonable degree so as to allow for a “sufficient” number of observation points.⁶ Obviously the greater the disaggregation at which the data are available, the better the estimate obtained from any DEA will be. It is also necessary that the two data sets can be linked, that is, if data are, for example, obtained at the vessel level, then to conduct DEA it is necessary that the data on the physical characteristics of each vessel can be associated with its catch data.

To allow for consideration of skill of the captains in estimating fishing capacity (that is, purging measured capacity for variations in skill of different captains) it is necessary to also have a data set detailing variable inputs, such as, for example, fishing or searching days, number of hooks set and/or fuel consumption. It is also necessary that these data can be directly associated with the fixed input and output data sets at whatever level of disaggregation the analysis is conducted.

3.3 Data availability

3.3.1 Purse seine fisheries

Reid *et al.* (2005) conducted a DEA of global tuna purse-seine fishing capacity by ocean area (eastern Pacific Ocean (EPO), western and central Pacific Ocean (WCPO), Indian Ocean and Atlantic Ocean), and the following observations can be drawn from this analysis and associated work. With regard to the EPO and WCPO, it was possible to obtain data at the vessel level that could be used to represent fixed inputs, variable inputs and outputs *and* to link these data sets. The data for the EPO were obtained from the Inter-American Tropical Tuna Commission (IATTC). The data for the WCPO were obtained from the Secretariat for the Pacific Community (SPC), with the exception of data for the Japanese fleet, which were obtained from the Fisheries Research Agency (FRA) of Japan. The reason for this was that the Japanese purse-seine fleet do not provide data relating to fishing activities outside the Exclusive Economic Zones (EEZs) of members of the SPC (*i.e.* the high seas and Japan’s EEZ).

⁶ An “insufficient” number of observations gives an estimated piece-wise linear frontier with more and/or longer linear segments and a less accurate measure of capacity output. Without enough “kinks” (from shorter and a larger number of segments) in the piece-wise linear frontier, the distance from an observed output to the frontier, where the observed frontier gives the capacity output, is reduced.

Reid *et al.* (2005) found that data sets that could be used to represent fixed inputs, variable inputs and output at a vessel level are also available for the Indian and Atlantic oceans. However, it was not possible to link these data, nor were the organizations holding the data prepared to undertake the work to do so. As a consequence, Reid *et al.* had to use highly-aggregated data in estimation of purse-seine fishing capacity in these areas.

3.3.2 Longline and pole-and-line fisheries

Reid, Kirkley and Squires (2004) examined the feasibility of applying DEA to measure fishing capacity of the global longline and pole-and-line fleets, given available data, and made the following observations:

In the Indian Ocean IOTC [Indian Ocean Tuna Commission] provides two sets of data which are of interest. First, is the catch data by fishing method. From this we can ascertain the level of catch taken by longline vessels and pole and line vessels (baitboats) in the Indian Ocean and within smaller areas within the Indian Ocean over a significant period. Second, is the IOTC positive list which contains a list of vessels and some of their characteristics that are currently on the IOTC positive list. These two data are in themselves insufficient to conduct DEA as, as was noted in the conduct of the purse seine fishing capacity DEA, the positive list is not available as a time series nor is it a reasonable proxy of the actual number of vessels operating in the fishery. Given this attempts were made to obtain data from national fisheries agency on their long line and pole and line fleets and catches. The only response from these request were from Indonesia and Japan with Indonesia providing some data from a proportion of their longline fleet. Japan indicated that it may be possible to obtain some data with the permission of its fishing industry. Attempts were also made to construct a time series of vessel numbers from other sources such as IOTC publications. Given these factors, at this stage it appears that there is not sufficient data to under any meaningful DEA of longline or pole and line fishing capacity in the Indian Ocean.

The story is similar in the Atlantic and Eastern Pacific Ocean, although a more thorough search is required in the case of the Eastern Pacific Ocean.

For the Western and Central Pacific Ocean vessel level data is available in terms of both vessel characteristics and catch. However, the catch data does not in most case include catches taken outside of the waters of member countries of the Secretariat of the Pacific Community (SPC). Nonetheless, the data should be sufficient to allow for a meaningful DEA to be conducted.

Overall it appears that there is not sufficient data to allow for a meaningful DEA to be conducted that would provide for better estimates of global longline and pole and line fishing capacity than those provided by other papers presented at this meeting.

An informal meeting on DEA held in conjunction with the 17th meeting of the Standing Committee on Tuna and Billfish of the Oceanic Fisheries Programme of the SPC in August 2004 considered, among other issues, conducting DEA to estimate global longline fishing capacity, and reached the following conclusion:

... the data representing the minimum data requirements for Project 2 [measurement of longline capacity] are available only for the Japanese industrial longline fishery. Even if such data were collected for other major industrial longline fleets, the DEA can be carried out only at a very basic level and no significantly better information would be expected than input measurements presented at the 2nd TAC [Technical Advisory Committee] for these fleets. (FAO 2004).

3.4 Summary

It appears that a reasonable set of data of fixed inputs (vessel characteristics) can be obtained for larger scale purse-seine, longline and pole-and-line fleets and, in some cases, smaller-scale vessels.

However, this is not the crux of the problem that is faced in trying to conduct a DEA at a level of disaggregation from which worthwhile results can be obtained. The problem is associating the input data with variable input (effort) and output (catch) data at anything but a fishery level. Thus, the problem is often not the availability of fixed input data but the availability of the data in an appropriate form for DEA (*i.e.* cases for which catches can be associated with a particular vessel or subset of vessels and the characteristics of the vessel or sub-set of vessels are available). The answer to the question as to whether it is technically feasible to obtain fixed input data is, in many cases, yes; however, the real question is whether regional fishery management organizations (RFMOs) and others are prepared to provide disaggregated data that allow catches to be associated with particular vessels, or at least a reasonably disaggregated grouping of vessels. From previous experience, the answer to this latter question is mixed. There are also other problems, such as, for example, obtaining a full set of variable input and output data for the WCPO for longliners of “distant-water fishing nations” in areas outside of the Exclusive Economic Zones (EEZs) of SPC members. This means that, while vessel characteristics data can be obtained, they can be associated only with the variable inputs and outputs of a vessel within the EEZs of SPC members, rather than for that vessel’s entire operations. The question then arises as to whether it would be possible to collect such data for conducting a DEA. This is a question that can be answered only by the flag states. As such, the issue at hand is not the feasibility of collecting fixed input (vessel characteristic) data, but of collecting vessel level variable input (effort) and output (catch) data for the entire operations of vessels and whether this can be associated with the fixed input (vessel characteristic) data.

4. FEASIBILITY OF PERFORMING INDUSTRY SURVEYS OF TUNA FISHING CAPACITY UTILIZATION

Surveys of plant capacity and its utilization for many industries are routinely conducted in many countries that are members of the Organisation for Economic Co-operation and Development (OECD). These surveys could be adapted to tuna fishing. A pilot project to determine feasibility could begin with tuna purse-seine vessels because there are fewer tuna purse-seine vessels than longline or pole-and-line vessels, and because DEA studies of fishing capacity of purse-seine vessels have been conducted that can serve as a basis for comparison. If these surveys are deemed feasible and desirable, the approach could be extended to the other gear types.

4.1 Two basic survey approaches

Two basic approaches are possible on an annual basis. The first approach directly surveys individual vessels for their annual fishing capacity, capacity utilization and vessel size (well capacity, GRT, engine power, *etc.*), where fishing capacity is defined by potential catch or output following FAO (1998, 2000). An entire fleet (or some other well-defined unit) or a sample from the fleet (or well-defined unit) could be surveyed. Similarly, direct surveys of full production capability or full capacity production—plant capacity—and the rate of capacity utilization are routinely conducted in many OECD countries by central banks, central government statistical agencies and the like. These surveys query plants directly about their current levels of production and the production that could have been produced if the plant were operating at full capacity, *i.e.* its capacity output or plant capacity.⁷ These concepts of capacity and capacity

⁷ Plant capacity or full production capability, which is comparable to a fishing vessel’s fishing capacity, as defined by the FAO and to the Johansen (1968) definition, is evaluated by its capacity output in a manner exactly parallel to the FAO definition. The plant’s capacity base is not assessed by its area (square meters) or volume (cubic meters), but by its potential production under normal and realistic operating conditions. Capacity of elevators, theaters and passenger vessels is similarly assessed by its potential output or number of persons carried under normal and realistic operating conditions (and subject to safety considerations).

utilization correspond directly to the FAO concepts of fishing capacity and capacity utilization. This approach is discussed more fully below.

The second approach would assess annual fishing capacity and its utilization by surveying vessels for their actual and potential fishing effort, as measured by some measure of fishing time (*e.g.* days fished), and their capital stock, as measured by some proxy such as well capacity, GMT (or net registered tonnage) or horsepower.⁸ This approach assesses what was called “Physical Capacity” by the 1999 FAO Technical Consultation on the Measurement of Fishing Capacity (FAO 2000), and which corresponds to that used by the European Union (Lindebo 2003).^{9 10} This measure is discussed more fully below.

4.2 Direct surveys of the FAO measure of fishing capacity¹¹

The FAO definition of fishing capacity corresponds to the measures of plant capacity—full production capability, such as that used by the US Department of Commerce and the US Census Bureau (see the Appendix). These measures are output-oriented, as is the case for the FAO definition.

The US Department of Commerce and US Census Bureau survey of plant capacity (*i.e.* full production capability) and plant capacity utilization for many industries asks about the market value (*i.e.* market revenue) of the products (emphasis added):

1. the actual products produced;
2. the **value** of products that could have been produced if the plant was operating at full capacity in the **fourth quarter**;
3. the **value** of products that could have been produced if required in a **national emergency**.

To adapt this approach to tuna fisheries, several unique features of tuna vessels would have to be accommodated:

1. Only the first two of the three levels of operating capability of a plant are germane for surveys of tuna vessels, *i.e.* actual and full capacity production. National emergency is germane to the question at hand.
2. Tuna vessels correspond to plants, so that the focus is on vessels, rather than on firms or companies (in cases for which a tuna firm may own more than one vessel).
3. Survey vessels for their catches of all tuna species, in metric tons, rather than survey market value of the catch or revenue.
4. The catches of individual tuna species would be summed to total catch (in metric tons), according to the catch species mix during the period of the survey. (This corresponds to an industrial plant producing multiple products.)
5. The fourth-quarter focus could be broadened to the entire year, owing to the seasonality of fisheries and the importance of a more accurate measure of capacity to manage a renewable resource.

⁸ This second approach is fundamentally a measure of capital utilization, and the extrapolation from fishing effort to fishing capacity and capacity utilization requires the following assumptions: (1) fish stocks are constant (so that increases in potential fishing effort generate constant catch rates); (2) there is a single capital stock; (3) all variable inputs are in fixed proportions; (4) constant returns to scale (a proportional increase in all inputs leads to a proportional increase in output or catch) (Berndt 1990, Kirkley and Squires 1999).

⁹ Changes in the quality of the capital stock over time are not captured by this measure. For example, technical progress which is embodied in the capital stock, such as vessel electronics or improved brailing systems, is not captured.

¹⁰ Fishing effort, as a measure of time in a flow of capital services, in technical economics terms, is an important component of capital utilization, rather than capacity utilization. Capital utilization in formal economics is defined as the ratio of the flow of services from the capital stock to the stock (Hulten 1990).

¹¹ We thank Joseph Terry for calling our attention to this website.

Surveying vessels for their actual and full production capability catches in volume units (metric tons), rather than value units (US dollars, yen, Euros, *etc.*) more closely corresponds to the biological management of fisheries and abstracts from exchange rate fluctuations when comparing across flag states and fisheries.

Based on the definition of full production capability in the Appendix, the following assumptions would be specified:

Full production capacity or capability is defined as the maximum level of production that this establishment could reasonably expect to attain under **normal** and **realistic** operating conditions, fully utilizing the machinery and equipment in place. The following factors are to be considered in estimating market value at full production capacity or capability:

- Assume **only** the machinery, gear and equipment in place and ready to operate will be utilized. Do not include facilities or equipment that would require extensive reconditioning before they can be made operable.
- Assume **normal** downtime and time in port for maintenance, repair, cleanup, fueling, provisioning, assembling crewmembers, off-loading and other such activities. If full production requires additional time in port for repairs, drydocking, refitting, *etc.*, then appropriate downtime should be considered in the estimate.
- Assume number of shifts, hours of vessel operations and overtime pay that can be sustained under **normal** conditions and a **realistic** work schedule.
- Assume crewmembers, other labour, fuel, provisions, gear, materials, utilities, *etc.* are fully available.
- Assume a species mix that was **typical** or representative of production during the time period of concern. If a vessel is subject to short-run variation, then assume the species mix of the current period.
- Assume methods of fishing (unassociated schools, flotsam, drifting fish-aggregating devices, dolphins, *etc.*) that are typical or representative of production during the time period of concern.
- Assume biological resource abundance and environmental conditions, such as weather, sea-surface temperature, currents, *etc.*, that are typical or representative during the time period of concern.
- Do not assume increased use of productive facilities outside the vessel for services (such as at-sea off-loading if off-loading at shore-based operations is the usual case) in excess of the proportion that would be normal during the fourth quarter.

The vessel's capacity utilization rate should be based on a capacity catch and species mix that the vessel could have sustained under **normal**, not emergency, conditions.

4.3 Surveys of physical capacity: potential fishing effort

Physical capacity, in terms of potential fishing effort, is defined by FAO (2000, Appendix E, page 26). Vessel units (VU) were defined as measures of the capital stock, such as boat numbers, GRT, carrying capacity, *etc.* Effort units (EU) were defined as a measure of flow of capital services, such as sum (days fished*VU). Potential effort units (PEU) were defined as effort if all capacity was fully utilized, such as sum (maximum days fished*VU). Capacity utilization was then defined as $CU_t = EU_t/PEU_t$, where $0 < CU_t < 1$.

Surveys to establish potential fishing effort would be similar to those for plant capacity or full production capability. The unique features would be questions pertaining to the potential fishing effort if there were not any constraints, such as those imposed by weak markets, regulations, breakdowns in equipment, difficulties in finding captains or other crewmembers, issues related to vessel monitoring systems or access rights and so forth. Surveys would also ask for actual time spent away from port (days absent) and for the preferred measures of vessel size (well capacity, carrying capacity, registered tonnage, length, *etc.*).

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APPENDIX

SURVEYS OF PLANT CAPACITY UTILIZATION IN THE UNITED STATES

Surveys of plant capacity utilization for many industries are routinely conducted in many OECD countries. In the United States, the Survey of Plant Capacity Utilization for many industries is conducted jointly by the US Census Bureau, the Federal Reserve Board and the Defense Logistics Agency. The US Census Bureau website, <http://www.census.gov/cir/www/mqc1pag2.html>, contains considerable information on this subject.

The survey collects data for the fourth quarter, and includes operational status (sold, leased, permanently ceased), number of days and hours worked, number of workers, number of shifts worked and three levels of operating capability of the plant during the fourth quarter: (1) the market value of actual goods produced; (2) the value of products that could have been produced if the plant was operating at full capacity during the fourth quarter; and (3) the value of products that could have been produced if required in a national emergency.

The following is a copy from selected text of the US Census Bureau website report. Boldface type is used as it appears in the instructions.

Seasonal Operations:

- a. If this plant is usually temporarily idle during the fourth quarter *due to seasonal factors*, report as instructed for idle plants.
- b. If this plant was not temporarily idle during the fourth quarter, but its operations vary substantially from quarter to quarter, *due to seasonal factors*, complete items 2 through 5 (2. Value of Production, 3. Work Patterns of Fourth Quarter Operations, 4. Fourth Quarter Actual Operations vs. Full Production Capability, 5. National Emergency Production), and report full production and national emergency production capabilities based on the plant's **peak** quarterly production during the year.

Full Production Capability:

Full production capacity or capability is defined as the maximum level of production that this establishment could reasonably expect to attain under **normal** and **realistic** operating conditions fully utilizing the machinery and equipment in place. The following factors are to be considered in estimating market value at full production capacity or capability:

- Assume **only** the machinery and equipment in place and ready to operate will be utilized. Do not include facilities or equipment that would require extensive reconditioning before they can be made operable.
- Assume **normal** downtime, maintenance, repair, and cleanup. If full production requires additional shifts or hours of operation, then appropriate downtime should be considered in the estimate.
- Assume number of shifts, hours of plant operations, and overtime pay that can be sustained under **normal** conditions and a **realistic** work schedule.
- Assume labor, materials, utilities, etc. are fully available.
- Assume a product mix that was **typical** or representative of your production during the fourth quarter. If your plant is subject to short-run variation assume the product mix of the current period.
- Do not assume increased use of productive facilities outside the plant for services (such as contracting out subassembly work) in excess of the proportion that would be normal during the fourth quarter.

Capacity Utilization

Your plant's capacity utilization rate should be based on a capacity output measure that your plant could have.