THEORETICAL AND EMPIRICAL CONSIDERATIONS FOR ESTIMATING CAPACITY AND CAPACITY UTILIZATION IN COMMERCIAL FISHERIES

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INTRODUCTION

Capacity and capacity utilization within firms and industries has historically been an important consideration in economics. Their importance and application to fishery problems has increased considerably in recent years. Economic efficiency is often discussed in terms of optimum capacity. Supply responses are predicted on the basis of capacity for given changes in market and fish stock conditions. Comparisons of capacity with available fish stocks are often made for purposes of determining investment potential and required credit sources. Lack of adequate capacity is a major constraint in justifying larger investments for waste disposal or other means of meeting environmental standards. Perhaps the most important area being addressed today where capacity considerations are of importance is the development of fishery management plans for the U.S. fishery conservation zone.

The Fishery Conservation and Management Act of 1976 (hereafter referred to as FCMA) requires plans proposed by Fishery Management Councils to "assess and specify the capacity and the extent to which fishing vessels of the United States on an annual basis will harvest the optimum yield..." [U.S. Congress, p. 38]. This assessment and specification is important in determining appropriate management regulations which may be imposed on

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domestic fisheries and in determining the allowable level of foreign catch. The purpose of this paper is to address the question of capacity with particular reference to the development of fishery management plans. The discussion is divided into three parts. First, the theoretical construct of capacity will be examined. The second part is a discussion of methodological problems in empirical measurement. The final section contains a review of measures of capacity used in a sample of fishery management plans. The discussion is limited to questions of capacity in commercial fisheries. Recreational capacity is not discussed in the paper.

Theoretical and Conceptual Considerations

The state of economic science with respect to capacity considerations has been summarized by George Stigler as follows:

> The notion of capacity is widely used, but seldom defined precisely. Yet it is an ambiguous concept even at best, [Stigler, p. 156].

In fishery or marine economics the question of capacity is generally addressed in terms of a bioeconomic or equilibrium-yield framework. Here in its simplest form, catch or landings are related through an industry or aggregate production relationship to units of effort. The data base is a time series of production and effort variables and often some adjustment variables are included for stock or related biological and environmental conditions. This physical relationship is examined along with prices and costs to determine maximum economic yield and the most efficient or profitable level of effort. Optimum capacity is then determined and implications with respect to over or under capacity are

made.

The more general body of economic theory approaches the question of capacity from the viewpoint of the individual firm. The most frequent definition of economic capacity in the short-run refers to the output level indicated by the minimum cost position on the short-run average total cost curve. This definition, as such, is a value concept to be distinguished from optimum physical capacity which occurs at the point of absolute diminishing returns.

In the long-run, optimum economic capacity generally refers to the scale of plant at which minimum long-run average cost equals minimum short-run average cost. An alternative long-run economic capacity position is defined to be the level of output where short-run and long-run marginal cost are equal and the short-run average cost curve is tangent to the long-run average cost curve at a scale of plant where average cost is above the minimum. Of course, for this to be a competitive equilibrium, entry into the industry must be restricted. Otherwise, entry of new firms will theoretically drive prices down such that the former definition of long-run optimum capacity will prevail.

Output capacity defined for the individual firm level may be aggregated to determine total industry capacity. Such an aggregation, however, gives a measure of capacity at one horizontal level in the total system. The definition or concept needs to be further expanded for two reasons. First, market price obviously affects long-run industry capacity in terms of investments in plant and equipment and prices also affect the level of output or utilization of existing physical capacity in the short-run. Second, capacity limitations at one level in the vertical structure of the system will limit volumes throughout the remaining levels. The question

of capacity and capacity utilization must then be addressed in the context of the total system.

Investments in vessels, gear and other determinants of capacity in the harvesting sector and the extent of capacity utilization are a function of expected catch per unit of effort, input prices, and dockside prices. The first two variables affect average cost and thus the level of capacity and capacity utilization. Currently, an important input price likely to affect U.S. fisheries is the price of energy. Alternative engine sizes and types and alternative power sources, such as sail, will likely require modifications of vessel size and construction. This will likely affect the capacity of the fleet. Catch per unit of effort is a function of both units of effort and stock levels to which effort is applied. Thus, stock levels should be considered as determinants of economic capacity. They in part determine catch per unit of effort and thus determine average cost per unit of output which is used as the basis for determining economic capacity.

Dockside or ex-vessel prices directly affect the rate of capacity utilization in the short-run and the level of capacity in the long-run. In fact, prices may be used in an alternative definition of economic capacity. In the short-run, optimum economic capacity may refer to the level of output where price equals marginal costs and profits are maximized. In addition, dockside prices relate the harvesting sector to the processing and marketing sectors. Demand for raw fishery products from fishermen is a derived demand. Fishery products from the harvesting sector are considered as inputs into the "production" process of the processing and marketing sectors. Demand for fishermen's product is thus a function of prices of other inputs, substitutability of inputs in production and

consumer or retail market prices. There is relatively little substitution of inputs for raw fishery products except for products where specific species are not identified, such as the market for fish sticks. In this case, supply and demand for substitute species affects prices for the species being considered. The question of the effect of imports on domestic ex-vessel prices is of importance in this respect because imports may compete in the market system directly with specific species or indirectly in the unidentifiable species product market.

Retail price flexibilities or elasticities reflect the capacity of the market to absorb various quantities of fishery products. These prices also affect optimum capacity and rate of capacity utilization in the processing and marketing sectors. In addition, profitability of processing alternative products limits the processors ability to process or handle lower valued products from other fisheries. In cases where there is an absolute physical limit in the processing sector due to plant, equipment and other inputs such as qualified labor, quotas may be put on the harvesting sector or effectively, ex-vessel prices are reduced to zero.

In summary, the theoretical components which determine capacity and the extent of capacity utilization are the factors affecting individual firm cost structures such as input prices and catch per unit of effort, price levels throughout the market system, prices and quantities of substitutable products and input constraints. This total or systems approach to capacity and its utilization is not inconsistent with empirical measures of capacity employed by economists interested in questions of capacity of total segments within the economy or the total economy. For example, full capacity has been defined as the "full" input point on an aggregate production function or as a bottleneck point in a general

equilibrium system [Klein]. Preoccupation with measures for individual industries or production or market levels within a system, considered separately from others at the same time, may overstate the capacity of the system as a whole. Furthermore, consideration of capacity and its utilization is consistent with the requirement of the FCMA which requires both specification and assessment of capacity and its utilization throughout the total system.

Methodological and Measurement Problems in Assessing Capacity and Capacity Utilization

Empirical estimates of capacity and its utilization are extremely difficult to make for any industry because of insufficient basic research, required data and consistent reporting procedures. These basic needs also affect estimates of capacity for fisheries. Rather than review the general problem areas, the following discussion will be limited mainly to a brief review of problems somewhat specific or limited to analysis of economic capacity in U.S. fisheries.

In estimating optimum capacity and capacity utilization in fisheries the economist operates under one additional constraint compared to many other areas of applied economics. The fisherman, in most cases, is harvesting from a relatively fixed pool of resources which are common property. Cultivation of fishery products is presently rather limited. As a point of contrast, agriculture has been able to reduce this fixed resource constraint through development of improved seed varieties, augmentation of the soil's natural nutrient content, etc. Stock limitations in the natural environment place limits on fishery production. Thus, appropriately biological variables must be included in estimation

procedures. These are recognized in the bioeconomic or equilibrium-yield models. Unfortunately, empirical estimates of biological parameters are nearly as scarce as estimates of economic parameters.

The fact that many fisheries are defined by type of gear rather than specific species make multiple-species fisheries a common characteristic of many U.S. fisheries. What may be optimum capacity for one species may be over or under capacity for other species. Two examples are the Tropical Pacific tuna fishery and the Gulf of Mexico reef fish fishery. In the tuna fishery, the yellowfin tuna is fully exploited but the skipjack tuna which is caught jointly with the yellowfin is fished at less than optimal capacity [Flagg]. In the Gulf of Mexico, preliminary estimates show the red snapper to be fully exploited but the jointly caught grouper to be fished at less than optimum capacity. In these cases, optimum capacity to fish one species will be excess capacity for the other jointly caught species. Recently a linear programming approach has been offered as a means for predicting fleet capacity for a multiple-species fishery [Siegel].

A similar capacity estimation problem occurs when the same fleet fishes several species, not concurrently, but at different times or seasons of the year. An example is provided by the same fleet fishing for stone crab, spiny lobster and king mackerel in Florida during different seasons of the year. Optimum capacity in terms of vessel size may be different for each specific species. When the fleet is participating in the lobster fishery there may be excess capacity in terms of an economically efficient size of vessel and/or total fleet but optimum capacity when fishing for king mackerel.

The seasonal nature of production raises other problems related to capacity in the processing and marketing sectors. Storage, processing

and on shore holding capacity may limit or prevent the harvesting sector from fully utilizing its capacity during peak production seasons. Placing limits on volume of catch is not uncommon in U.S. fisheries during peak production seasons for a given species or during the peak season for another more valuable species processed in the same plant. In spite of the seasonal capacity constraints during seasonal peaks there is considerable over-capacity in the U.S. seafood processing industry. Using a trend through peaks of quarterly production data shows some processing industry segments operating at between 50 to 80 percent of annual capacity [Vondruska]. Studies of the shrimp processing industry conclude the industry is operating at considerably less than full capacity in spite of substantial imports of foreign caught shrimp for processing [Prochaska]. Thus, the question of capacity in the processing sector is important. In some cases, under-capacity during peak production seasons limits the harvesting sector but during other seasons or for other seafood processors there appears to be considerable over capacity. Related problems arise in the processing of species where year-to-year production cycles exist. During the "off years" excess capacity exists but profits earned from being able to handle the good years may more than offset the apparent inefficiencies in the "off years."

Currently the question of joint ventures is of particular concern. The Secretary of Commerce may issue permits allowing foreign vessels to receive U.S. harvested fish from vessels within the U.S. fishery conservation zone. The applications and activities must meet the requirements of the FCMA [Federal Register]. This alternative is capable of relieving processing capacity constraints in some cases but could also lead to still more excess capacity in other cases. A careful evaluation of each application

will be required.

Economies of scale in management, advertising, physical efficiency, warehousing and storage, transportation, state and local taxation, financing and other areas in addition to volumes produced by fishermen must be considered to fully analyze and evaluate the question of capacity in the processing industry. Because of these factors affecting economies of scale and capacity, there probably is no one optimum size plant. This of course, is a common phenomenon in many industries [Stigler]. Recent research has shown two sizes of shrimp processing firms to be of optimum size [Alvarez]. Thus in assessing and specifying capacity in U.S. fisheries the simple approach of projecting total capacity as a product of number of firms and the output of the "average" or optimum firm may not be appropriate.

Estimates of capacity and capacity utilization will be particularly troublesome for fishery management plans for presently under-utilized species. Difficulties in estimation may occur in the three areas of harvesting, processing and marketing. To harvest these potential marketable species new types of vessels and gear may be required. Estimates of needed vessel and gear capacity to harvest an optimum yield may be almost speculative. Markets, prices, and types of products will probably not be fully known. Without this information, the number of processing plants and their capacity will be difficult to estimate. Considerable research and experimentation will be required before acceptable estimates of capacity and capacity utilization are forthcoming for these undeveloped fisheries.

Capacity Estimates in the Initial Fishery Management Plans

The conceptual and methodological issues discussed above make it apparent that the job of estimating capacity and its utilization by the industry and support personnel will be difficult. Nevertheless, the FCMA requires these questions be addressed based on the best available scientific information. Past basic research concerning capacity at the processing level has been extremely limited. The question of optimum capacity in the harvesting sector has been often theoretically addressed and empirically to a lesser extent. Much of the basic research performed prior to the 1976 FCMA has had little or no direct impact on the limited number of management plans developed at the time of the writing of this paper. This is probably so for several reasons. Species or multiple species studied may not correspond directly to management units chosen by the respective councils. The geographic area covered by the study may not coincide with areas allocated as specific management areas. Rather than review this basic research, the remainder of this paper is devoted to a review of capacity estimates in a sample of fishery management plans developed in the first year of Council activities.

Hold capacity appears to be the most frequent basic measure of vessel capacity used. Estimates of hold capacity in the industry are made from either a survey of participating vessels, registration and documentation information or a combination of the two. Adjustments are made (usually assumed) for percent of hold capacity actually used or filled on any one trip. This adjusted average trip capacity is then multiplied by number of trips made per year. Once these components are estimated it is a simple matter to project total physical capacity and expected use of capacity.

Other plans simply project capacity (volume produced) based on historic trends or catch per unit of effort models where effort is measured as number of fishermen, gear units, or some other input measure. These estimates do not specifically address the question of optimum economic capacity. They are based on present or historic levels of capacity which may be assumed to be optimum if the system was in a competitive equilibrium. This optimum capacity situation is highly unlikely because of the rarity of an equilibrium situation and also because of the lack of private property rights in fisheries.

Several of the preliminary plans have gone beyond estimating capacity exclusively in the harvesting sector and have considered some of the suggestions offered in this paper. In the Northwest Atlantic Herring Fishery Plan, specific account was taken to relate capacity to expected favorable dockside prices. Favorable prices were based on expected high import prices and the entry of new processors into the industry due to expected favorable export markets. Also considered in their estimates was added harvesting capacity which was projected to come from related fisheries where effort will be limited through fishery management plans.

The Gulf of Alaska Ground Fish Plans specifically considers capacity in terms of "total capacity." Total capacity was defined to be the sum of harvesting, handling, freezing and holding capacity. Harvesting capacity was estimated using hold capacity as a base with adjustments similar to those discussed above. Capacity estimated at the other levels in the system were based on interviews. Daily rates were estimated with specific consideration of seasonal variation in production by the harvesting sector. Also considered were capacity limitations due to processors desiring to process more valuable species during particular seasons of the

year. Shoreside holding capacity appeared to be the most limiting factor in terms of physical capacity while a lack of an adequate supply of labor was a constraint on capacity in some levels of the processing industry.

In addition to physical hold capacity, abundance and availability of fish were considered as specific determinants of capacity in the Northern Anchovy Fishery Plan. Processing capacity was concluded to be the limiting factor preventing full utilization of harvesting capacity in this fishery. A dual approach was taken in determining processing capacity. "Nominal" capacity was based on engineering and design characteristics of a plant. The second estimate was based on the "performance of the plant." This estimate considered business and economic decisions as well as physical conditions of the plant. The latter approach provided the lower, but the more realistic estimate of processing capacity. During the peak harvesting season nightly quotas were placed on the fleet.

Other management plans available for review were considerably less sophisticated in approach to the estimate of capacity. This was often due to a lack of information. For example, the Caribbean Spiny Lobster Plan simply noted the market did not appear to be a limiting factor beacuse of sizeable imports of spiny lobsters and a local preference for non-processed lobster products. Harvesting capacity was based on catch per unit of effort and projected number of effective units of effort.

Summary and Conclusions

Capacity and capacity utilization are required considerations for determining expected domestic annual harvest by U.S. fishermen and level of allowable foreign catch. Conceptually, the broad systems approach to

defining capacity and its utilization seems theoretically appropriate and is consistent with requirements of the FCMA. Capacity and the level of capacity utilization depend on input prices, physical productivity, and activities and constraints in the market and processing sectors which are transmitted to the harvesting sector through the pricing system. Methodologically and empirically there are many obstacles to complete answering of the required questions of capacity. Some of the most important problems in estimation are related to a lack of basic research and data, complexities of multiple species fisheries, seasonality of production and unknowns in the production, processing and marketing of under-utilized species. Some of the presently proposed plans do a commendable job of addressing many of these suggested considerations. Although it may always be impossible to completely address the question of capacity and capacity utilization, these conceptual considerations are of importance for suggestion of data and research needs which are a specific requirement of fishery management plans. Refinements in data collection and additional basic research will allow future and revised plans to more completely estimate capacity and its utilization.

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