

# Capacity, Excess Capacity, and Fisheries Management

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**Abstract:** Excess capacity results because fishermen do not have an incentive to conserve fish in-the-sea causing them to over-invest in the capital used to harvest fish as well as other production or factor inputs.<sup>1</sup> Excess capacity like overcapitalization and overfishing is a symptom of our regulated, open access fishery management system. Because capacity has been an ill-defined term in the fisheries literature, it has been poorly understood by fisheries managers. Excess capacity exists in a fishery when the yield from the fishery exceeds the point where net benefits to society are at a maximum; i.e., once maximum economic yield (MEY) is exceeded. Since MEY often occurs before maximum sustainable yield (MSY) is achieved in a developing fishery, excess capacity already exists in a fishery with a fully utilized fish stock. Even where barriers to entry exist in a fishery, such as exclusive economic zones (EEZs), permit moratoriums, or transferable licenses, fishermen who participate in the fishery retain a market incentive to race for the fish since no property rights exist for the in situ marine resource; i.e., the fish-in-the-sea. While the adverse effects of excessive capacity levels have become too obvious and severe to ignore,<sup>2</sup> they can be corrected. With economically rational fisheries management, fishermen behave as if a private property right exists for the in situ marine resource. This creates a market incentive for fishermen to conserve the fish stock by divesting capital and other factor inputs needed to harvest fish until the yield from the fishery corresponds to MEY, the fish stock is conserved, and excess capacity in the fishery is eliminated. Achieving this objective is a matter of great debate. Without an unbiased and objective capacity measurement metric, the success or failure of regulations designed to reduce capacity cannot be accurately assessed.

**Keywords:** Capacity, Excess Capacity, Fisheries, Economics, Management

## Introduction

“In one fishery after another over the past 45 years, the world’s marine fishery resources have been overfished to the point of collapse” (Porter, 1998).

Excess capacity and overfishing have been identified as the two most important problems presently facing fisheries managers. While a long history of remedies for overfishing have been tried and can be documented, concerns with excess capacity have been expressed relatively recently. Implicit in a number of recent attempts to assess capacity levels has been the notion that excess capacity is the cause of overfishing. This makes a certain amount of intuitive sense since without an excessive number of fishing vessels and factory trawlers, how could fish stocks become overfished. Intuition also suggests solutions. If subsidies to the fishing industry were eliminated, then excess capacity in a fishery would no longer exist. Or, if fishing craft could be bought out of the fisheries by government or industry funded programs, then capacity levels in a fishery could be reduced.

Unfortunately, in this case, our intuition fails us. For most of us, our frame of reference is a world in which clearly defined and enforceable property rights govern the allocation of goods and services through market transactions. Experience with these types of markets cause the outcomes that occur in market systems that operate

without clearly defined and enforceable property rights to appear counter-intuitive and sometimes paradoxical. As a result, attempts to address the excess capacity and overfishing problems in fisheries can lead to the counter-intuitive result that despite short run improvements they will again become critical problems in the long run.

Consider an analogy where, for example, a paper company in Maine decides to lay off some of its woodsmen because increased competition from personal computers in delivering the news has caused a decrease in demand for newsprint which results in reduced pulp wood production. If these woodsmen migrated to the central part of the state, they could become dairy farmers by fencing off existing pastures and cow herds and building barns and houses. In this event, the original owners of these farms could have them arrested for trespassing, vandalism, and theft as well as sue them in civil court for damages. Now consider a real experience that actually happened in the southern United States when the oil crisis of the early 1980's ended. Secondary and tertiary oil recovery fields closed as oil prices fell, field hands were laid off who returned to their homes where unemployment rates in coastal communities exceeded 16 percent. Shortly after that, permits issued by the state of Louisiana to fish for crabs increased substantially from less one thousand in 1986 to over 3 thousand by 1991 (Table 1). At the same time in the shrimp fishery, 17 percent of shrimpers interviewed indicated that they had changed their occupations as a

result of the end of the oil crisis (Keithly and Mounce, 1991). In this case, however, existing crabbers and shrimpers faced with new competitors from the oil recovery fields had no legal recourse to protect their livelihood. Without clearly defined and enforceable property rights capacity in these fisheries increased with the change in market conditions in another sector of the economy.

Rather than being the cause of overfishing, excess capacity and overfishing are both symptoms of another problem in our fisheries; i.e., the lack of clearly defined and enforceable property rights for fish in the sea. Market incentives are created by this lack of property rights for fish in the sea to over fish resource stocks by investing in excessive levels of capital and labor to harvest fish. Directly addressing excess capacity or overfishing through fishery management regulations will not eliminate this market incentive. The government in its role of a good natural resource steward will have to continually monitor and manage the fishery through a series of regulations designed to address symptoms of this problem rather than “fixing” the problem and allowing the markets to operate efficiently. Addressing the common property externality directly would allow the government to withdraw from the fish monitoring activities with the market determining the appropriate levels of capacity and fishing levels. Instead, scarce government resources could be focused on related fishery problems, such as community impacts in National Standard 8 or bycatch in National Standard 9 of the Magnuson Stevens Act.

### History

International and domestic interest in the problem of excess capacity has grown steadily over the last decade. International studies have attempted to measure global fishing capacity levels. These studies have been cited as examples of how excessive levels of investment in fish harvesting technology have led to the decimation of global fish stocks. Fitzpatrick (1995) calculated a 270 percent increase in an average fishing technology coefficient between 1965 and 1995; a 9 percent annual growth rate. This increase in technological efficiency has been coupled with an increase in total vessels from 0.6 million in 1970 to 1.2 million in 1992; a 2.2 percent annual growth rate. Garcia and Newton (1995) estimated that world fishing capacity should be reduced by 25 percent for revenues to cover operating costs and by 53 percent for revenues to cover total costs. A substantial reduction in global fleet capacity would be required for levels to become commensurate with sustainable resource productivity, perhaps as much as a 50 percent reduction in existing global fishing capacity (Mace, 1996). In addition, substantial levels of subsidization are allegedly required to

support the resulting fishing fleets. The Milazzo (1998) study found that subsidies approach 20 to 25 percent of global fisheries revenues.

Fishing capacity has become the subject of much debate in the international fisheries management community. The Environmental Agenda for the 21<sup>st</sup> Century (Agenda 21), which resulted from the 1992 Green Summit in Rio de Janeiro, included a call for governments to cooperate in addressing crises in global fisheries. As a result of a series of negotiations beginning in 1993, three international agreements were completed; i.e., the Food and Agricultural Organization (FAO) Code of Conduct for Responsible Fisheries, The FAO Agreement on Compliance, and the United Nations (UN) Agreement on Highly Migratory and Straddling Fish Stocks. The FAO Code of Conduct for Responsible Fisheries states<sup>3</sup> that “states should prevent overfishing and excess fishing capacity and should implement management measures to ensure that fishing effort is commensurate with the productive capacity of the fishery resources and their sustainable utilization” and<sup>4</sup> “where excess fishing capacity exists, mechanisms should be established to reduce capacity to levels commensurate with the sustainable use of fisheries resources so as to ensure that fishers operate under economic conditions that promote responsible fisheries. Such mechanisms should include monitoring the capacity of fishing fleets.”

With this increased interest in global fisheries, the National Oceanic and Atmospheric Administration (NOAA) and the United States Department of State, tabled a proposal at the 1997 Committee on Fisheries (COFI) meeting that led to three international plans of action (IPOA) concerning sharks, sea birds, and fishing fleet capacity. The fishing capacity IPOA directs FAO member nations to assess their domestic fishing capacity through a series of voluntary individual and collective national plans. The most significant elements of the capacity IPOA are voluntary commitments to assess levels of capacity in the domestic fisheries of each FAO member and to develop national capacity management plans. To facilitate these actions, FAO organized a technical working group meeting in La Jolla, California in April 1998 that developed definitions of fishing capacity. A second technical consultation held in Mexico City, Mexico in November 1999 continued this analytical work and reviewed case studies prepared by experts from a number of developed and developing FAO member nations. Most significantly, specific metrics to measure fishing capacity that U.S. Government and academic experts had developed were endorsed by the Mexico City consultation as standards that FAO should disseminate globally.

Domestic concerns with fishing capacity also exist as can be seen in the 1996 reauthorization of the Magnuson-Stevens Act, or the Sustainable Fisheries Act (SFA). The SFA has provided the Agency with expanded authority for implementing fishing capacity reduction programs: “to obtain the maximum sustained reduction in fishing capacity at the least cost and in a minimum period of time.” The reauthorization also mandated a study completed in the summer of 1999 on the role of the Federal Government in subsidizing the expansion and contraction of fishing capacity, and otherwise influencing the aggregate level of capital investment in fisheries (Federal Fisheries Investment Task Force, 1999). The SFA is also the primary factor behind the inclusion of capacity management as a formal NOAA planning objective. Under the Build Sustainable Fisheries (BSF) element of the NOAA Fisheries Strategic Plan, a 20 percent reduction in the number of overcapitalized fisheries must be achieved by the year 2005.<sup>5</sup> This planning element gives NOAA, for the first time, a quantitative capacity management target and a deadline.

In addition, the recommendations of the National Research Council (1999) report calls for a reduction in excess fishing capacity and states that “...managers and policy makers should focus on developing or encouraging socioeconomic and other management measures that discourage overcapacity and that reward conservative and efficient use of marine resources and their ecosystems.” This report also notes that “... there is a need for better information about capacity, including fleet size, types of ships and gear, ownership, and status of operation.”

The National Marine Fisheries Service (NMFS) and FAO are not alone in pursuing the issue of subsidy impacts on domestic and international levels of fishing fleet capacity. The Organization for Economic Cooperation and Development (OECD) is conducting a study of the impacts of financial transfers on the transition to responsible fisheries. The World Bank is working with Argentina to develop a fishing capacity reduction program (Schonberger, 2000). The UN Commission for Sustainable Development resolved in 1997 that nations should cooperate in analyses to identify and assess the positive and negative environmental roles of subsidies in fisheries. The White House and United States Trade Representative (USTR) proposed a fisheries’ sectoral initiative for the next World Trade Organization (WTO) multilateral trade round that will address all major trade issues, including subsidies (as opposed to a focus on tariff reductions) and explicitly sought to deal with both the trade and conservation implications of trade liberalization in the fisheries sector.

As a result of these international agreements and plans of

action to monitor and assess fishing capacity, and a NOAA Fisheries Strategic Plan objective to eliminate overcapitalization in 20 percent of federally managed fisheries by 2005, NMFS has undertaken a project to quantitatively and qualitatively assess domestic fishing capacity in each of its federally managed fisheries. While estimates concerning world fisheries exist, estimates of the amount of capacity in United States fisheries are lacking. The goal of this project is to allow for the ordinal or cardinal ranking of fishing capacity in each of our federally managed fisheries by major user group or by gear type based on definitions developed by the NMFS (Ward, et al., 2000).

### Causes

Ideally, perfectly competitive markets allocate resources efficiently. The perfectly competitive market model depends on four assumptions. First, no individual agent (consumer, producer, or resource owner) in the marketplace can affect prices, though in aggregate prices respond to their actions. Second, products are homogeneous. Third, each agent in the marketplace has perfect knowledge. Fourth, free mobility of resources in response to pecuniary signals exists. To ensure free mobility, each resource must have clearly defined and enforceable property rights to facilitate its transfer. As these assumptions become compromised due to patents, imperfect or uncertain information, or market power, the efficiency of the market becomes impaired. The government’s role as a manager is to determine when economic inefficiency is “good” or “bad.” While patents restrict free entry into the market for a good or service, for example, they allow inventors to profit from their inspiration and encourage research and development for new products and technology. However, market power can restrict production, raise prices to consumers, and reduce consumer surplus plus create a dead loss in net benefits to society which is why the government generally opposes monopolies and oligopolies.

In fisheries, the free mobility of resources to respond to pecuniary signals is compromised because clearly defined and enforceable property rights for fish in the sea do not exist; i.e., the common property externality. If property rights for fish in the sea existed, then the owner of the fish stock would receive a higher price per unit of fish from the producer as the stock of fish decline. As the producer’s costs increase due to the higher price paid for this input in this production process, the less he produces to maximize his profits. When profits from the production of fish decline, the producer will begin to move his capital and labor into other markets where profits are greater. This will continue until profits in each market are equal. That is, as the abundance of the fish stock decline, fishermen

produce less fish because the production costs are increasing and capital and labor resources begin to move to other markets where the return on their investment is greater.

However, where these property rights for fish in the sea do not exist, no owner is paid for the fish as an input into the production process; i.e., the fish is free to the producer or fisher. Production costs do not increase because of increased payments to the owner of the fish stock resource when its abundance declines. As the stock becomes scarce, there is no pecuniary signal for fishers to move their capital and labor resources out of the fishery to other markets. Instead, the payments to the resource owner or resource rents become payments to the most fixed factor of production; e.g., skilled crew or the value of the fishing craft. With biological stock management increasing abundance through, for example, restrictive TACs, the return on investment increases for the labor and capital resources creating a pecuniary market signal that attracts these resources into the fishery resulting in capital stuffing and increased numbers of fishers. This results in the race for fish that is a characteristic of excess capacity in the fishery and results in the overfishing of the fish stock resource.

Ideally, the government's role should be to correct the common property externality, withdraw from the fishery, and let the relatively perfectly competitive market allocate resources efficiently. However, creating property rights for fish in the sea is not as simple as it sounds. Fisheries consist of consumptive and nonconsumptive user groups, multiple species of fish or multispecies fishing operations, migratory stocks, multiple jurisdictions within competing national jurisdictions. Even within user groups diversity exists. Consumptive users of a fish stock can have different objectives and goals. Recreational fishermen attempt to maximize satisfaction from catching fish. Commercial fishermen attempt to maximize profits or minimize costs subject to a constraint on their production levels. For hire captains and crews may attempt to maximize total revenue levels to increase their crew shares. In the Magnuson Act, the fishery management objective of preserving communities compete with objectives to conserve fish stocks, reduce bycatch, and promote safety at sea. While the federal government attempts to reconcile these management objectives, the state governments and regional fishery commissions have other management objectives; e.g., using fisheries as the employer of last resort. Within this complex political, economic, sociological, and biological environment, building a management consensus is difficult. Unable to correct the common property externality, the government cannot withdraw from the fishery and must continue to monitor and regulate the fish

stock resource to ensure that it does not result in the collapse of the fishery. This is particularly true with excess capacity simply because it is not well understood.

### Definitions

Once the concept of capacity is understood, defining excess capacity is the first step toward developing a meaningful measure of excess capacity or capacity utilization to determine if proposed or imposed regulations to reduce capacity levels will be or are successful. Capacity is not an unknown concept in other sectors of our economy and can be developed as either an input or output measure. Terry (2000) provides a review of a number of definitions for capacity and their implications for measurement and policy assessment. In the case of fisheries, capacity definitions fall into two groups. Those that are based on economic criteria and those that are based on technical criteria. In a fishery, excess capacity begins to develop once maximum economic yield (MEY) is exceeded. In the simple Schaeffer-Gordon model of a fishery, this occurs well before maximum sustainable yield (MSY) occurs. That is, if economic overfishing has occurred, then excess capacity exists in the fishery. Technical definitions are based on target levels of inputs into or outputs from the fishery. While simpler in that less data is required, the target level of output chosen can be based on any criteria. For example, MSY instead of MEY could be chosen as the target level of output for the fishery. As a result, economic based definitions of capacity could result in different estimates of capacity than technical definition based measures of capacity.

The NMFS in conjunction with and based on technical working groups developed by FAO have developed both economic and technical measures of capacity based on output levels (Ward, et al., 2000). Given that capacity is the level of output a fishing fleet is able, or willing and able to produce given specified conditions and constraints, then the technical definition of capacity is the level of output of fish over a period of time (year, season) that a given fishing fleet could reasonably expect to catch if variable inputs are utilized under normal operating conditions, for a given resource condition, state of technology, and other constraints. Fishing capacity is the ability of a vessel or fleet of vessels to catch fish.

The traditional economic definition of economic capacity, based on cost minimization, is that level of output of fish caught over a period of time (year, season) where short-run and long-run average total costs are equal, for a given fleet size and composition, resource condition, market condition, state of technology, and other relevant constraints. This traditional definition can be modified to define capacity

based on alternative objective functions to be those levels of output of fish caught over a period of time (year, season) where objectives such as profits or net social benefits are maximized for a given fleet size and composition, resource condition, market condition, state of technology, and other relevant constraints.

Economic definitions<sup>6</sup> are preferred to technical definitions<sup>7</sup> because the behavioral responses of fishermen to market and other incentives are taken into account. In short, they provide a more realistic and useful measure of capacity for most management applications. Economists have developed theoretical and empirical models that correspond to these definitions. Unfortunately, all of these models require detailed economic data that are rarely available for domestic fisheries. As a consequence, most short-term efforts to empirically measure capacity in US fisheries will likely focus on the technical definition. However, estimates of technical capacity should not be used to approximate economic capacity. The two types of definitions are quite different and no theoretical correlation exists between them (e.g., one could be increasing through time while the other is decreasing). The intent is to use these definitions as the basis for quantitative measures of capacity in our domestic fisheries. A number of quantitative methods have been developed in the economics literature that may be used to estimate various types of fishing capacity.

### Measuring Fishing Capacity<sup>1</sup>

Ideally, empirical estimates should be based on an economic definition of capacity (Ward, et al., 2000). Unfortunately, the data sets necessary to develop these economic based estimates of capacity are not presently available in all domestic fisheries being managed under federal fishery management plans. Empirical estimates based on a technical definition of capacity can be developed (Ward, et al, 2000) and used to determine capacity levels relative to a target level of output with presently existing data in most fisheries. Empirical estimates from which excess capacity levels can be determined are preferable since the impacts of management regulations designed to reduce capacity levels can be quantitatively assessed. However, until these analyses can be developed, a qualitative assessment of capacity levels in federally managed fisheries can be used to identify if excess capacity exists and whether the levels are substantial, moderate, or trivial.

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This section of the report is taken from Ward, et al., 2000 and credit for its content belongs to the coauthors of that report.

Three quantitative approaches to estimating technical capacity are peak-to-peak, data envelopment analysis (DEA), and stochastic production frontiers (SPF). The peak-to-peak method of Klein (1960) and the DEA model developed by Fare et al. (1989) are two approaches that have been used to estimate technical capacity in fisheries. SPF is an alternative method that has been used to estimate efficient (frontier) production in fisheries (Kirkley, Squires, and Strand, 1995). Each method has strengths and weaknesses, and the choice of the appropriate model will vary depending on the nature of the fishery, the data available, and the intended use of the capacity measure.

In addition to these quantitative methods, qualitative measures of capacity exist that may be useful to fishery managers. These measures point to the probable existence of excess capacity without attempting to provide a quantitative measure of capacity that fits either the technical or economic definitions. These indicators need to be considered relative to other relevant considerations, such as their participation in multispecies fisheries and the regulatory history of the fishery.

### Quantitative Measures of Excess Capacity

#### 1. Peak-To-Peak

The peak-to-peak method is best suited when capacity related data are especially limited; i.e., when the data are limited to catch and number of participants. The approach is called peak-to-peak because the periods of full utilization, called peaks, are used as the primary reference points for the capacity index. In practice, a peak year is often identified on the basis of having a level of output per producing unit that is significantly higher than both the preceding and following years. Capacity output is compared to actual output in different time periods to give measures of capacity utilization after adjusting catch levels for technological change. The peak-to-peak method requires data on landings and participants, such as vessel numbers, and some identification of a technological time trend. Minimum fleet sizes (number of vessels) that correspond to different levels of capacity can be calculated.

The peak-to-peak method is quite simple to apply even when sparse data are available. The method has been applied to fisheries and examples can be found in the literature [e.g., Kirkley and Squires (1998), Ballard and Roberts (1977) and Garcia and Newton (1995)]. However, peak-to-peak has a number of shortcomings that should be considered when evaluating the meaning of the capacity measure it provides. In most cases, peak-to-peak estimates can be expected to provide only a rough measure of capacity since the number of vessels or other measures of

physical capital are only a loose proxy for the actual catching power of the fleet. The analysis ignores economic factors that impact what the fleet will actually catch. If only the total number of participants and catch are used in the model, differences in capacity across gear types or other sectoral disaggregations cannot be identified; thus the index may not account for changes in the composition of the fleet that may have significantly changed its overall capacity. Determining the impacts of removing different groups of participants from a fishery will not be possible since the capacity of individual producing units is not identified. Also, if significant changes in fishery regulations that impact capacity have occurred, this measure of capacity may not be a reliable predictor of current capacity. Finally, while this approach provides an estimate of potential output and the potential level of capital, the measure is based on observations over time where both the resource stock and the intensity of capital input utilization have varied.

## 2. Data Envelopment Analysis (DEA)

Data envelopment analysis (DEA) uses linear programming methods<sup>8</sup> to determine either the maximum output that can be produced with a given set of inputs or the minimum level of inputs required to produce a given level and mix of outputs. DEA models were originally designed to measure technical efficiency. Fare et. al (1989) proposed a variation on the standard output oriented model that is designed to measure capacity output and capacity utilization assuming unconstrained use of variable inputs. Thus, to be on the frontier, firms must have produced the most output for a given level of fixed inputs. For the frontier to correspond with the definition of technical capacity, the firms on the frontier must be both efficient and fully utilizing variable inputs. Firms that are not on the frontier can be below it either because they are using inputs inefficiently or because they are using lower levels of the variable inputs relative to firms on the frontier.

DEA has several attributes that make it a useful tool for measuring capacity in fisheries. Capacity estimates can be calculated for multispecies fisheries if certain, fairly strong, assumptions are made about the nature of production.<sup>9</sup> DEA readily accommodates multiple outputs (e.g., species and market categories) and multiple types of inputs such as capital and labor. The analysis accepts virtually all data possibilities, ranging from the most limited (catch levels, number of trips, and vessel numbers) to the most complete (a full suite of cost data), where the more complete data improve the analysis. The DEA model may also include constraints on outputs of particular species (e.g., bycatch or trip limits). Since DEA identifies the efficiency and capacity of individual firms, it can be used to identify operating units (individual vessels or vessel size classes)

which can be decommissioned to meet various objectives. Capacity estimates can be made for different groups of firms (e.g., by region and vessel size class) and the number of operating units could be determined by adding the capacities of each operating unit until the total reaches a target. If data on input costs or output prices are available, DEA can be used to measure both technical and allocative efficiency of firms<sup>10</sup> (i.e., the model will calculate how much costs could be reduced or revenues increased by efficiently producing the optimal product mix).

As with the other capacity measurement methods, DEA has a number of potential shortcomings. First, a quite significant problem with DEA is that it is typically a deterministic model. Random variations in measured output (which may have been caused by measurement error or simply by normal variation in catch rates) are interpreted as inefficiency and influence the position of the frontier. In effect, the model assumes that vessels should be able to duplicate the highest catch rates observed. Recent research in the economics literature has focused on methods to overcome this problem. However, this research is not yet conclusive and such models are not likely to be widely available or implemented in the short-term. Second, efficiency scores are only relative to the best firms in the sample and cannot be compared to scores from other samples. This means that DEA cannot be used to rank different fisheries based on their level of capacity. Third, capacity output is based on observed practice and the economic and environmental conditions at the time observations were made. If fishermen were not operating at capacity in the past it may not be possible to identify the true technical capacity, and changing conditions may have altered what the fishermen can produce currently.

## 3. Stochastic Production Frontier Analysis (SPF)<sup>11</sup>

Stochastic production frontier analysis is an econometric approach that can be used to estimate the maximum potential output (i.e., catch) for the observed factors of production (Kirkley and Squires, 1998). The estimated frontier production function can be used to estimate the capacity of a vessel or firm by predicting output with their actual level of fixed inputs and a maximum level of variable inputs. SPF can be used to calculate both technical and allocative efficiency if data on input and output prices are available.<sup>12</sup> Additional advantages of SPF relative to the other approaches are that it is designed to handle noisy data and it allows for the estimation of standard errors and confidence intervals.

SPF has the same shortcomings as DEA to varying degrees. In addition, the usual problems and assumptions associated with parametric analysis are also present. The selection of

a distribution for the inefficiency effects may be arbitrary. A particular functional form must specify the production technology. The SPF approach is only well developed for single-output technologies unless a cost-minimizing objective is assumed. To accommodate multiple outputs in a multiple species fishery, SPF requires creating an aggregate output index (e.g., total pounds caught). The accuracy of capacity estimates will decline if species are heterogeneous in price, catchability and costs of production. In addition to these problems, using the SPF approach for measuring technical efficiency makes the estimation of capacity more complex. The variable input levels that correspond with normal operating conditions must be identified for each vessel. These variable input levels, along with the levels of fixed inputs, would then be used in the SPF production function to estimate capacity output for each vessel. Simplistically, under SPF as a measurement of capacity, the most binding input must be identified. Capacity is then a measure of the maximum output that can be produced given this fixed input. With multiple inputs, this must be determined in an iterative process which may not result in an efficient solution. The data requirements include firm or vessel output and input quantities, but richer models can be estimated if prices are available.

### Qualitative Indicators of Excess Capacity

While qualitative assessments are feasible, they should be based on a methodology that is as rigorous and scientific as possible. Toward that end, the qualitative assessments, to the extent possible, should be based on verifiable indicators. The fundamental rationale of this approach is to apply common yardsticks to all fisheries, and minimize the role of subjective judgment. At the same time, it is recognized that the judgement, individual knowledge, and experience of the analysts will necessarily play an important role, especially in these initial assessments. Nevertheless, the 'indicators' approach has important advantages. It is based on hard data; makes maximum use of existing information; incorporates biological, management, and fleet-specific data; and, most important, gives a common framework and therefore lends itself to more general conclusions about regional and national levels of capacity and excess capacity.

Qualitative capacity indicators can be developed from bioeconomic theory based on existing conditions in or characteristics of a fishery. Some commonly proposed indicator categories have been omitted for practical reasons. For example, a "good governance" indicator is hard to assess with precision. Purely economic indicators, like profitability, would be particularly insightful, but insufficient data on firm operating costs prevents its calculation. However, other indicators based on stock assessment analyses or management institutions can be

used in conjunction with theoretical economic knowledge of a fishery to make an assessment of capacity levels.

These indicators have been divided into two categories of excess capacity. Necessary indicators are almost certainly associated with excess capacity. In and of themselves, they provide enough evidence to make a determination of excess capacity in a fishery. Sufficient indicators, while associated with excess capacity, are not sufficient evidence that excess capacity exists in a particular fishery in and of themselves. If enough sufficient indicators exist for a particular fishery, then a determination that excess capacity exists can be made.

#### 1. Biological Status of the Fishery

The annual report to Congress entitled Status of Fisheries of the United States, prepared by the National Marine Fisheries Service, determines if a fish stock is overfished. Overfishing and excess capacity are both symptoms of the same underlying fisheries management problem. An overfished stock is almost certain to have excess capacity in the fishery. However, a fully utilized fish stock harvested at maximum sustainable yield (MSY) is also likely to be fished by a fleet that exhibits excess capacity since excess capacity begins once maximum economic yield (MEY) harvest levels are exceeded. Since the MEY harvest level in a fishery is not generally calculated, a developing or underutilized fishery may or may not be considered to have excess capacity. An overfished or fully utilized fish stock is considered a necessary condition for a determination of excess capacity in a fishery.

#### 2. Management Category

Three broad categories are proposed: (1) Open access (no limits on the number of participants or vessels); (2) limited access (controls on the number of participants); and (3) rights-based systems (ITQs, cooperatives, IFQs, or CDQs). The rationale for this indicator is that open access fisheries tend almost inevitably to promote excess capacity; limited access fisheries usually do the same but not as severely, and rights-based fisheries tend over time to eliminate excess capacity.

Clearly defined and enforceable property rights for fish-in-the-sea, for all practical purposes, do not exist in open access fisheries. Whenever rents exist in the fishery, new fishing firms enter the fishery causing a race for fish or derby fishery that results in excess capacity and overfishing. Limited access fisheries prevent new entrants, but allow the permit holders to behave as if they remain in an open access fishery. The derby fishery continues to develop as overinvestment in capital (capital stuffing)

occurs if profits or more accurately resource rents develop in the fishery leading to excess capacity. Where limited entry is imposed on a fishery that already has excess capacity, a market incentive does not exist for fishermen to disinvest in capital to harvest fish and the excess capacity remains in the fishery. Where permits are transferable, the rate of investment in capital is slowed, but continues to augment excess capacity over time. A rights-based management program has been demonstrated to reduce excess capacity in fisheries around the world by creating a market incentive for fishermen to reduce their fishing capacity. Open access and limited access (to a lesser degree) management programs could be considered sufficient conditions for a determination of excess capacity in a fishery while a rights-based management program could be considered a necessary condition for no excess capacity in a fishery.

### 3. Harvest - TAC Relationship

A total catch level is usually estimated for each managed fishery; e.g., a TAC. The target capacity for a fishery would be that necessary to harvest the TAC over the course of the normal fishing season. Excess capacity may exist if the TAC is exceeded in the fishery on a regular basis. A simple ratio (harvest/TAC) or the percent difference ( $(\text{harvest}-\text{TAC})/\text{TAC}$ ) between the harvest level and the total allowable catch could be used as an indicator of excess capacity in a fishery. This is not a perfect measure since effective enforcement and the monitoring of harvest levels could close the fishery before the TAC is exceeded. In addition, it does not account for multi-species fisheries. However, if the harvest to TAC ratio exceeds one, excess capacity could exist in the fishery, and this indicator could be considered a sufficient condition for a determination of excess capacity in a fishery.

### 4. TAC/Season Length

Another indicator of excess capacity is a derby fishery, a symptom of which is a declining fishing season when the total catch level is constrained by a TAC. The total catch level divided by the days the fishery is open could be an indicator of excess capacity. For example, the larger the ratio of the annual quota to the length of the fishing season, the more likely that the fishery in question suffers from overcapacity. This is not a perfect indicator of excess capacity for the same reasons as the harvest to TAC relationship, but it could be considered a sufficient condition for a determination of excess capacity in a fishery.

### 5. Latent Permits

The percent of active permits to total permits is an indicator of latent capacity in a fishery. Under limited access management with or without permit transferability, a large number of inactive permits would indicate the potential for excess capacity to develop in response to the creation of rents in the fishery as the stock recovers from an overfished condition. As this percentage declines, the likelihood of excess capacity developing in the fishery increases and could be considered a sufficient condition for a determination of excess capacity in a fishery. This is not a perfect measure since speculators who never intend to harvest fish may hold a permit or fishery managers may decide to purchase or cancel inactive permits. Speculators are hoping to benefit by selling or leasing the permit if they are made transferable.

### 6. Catch Per Unit of Effort

Declining catch per unit of effort (CPUE) are highly suggestive of overfishing, and resource overuse, thus overcapacity. However, fluctuating TACs under, for example, a constant fishing mortality management strategy could mask this effect. The CPUE could remain constant or improve even with excess capacity in the fishery as the TAC increases with the recovery of the stock. A declining trend in CPUEs over time could be considered a sufficient condition for a determination of excess capacity in a fishery where total catch levels are constant.

## Capacity Assessment

Once quantitative or qualitative indicators of capacity have been estimated and other relevant information has been assembled such as the regulatory history of the fishery, an assessment can be made to determine how each fishery should be categorized based on the consensus of a group of experts. The suggested minimally-acceptable procedure for developing a consensus on categorizing fisheries is to form regional teams of experts (Ward et al., 2000). These teams would consist of NMFS fisheries economists, academic economists, industry participants, biologists, marine policy analysts, and others who are familiar with the regional fisheries to be evaluated. Each team should consist of at least three experts, one of whom acts as a coordinator or facilitator. All relevant information about the fishery would be compiled and discussed by the experts. Such information would include the numerical estimates of capacity in each fishery and indirect indicators of excess capacity, as well as information on the dynamics of the fishery, adjacent and alternative fisheries, existence of latent effort, and the structure of the fishing fleet, including vessel types and sizes and gear types and sizes. The experts

would then independently make their own estimates, in writing, of the extent or severity of the level of excess capacity. Individual estimates or evaluations would be compared and the reasons for any substantive differences would be identified by the facilitator for subsequent group discussion. The process would continue until a consensus is reached.

Collective evaluation of the qualitative indicators will present certain practical problems. While boundaries and ranges can be established, the degree of excess capacity cannot be determined using solely the qualitative measures. For example, if the necessary and all sufficient conditions are met in a particular fishery, a determination of substantial excess capacity can be made. If the necessary and three of the sufficient conditions are met or if the necessary condition is not met and all of the sufficient conditions are met in a particular fishery, a determination of moderate excess capacity can be made. If neither the necessary condition nor any of the sufficient conditions are met in a particular fishery, a determination of no excess capacity can be made. It is important to remember that these qualitative rankings will depend most fundamentally upon the capacity experts in each region who are familiar with each managed fishery.<sup>2</sup>

What constitutes no appreciable, moderate, and substantial levels of capacity in each fishery may differ for each fishery depending on many factors. For example, the acceptable level of capacity in highly variable resources, such as shrimp, would be higher than in more stable, longer lived resources, such as cod. Multispecies fisheries may have different thresholds than single species fisheries. Fisheries with both recreational and commercial components have different objectives for each user group and need to be evaluated differently than fisheries which have only one type of user group. Recreational capacity measures need to be developed based on the welfare theory.

### Conclusions

Excess capacity is a serious national and international issue that coexists with overfishing that results in a reduction in the net benefits derived from fishery resources. Excess capacity and overfishing are both symptoms of a fundamental market failure that needs to be corrected by the fishery management system. Regulations designed to reduce or control capacity that ignore the lack of property rights for fish in the sea will likely fail as uncontrolled input use expands. The failure to correct this externality

will ensure that fishery managers will revisit the same problem repeatedly.

Necessary for dealing with excess capacity is a clear definition of capacity. While economic based definitions are preferable, technical definitions can be used where data is sparse. Quantitative and qualitative measures can be developed to access capacity levels in fisheries. The quantitative estimates are preferred. DEA, SPF, and peak to peak methods of capacity measurement provide both the magnitude and direction of change as a result of proposed or implemented capacity reduction regulations.

However, it has been argued that measures of capacity are not needed. If the proper market incentives are created, fleets will adjust toward the correct level of capacity automatically (Holland, 1999). While this is true, fishery managers hold different opinions as to the true cause of excess capacity and, as a result, offer different solutions to solve this problem. For example, a GAO (2000) report questions the capacity reduction efficacy of vessel buyback programs, while the Military Construction Appropriations Act (HR4425) allocates \$10.0 million to the Northeast multispecies fishery to be used to support a voluntary fishing capacity reduction program that permanently revokes multispecies, limited access fishing permits so as to obtain the maximum sustained reduction in fishing capacity at the least cost and in the minimum period of time and to prevent the replacement of fishing capacity removed by the program. It is because these different approaches to deal with the excess capacity problem exist that a capacity metric is needed.

Clearly defined and enforceable property rights cannot and probably should not be established in publically owned natural resources like fisheries. However, regulations designed to cause user groups to behave as if these property rights existed will have different impacts on capacity levels depending on the strength or weakness of these pseudo-property rights. A quantitative metric based on an economic definition of capacity is a tool with which fishery managers can determine the relative merits of various proposed capacity reducing regulations. These capacity measures are needed to comply with international agreements, to effectively conserve and manage our fisheries, to promote the competitiveness of the United States fishing industry, to aid in the development of sustainable fisheries and fishing communities, and, most importantly, to be employed as a metric by which we can determine if our capacity reduction objectives are being achieved through our management regulations.

However, many problems remain to be solved before capacity levels can be estimated for domestic fisheries.

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<sup>2</sup>Obviously, NMFS will not be able to develop all six indicators for each federally managed fishery.

How to treat recreational capacity levels is of particular concern since quantitative measures do not necessarily reflect the satisfaction or utility maximizing behavior of recreational fishers. Capacity measurement techniques for multispecies commercial fisheries need to be developed along lines similar to that of multiple output industries. Fundamental questions remain concerning differences between DEA and SPF estimation techniques and both these quantitative measures have shortcomings.

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**Table 1. Louisiana Crab Fishery Permits**

Year	crab permits
1980	885
1981	891
1982	975
1983	826
1984	1019
1985	1030
1986*	916
1987	1231
1988	1343
1989	1892
1990	2303
1991	3020
1992	2711

\*Oil crisis ends.

Keithly, Walter, personal communication.

**Endnotes**

1. Factor inputs in the production process include labor, capital, fuel, ice, bait, electronic equipment, fishing gear, etc.

2. These effects may include (i) decreased economic performance from increased costs of owning and operating vessels in a fishery and decreased product quality and prices, (ii) possible increases in enforcement costs and/or diminished effectiveness of enforcement, (iii) increased costs to develop and implement management actions to address allocation conflicts; (iv) increased in-season management; (v) more intrusive regulations; (vi) a less stable regulatory environment; (vii) increased conflict on fishing grounds; (viii) decreased fishing safety; (ix) increased cost of owning and operating fishing vessels; (x) decreased stability of the industry and dependent communities; (xi) decreased access to the fishery for certain groups; (xii) decreased season length; (xiii) increased processing and product storage costs; and (xiv) decreased product quality and prices. In addition, the problems associated with excess capacity may extend well beyond those related directly to economic efficiency. Although in theory excess capacity need have no implication whatsoever for resource conservation provided that a TAC or similar constraint is set and enforced appropriately, in reality excess capacity can seriously compromise fisheries management and enforcement as well as the financial viability of the commercial and recreational fishing fleets. Thus, excess capacity may also exacerbate the following problems: (xv) challenges to the validity of the science, including litigation; (xvi) pressure on managers to choose TACs from the upper range of confidence intervals; (xvii) higher discard rates; (xviii) higher mortality of discards due to lack of time available for careful handling of discards; (xix) higher cryptic mortality from encounters with unnecessarily large amounts of fishing gear; (xx) greater amounts of ghost fishing from lost or abandoned fishing gear; (xxi) reduction in the quality of mandatory catch, effort and earnings data submitted by fishers, due to lack of time for careful recording; (xxii) increased probability of exceeding the quota or target fishing mortality as a result of the preceding items; i.e. actual removals including reported landings, unreported landings, at-sea discards, cryptic mortality from encounters with fishing gear, and ghost fishing that may greatly exceed the catch level needed to achieve conservation; (xxiii) decreased probability of correctly specifying the TAC as a result of errors in inputs.

3. Article 6.3

4. In Article 7.6.3.

5. NOAA's BSF planners have indicated that the term "overcapitalized fisheries" may be interpreted to mean "fisheries in which there is excess capacity."

6. The economic definitions of capacity are usually measured by employing a cost or profit function. These functions are developed empirically by estimating a relationship between costs or profits and variables that affect the levels of these functions. For example, the estimation of a cost function requires data on the level of output (catch) and input prices for each vessel during each decision making time period (e.g., a trip). Once a cost function is estimated it can be used to derive an economic definition of capacity. These functions are estimated by using well-established and standard econometric methods. An added advantage of this approach to estimating capacity is that it accommodates multiple outputs and random variation in the data.

7. Estimation of the technical definition of capacity is less data intensive since no economic information is required. Currently, information exists on most US fisheries that will allow for the estimation of a technical capacity measure. However, none of the currently available or widely used methods of estimating technical capacity measures it in a strict sense. Most of the methods rely on adding a further requirement to the definition: that all the firms are technically efficient. This leads to an upward bias relative to the definition stated in the report. It is not possible to theoretically determine the net effect of this biases. It will depend on the characteristics of the fishery, the type and quality of data used, and the particular approach employed. The resulting estimates must therefore be treated with some caution.

8. Mathematical programming, which includes linear programming, is the optimization of an objective function given a series of constraints.

9. Since outputs and inputs are expanded in fixed proportions, the model assumes and imposes Leontief separability, but does not test for it.

10. Technical efficiency occurs when the maximum level of output is produced with the inputs (e.g., capital and labor) available to the firm. Allocative efficiency in input selection involves selecting that mix of inputs that produce a given quantity of output at minimum cost given the input prices that prevail.

11. This is taken from Kirkley and Squires (1998); and, Coelli, Tim, D.S. Prasada Rao, and George E. Battese (1998) An Introduction to Efficiency and Productivity Analysis. Kluwer Academic Publishers, Boston.

12. Technical efficiency occurs when the maximum level of output is produced with the inputs (e.g., capital and labor) available to the firm. Allocative efficiency in input selection involves selecting that mix of inputs that produce a given quantity of output at minimum cost given the input prices that prevail.