A Limited Economic Assessment of the Northeast Groundfish Fishery Buyout Program

John B. Walden, James E. Kirkley, and Andrew W. Kitts

ABSTRACT. *The United States and various European Union nations have used vessel buyout programs to reduce harvesting capacity in fisheries. In this paper, we present an analysis of the U.S. Northeast groundfish vessel buyout program. Using data envelopment analysis (DEA), we calculate capacity for both the fleet and for the vessels removed through the buyout program. Our analysis suggests that if capacity measures had been used to select vessels, both more capacity and more vessels could have been purchased with the funds allocated to the buyout program. We conclude with a discussion of alternative ways to reduce capacity in fisheries.* (JEL Q22)

I. INTRODUCTION

The levels of capacity and excess capacity are important issues for fisheries management. The United Nations Food and Agriculture Organization's (FAO) Code of Conduct for Responsible Fisheries, which was adopted in 1995, called on nations to reduce capacity to levels more aligned with available resources (Kirkley and Squires 1999). In the United States, the Sustainable Fisheries Act (SFA) required the Secretary of Commerce[1] to form a task force to study the role of the federal government in ''subsidizing the expansion and contraction of fishing capacity in fishing fleets under the Magnuson Fishery Conservation and Management Act'' (National Marine Fisheries Service 1999). These actions focused considerable attention, both domestically and internationally, on measuring fishing fleet capacity, and determining ways to reduce capacity.

The term—capacity—has been widely used and examined by the FAO and the National Marine Fisheries Service (NMFS). The Sustainable Fisheries Act and the FAO's Code of Conduct for Responsible Fisheries provide extensive discussion about capacity. Yet, the basic tenet of capacity is difficult to define. In very simple terms, capacity represents the productive potential of a firm or industry. More formally, capacity represents the productive potential of utilizing the available input stocks. The measure of capacity is typically in terms of the maximal, optimal, or potential output producible from the stocks.

It is important to stress that the mere presence of a particular capacity level for a given fishing fleet does not automatically mean that over-fishing will occur; rather it is the failure to restrict harvests to appropriate levels that leads to over-fishing. In fisheries where regulations have prevented over-fishing, there has been a tendency to have economic waste in the form of excess productive capacity and higher than necessary production costs (i.e., more productive capacity and utilization of the variable factors of production than are necessary) (Food and Agriculture Organization 2000). For fisheries that are overfished, reducing harvests without subsequent reductions in industry capacity, leads to a fleet with a very low capacity utilization rate. In either situation, aligning industry capacity with appropriate removal rates should yield both biologically sound fish stocks, and improved industry earnings, provided all other

John Walden and Andrew Kitts are economists with the National Marine Fisheries Service, Woods Hole, Mass. James Kirkley is professor, Department of Ocean and Coastal Policy, School of Marine Science, College of William and Mary, Gloucester Point, Va. The authors would like to acknowledge the helpful comments of Phil Logan, Fred Serchuk, Steve Edwards, Terry Smith, Jeff Stier, and two anonymous reviewers. The views expressed do not represent those of the National Marine Fisheries Service.

[1] The National Marine Fisheries Service that is responsible for management of U.S. marine fisheries is part of the Department of Commerce, making the Secretary of Commerce ultimately responsible for fisheries management decisions.

Land Economics • August 2003 • 79 (3): 426–439
ISSN 0023-7939; E-ISSN 1543-8325

inputs are strictly controlled. However, there is little or no institutional structure to allow fishing capacity to be aligned with resource levels. One approach, which has been increasingly utilized on a worldwide basis to reduce fishing capacity, is the buyout or buyback program. With the buyback program, either the government directly purchases vessels using public funds or provides low-interest loans to industry for the purchase of decommissioning vessels.

A comprehensive study of several buyout programs used by different nations concluded that buyout programs generally result in targeted welfare or income redistribution (Gates, Holland, and Gudmundsson 1996). Gates, Holland, and Gudmundsson (1996) suggests that there are three general goals of buyout programs: 1) conservation of fish stocks; 2) improvement in economic efficiency; and 3) enabling transfer payments to the fishing industry. Additionally, they point out that most vessel or license buyout programs originate in response to a crisis, and that conservation gains are often overwhelmed by input stuffing and input substitution.

The U.S. Government Accounting Office (GAO) recently completed a study that evaluated the long-term effectiveness of three buyout programs in the United States (GAO 2000). A major objective of the GAO study was to evaluate ''the extent to which buyout programs have affected fishing capacity.'' The GAO studied vessel buyouts in the Northeast groundfish fishery, the Bering Sea groundfish fishery, and the Washington State salmon fishery. Between 1995 and 2000, the United States expended approximately $130 million (U.S.) to reduce capacity in the three fisheries. The Northeast and Bering Sea[2] capacity reduction programs removed vessels, while the Washington State salmon fishery buyout program removed permits.

The buyout programs were designed with multiple goals such as reducing the capacity to harvest fish; providing economic assistance to fishers; and improving the conservation of fish (GAO 2000). The GAO criticized the Bering Sea and Washington State buyout programs because NMFS didn't evaluated the programs or measure the capacity removed by the buyouts. The Northeast program was criticized because it allowed fishermen who were bought out to re-enter the fishery through the purchase of other vessels, primarily those that were inactive, and there were no measures in place to prevent inactive vessels from increasing their effort, thereby eroding conservation benefits. In all three cases, however, the potential conservation benefits of the buyout were not explicitly estimated before the programs were implemented.

In this paper, we present a limited assessment of the Northeast groundfish buyout program. We initially present several definitions of capacity and provide an overview of the Northeast buyout program. We then introduce data envelopment analysis (DEA), and the Färe, Grosskopf, and Kokkelenberg (FKG) (1989) approach for estimating Johansen's concept of capacity. Next, we illustrate the use of DEA to estimate capacity of the groundfish fleet. We then offer a discussion about the amount of capacity believed to have been reduced with the buyout program versus the amount of capacity that might have been reduced if NMFS had *a priori* estimates of capacity.

We conclude that had NMFS initially estimated capacity and developed the capacity reduction program based on the empirical estimates of capacity, the agency may have been able to reduce slightly more capacity from the fishery than was reduced under the program. We also conclude that, even though the buyout program reduced the level of capacity in the fleet, the level of capacity actually reduced was inadequate relative to stated conservation goals. In all appearances, the buyout program was little more than a transfer payment program, which would be the predicted outcome of Gates, Holland, and Gudmundsson (1996) and Holland, Gudmundsson, and Gates (1999). The remaining fleet had substantial capability to expand days at sea beyond the level believed to be

[2] The American fisheries Act required NMFS to purchase 9 of 30 factory trawlers and their associated permits in the fishery. The buyout cost was $90.2 million with 15.2 million from federally appropriated funds and the remaining $75 million from a federal loan to Alaska pollock fishermen (GAO 2000).

consistent with sustainable resource exploitation. We further argue that future buyout programs should address latent effort, reentry into the fishery, and entry into other fisheries. Moreover, other management and regulatory measures will likely need to be imposed on fisheries even if capacity has been reduced; that is, a buyout program that matches capacity to resource levels, but without additional restrictions on fishing, will not prevent capital stuffing, and subsequently, again allow for excess capacity. Last, we offer that even though the level of capacity reduction that would have been achieved using a capacity based model are approximately equal to the level actually reduced by the Northeast buyout program, having estimates of capacity helps ensure a more cost-effective capacity reduction program by focusing on maximum capacity reduction per given level of expenditure.

II. CAPACITY CONCEPTS

At the time the various buyout programs were designed and implemented, no formal definition of capacity had been adopted by NMFS, and no methods had been developed to estimate fishing capacity. Numerous theoretical definitions were available, but few could be made operational for the purpose of implementing capacity reduction programs in fisheries. The GAO criticized NMFS because the agency had not developed an operational definition of capacity; had not estimated capacity removed in two out of three buyout programs; and had not developed better methods to estimate fishing capacity. This led to the creation of a NMFS task force, which adopted four definitions of capacity consistent with the existing methodologies for estimating capacity (National Marine Fisheries Service 2001a).

NMFS adopted the following four definitions of capacity: 1) technical or primal; 2) economic; 3) modified economic; and 4) the weaker variant concept of Johansen (1968) proposed by Färe (1984). Definitions one, technical, and four, Färe, are both primal-based concepts and have often been referred to as "technical-engineering" concepts. They focus on output levels and do not directly consider economic decision-making by the firm. On a broader scale, and when considered relative to empirical information, we may actually term concepts one and four to be "technological-economic" concepts. Albeit they are not directly determined from economic optimizing behavior, the economic constraints and decisions are implicitly embedded in the observed data. Definitions two and three define capacity in terms of the economic optimum relative to cost minimization or some other economic objective of the firm (e.g., profit maximization).

The concept of technical capacity is "the level of output of fish over a period of time (year, season) that a given fishing fleet could 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." Although this definition is not an economic concept of capacity, it does provide a notion of capacity that can be empirically estimated, and one that is partially indicative of economic optimization since data likely reflect economic constraints and decision-making behavior. It also provides a concept consistent with the definition of capacity used by the Federal Reserve, which is the output attainable under customary and usual operating procedures.

The second proposed definition was economic capacity, which is based on cost minimizing behavior by the firm. That is "the 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."

The third proposed definition was a modified economic capacity measure, which allows for satisfying firm level objectives such as revenue or profit maximization. That is the "level of output of fish caught over a period of time (year, season) where firm level objectives are maximized for a given fleet size and composition, resource condition, market condition, state of technology, and other relevant constraints."

The fourth definition adopted by NMFS, was also a technical definition, but based on a modification of the short-run capacity concept of Johansen (1968) and offered by Färe (1984). Johansen (1968, 52) defined capacity as ''the maximum output that can be produced given the availability of the variable factors is not limiting.'' Under the Färe (1984) concept, which is a weak variant of Johansen, maximum output occurs when a fixed factor binds or limits production, but the variable factors do not limit production. This is similar to the first technical definition, but allows for greater use of variable inputs than the ''normal operating conditions'' found in the former.

Most capacity studies found in the economics literature focus on the economic concept of capacity (e.g., Berndt and Fuss 1989; Berndt and Morrison 1981; Morrison 1985a, 1985b), which is the level of output consistent with the underlying behavioral objective of the firm (e.g., the level of output that maximizes profit, output, revenue, or minimizes cost). An economic concept of capacity, which reflects cost minimizing behavior, is preferred because it explicitly reflects decision-making behavior in response to changes in economic conditions. For fisheries, however, cost data necessary for determining the short and long-run average costs are seldom available. The National Marine Fisheries Service (NMFS), therefore, emphasized the ''technological-economic'' concept of capacity, which could typically be estimated given that NMFS maintains data on input and output quantities for many fisheries. Because NMFS has national and international obligations to produce capacity estimates for U.S. fisheries, it cannot wait until the necessary cost data are collected to make preliminary capacity determinations.

A review of various buyout programs used throughout the world to reduce capacity found that most buyout programs focused on the capital stock in the fishery, and capacity was usually estimated in terms of the historical landings of a vessel, some combination of vessel physical attributes, or a simple count of the number of permits attached to a vessel (Holland, Gudmundson, and Gates 1999). These types of capacity measures, however, are extremely limited. They do not permit the determination of the maximum potential output; recognize that capacity is determined by the level of the fixed factors; and they fail to recognize that producers may not produce at maximum capacity because of technical inefficiency.

III. THE NORTHEAST GROUNDFISH BUYOUT PROGRAM

The Northeast groundfish fishery is a large and diverse fishery in the Northwest Atlantic. Species managed as part of this complex include cod, haddock, yellowtail flounder, pollock, witch flounder, American plaice, windowpane flounder, winter flounder, white hake, redfish, red hake, silver hake, and ocean pout. Red hake, silver hake and ocean pout, are considered ''small mesh species'' because they are typically harvested by using a smaller mesh size than the other ten species; the other species are typically referred to as the ''large mesh species.'' The large mesh species are caught by vessels, which either actively fish by dragging a net through the water or passively fish using gillnet or hook gear.

In 1999, landings from the groundfish complex totaled approximately 51,000 metric tons (MT) with a dockside value of approximately $101 million (Northeast Fisheries Science Center 2001). Under Amendments 5 and 7 to the Northeast Multispecies Fishery Management Plan (FMP), fishing activity of groundfish vessels was constrained in order to rebuild cod, haddock, and yellowtail flounder stocks. The present regulatory regime allocates days at sea to each vessel; a vessel has a fixed, nontransferable number of days per year it may fish. Most vessels are allocated 88 days per year, although some have been allocated as many as 164 days per year. Closed areas have been enacted, on both a year round and seasonal basis, to reduce fishing mortality and to protect spawning fish and juvenile fish aggregations. There is also a moratorium on entry of new vessels into the fishery. Vessels are only allowed a 1% upgrade in their physical characteristics based on a combination of gross tons, horsepower, and vessel length. These measures have improved resource conditions of cod, haddock and yellowtail flounder stocks on Georges Bank and in the southern New England fishing areas (Northeast Fisheries Science Center 2001).

The Northeast buyout program was initiated in 1994 to help lessen the economic impacts generated by Amendments 5 and 7 of the Multispecies Plan. A pilot buyout program, designed to test the interest in participating in a buyout, concluded in February 1996 with the purchase of 11 vessels. Based on this pilot program, an additional $23 million was made available for an expanded program, which resulted in the purchase and removal of 68 more vessels (Kitts and Thunberg 1998). Both buyout programs selected vessels[3] based on the ratio of the owner's bid or willingness to sell price to the vessel's average annual groundfish revenue, with revenue being used as a proxy for capacity. Vessels were ranked by this ratio, and the vessels with the lowest ratios were selected until the buyout funds were exhausted. An initial evaluation of the buyout program indicated the vessels that were purchased accounted for 20.3% of the total revenue and 20.1% of the total landings of the 10 large mesh groundfish species (Kitts and Thunberg, 1998).

Further evaluations of the buyout program were done on an annual basis through reports to Congress (National Marine Fisheries Service 2001b). The evaluations consist of making comparisons against an established baseline condition of the pre-buyout fishery in 1996. The immediate results of the buyout program were a 3.8% reduction in the number of permits, a 10% reduction in physical capital, and a 5% reduction in allocated days-at-sea. Subsequent trends show a further decline in the number of vessels and permits due to vessel attrition and changes in regulations. However, the total number of used days-at-sea in 2000 was higher than 1996 levels, even with fewer vessels in the fishery. Additionally, 63% of the allocated days at sea are unused, which could lead to further deterioration of the groundfish stocks.

IV. METHODS AND DATA

Since cost and earnings data necessary for estimating the economic concept of capacity are not available for vessels participating in the northeast groundfish fishery, we adopt the short-run concept of Johansen (1968) and Färe (1984) to estimate capacity. Färe, Grosskopf, and Kokkelenberg (1989) demonstrated how data envelopment analysis or DEA could be used to estimate the Johansen concept of capacity. Data envelopment analysis is a mathematical programming approach originally developed to assess technical efficiency (TE) (Charnes, Cooper, and Rhodes 1978). The notion of TE originally examined by Charnes, Cooper, and Rhodes was the Farrell (1957) concept, which, depending upon an output or input orientation, projects outputs or contracts inputs along a ray from the origin. With the Farrell concept, output or inputs are radially expanded or contracted until the observation is on the production frontier. Coelli (1996) and Russell (1985) offer a DEA-based measure of TE consistent with the concept of Koopmans (1951); under Koopmans concept of TE, the expansion of outputs or the contraction of inputs need not be radial. Both the Coelli and Russell approaches, however, pose problems for zero-valued observations; solutions may not be feasible or obtainable.

Another possible method for estimating capacity is the stochastic production frontier (SPF) approach. The SPF approach, however, has several potential problems. First, unless a stochastic multiple output distance function is specified, the SPF approach can not handle multiple outputs, and many fisheries involve either multiple species or multiple products. Second, the SPF approach does not accommodate zero-valued outputs; zero valued outputs for some species or products may characterize firm-level production in many fisheries. For example, in the Northeast groundfish fishery, some vessels will not catch all ten groundfish species, meaning that the output for one or more species will be zero. Third, the SPF approach may impose omitted variable bias because in the case of more than one fixed factor, it must omit the

[3] Vessels could qualify for the program by demonstrating that 65% of their fishing revenues were derived from landings of the ten large mesh groundfish species in three out of four years between 1991 and 1994.

variable inputs from the statistical specification. Fourth, SPF requires specification of a particular functional form, which may unnecessarily impose structure on the technical interactions.

In this paper, we focus on DEA and the Farrell concept of TE, which estimates TE through the construction of a "best practice" frontier. DEA constructs a best practice frontier as a linear, piece-wise combination of observed maximum outputs given observed inputs. The reference frontier "envelops" data points with linear segments, and the technical efficiency of all observations are calculated relative to the constructed reference frontier. Technical efficiency is thus measured relative to a benchmark level, and represents actual observed achievements in similar operations (Färe, Grosskopf, and Lovell 1994).The DEA technical efficiency metric indicates how close observed production is to production corresponding to the best practice frontier level of output. DEA is particularly well suited for estimation of TE for fishing vessels because it easily handles multi-input, multi-output technologies, which are typical of fishing operations. Additionally, DEA can easily accommodate zero valued output for some species without data transformation.

Färe, Grosskopf, and Kokkelenberg (1989) and Färe, Grosskopf, and Lovell (1994) show how the Johansen concept of capacity for each producer j may be estimated by solving a modified DEA problem. The Färe, Grosskopf, and Kokkelenberg and Färe, Grosskopf, and Lovell DEA specification is as follows:

$$\operatorname*{Max}_{\theta, Z, \lambda} \theta, \qquad [1]$$

subject to:

$$\theta U_{jm} \leq \sum_{j=1}^{J} Z_j U_{jm}, \ m = 1, 2, \ldots, M, \qquad [2]$$

$$\sum_{j=1}^{J} Z_j X_{jn} \leq X_{jn}, \ n \in F_x, \qquad [3]$$

$$\sum_{j=1}^{J} Z_j X_{jn} = \lambda_{jn} X_{jn}, \ n \in V_x, \qquad [4]$$

$$Z_j \geq 0, \ j = 1, 2, \ldots, J, \qquad [5]$$

$$\lambda_{jn} \geq 0, \ n \in V_x, \qquad [6]$$

where:

u_{jm} is the quantity of the mth output produced by the jth producer;
x_{jn} is the quantity of the nth input used by the jth producer;
θ is the technical efficiency score;
λ_{jn} is the variable input utilization rate; and
z_j is a weight used to construct linear segments of the frontier.

The above linear programming model is estimated once for each observation in the data, and the values returned are for θ, λ, and z. Inputs are divided into a set of fixed factors (F_x), and variable factors (V_x), and there is one constraint for each input. The value of θ calculated by the model is the reciprocal of an output distance function and is a measure of technical efficiency relative to capacity production (Kirkley et al. 2001); the value of the inverse of an output distance function is ≥ 1.0. If $\theta = 1.0$, production is said to be technically efficient;[4] if $\theta > 1.0$, output or production may be increased by $\theta - 1.0$. The z_j's allows individual observed activities to be contracted or expanded and constructs unobserved but feasible activities (Färe, Grosskopf, and Lovell 1994). They determine convex combinations of observations on the frontier which are also feasible, and to which observations off the frontier are projected. Observations projected onto the frontier are assumed able to attain the frontier level of output by changing their operations to be similar to frontier observations.

Equation 2 constrains theta times the level of output m for observation j to be less than or equal to a convex combination of observed output levels of m from other observations. Equation 3 constrains the fixed produc-

[4] The firms with θ value of 1 map out the frontier, and a convex combination of firms on the frontier is also feasible. The DEA model is different than a standard firm level optimization problem in that the inputs and outputs are not the decision variables. We thank an anonymous reviewer for pointing this out.

tion factors by setting the left-hand side of the equation to be less than or equal to the observed level of the fixed input for observation j. Equation 4 includes the variable λ_{jn}, which is the input utilization rate by firm j of variable input n. This term allows variable inputs to be expanded or contracted to a level where they are not constraining. The optimal value λ^*_{jn} indicates how each variable factor needs to be adjusted for the observation to operate at capacity output. For example, a value of 1.4 for a particular input means that a firm needs to use 40% more of that input to operate at capacity, while a value of 0.7 means that the particular input needs to be reduced by 30%. The above model constrains the technology to constant returns to scale. Variable returns to scale, however, may be imposed by adding the constraint:[5]

$$\sum_{j=1}^{J} Z_j = 1 \qquad [7]$$

Model Application to the Northeast Buyout Program

The Färe, Grosskopf, and Kokkelenberg (1989) DEA specification, with variable returns to scale, was used to estimate capacity per day in the Northeast groundfish fishery for vessels which submitted buyout bids, and for all vessels eligible to fish groundfish in the Northeast region. The model generated an estimate of daily capacity conditional on groundfish abundance, regulations in place, and technology of the vessel. That is, the estimate of daily capacity assumed a constant resource abundance, regulations that did not change, and that vessels had similar technology and that no technological change occurred in the time period. Additionally, days at sea can not be transferred between vessels, and once a vessel is retired, its days at sea are also retired. Since there is a moratorium on entry of new vessels, once a vessel gives up a groundfish permit for whatever reason, the only way for the vessel owner to get back into the fishery is to buy a permit from another vessel.

An unobservable, but important consideration are differences in the skill level of the captain and crew between vessels. The DEA model accounts for these differences because vessels not on the frontier had their daily capacity determined by a convex combination of vessels that are on the frontier. Because their capacity is being determined by a projection onto the frontier, the model implicitly assumes that they should be able to attain that higher level of capacity as vessels on the frontier that had better captains and crew.[6] Therefore, if a captain and crew from a retired vessel migrated over to another active vessel, its capacity measure should already reflect that transfer of captain and crew skill. The revenue based proxy which was originally used to estimate capacity for the buyout did not account for a transfer of captain and crew skills.

Since the fishery has been regulated by constraints on the number of allowable days at sea, estimates of daily capacity per vessel were expanded to yearly capacity to determine total capacity output. An estimate of annual capacity removed is important for inferring the amount of potential capacity in the system. For example, two vessels might have nearly identical daily capacity but have different levels of allowable days at sea per year. Annual capacity was subsequently estimated using two different levels of days at sea. The first estimate, assumed that a vessel fished all of its allocated days; we refer to this estimate of capacity output as the maximum annual capacity. We next estimate annual capacity by multiplying the estimate of daily capacity by the average number of days a vessel fished during a three-year time period; we term this latter estimate ''historical capacity.'' This latter estimate is believed to be indicative of ''customary and usual operating procedures'' for a vessel; we pose this as an alternative method for estimating annual capacity output for fisheries that are

[5] Variable returns to scale and non-decreasing returns to scale can be imposed on the model due to the underlying assumption of convexity. The free-disposal hull model assumes non-convex sets.

[6] We thank two anonymous reviewers for raising this question.

TABLE 1
CHARACTERISTICS OF VESSELS INCLUDED IN THE CAPACITY ESTIMATION CLUSTERED BY HORSEPOWER

	Trawl Vessels			Gillnet Vessels		Hook Vessels
	Cluster 1	Cluster 2	Cluster 3	Cluster 1	Cluster 2	Cluster 1
Number	268	200	304	110	78	96
Gross Registered Tonnage						
Minimum	10	7	7	5	9	2
Average	135	28	64	19	30	38
Maximum	250	70	180	64	199	192
Horsepower						
Minimum	420	120	275	80	318	120
Average	618	211	352	231	457	325
Maximum	1300	275	450	308	1271	850
Length (Feet)						
Minimum	38	29	31	27	35	26
Average	79	46	60	41	47	46
Maximum	136	65	81	69	120	96

not managed with restrictions on the number of allowable days at sea per year.

Vessels that submitted bids were then ranked by the ratio of the bid to the following: a) maximum annual capacity; b) historical capacity; and c) daily capacity. This was done to determine if the ranking criteria differentially affected the amount of potential capacity that would be removed. Vessels were considered ''purchased'' when all the funds available were spent. Total capacity removed was then compared to capacity removed in the actual buyout program.

Vessels and Vessel Data

Vessel data on landings and inputs for the period 1991–1993 were obtained from the Northeast Fisheries Science Center (NEFSC). Outputs were measured as landings per day at sea for each of the ten ''large mesh'' species. Output per day was calculated by dividing total landings for each vessel during 1991 through 1993 by the total days at sea on trips in which any of the ten species were landed. This yielded an average over the three-year time period, and accounted for variability in the data due to environmental conditions, operational problems such as breakdowns, and changes in the regulations. Inputs used in the model were obtained from vessel permit records. Fixed inputs included gross registered tonnage (GRT), vessel length in feet (L), and vessel horsepower (HWP). A vessel was excluded from the analysis if data were missing for any of the three fixed inputs. Vessel crew size was the sole variable input.

Daily capacity was estimated separately by vessel gear type in order to keep technology the same for all vessels in a group. The gear types were otter trawlers, gillnetters, and longline/jigging (hook) vessels. Vessels were further stratified using horsepower as the clustering variable (Table 1). Based on conversations with fishermen, the most important determinant of fishing power is believed to be horsepower. A total of 1,056 vessels separated into six gear configuration and horsepower groups were used in the analysis. This data set included 118 of the 157 vessels that submitted bids in the expanded Northeast buyout program, of which 56 were bought back.

TABLE 2
CAPACITY REMOVED USING ALLOCATED DAYS AT SEA AS AN EXPANSION FACTOR

	Alternate Ranking Criteria		
	Expanded Buyout	Total Capacity	Daily Capacity
Vessels purchased	56	64	69
Cost ($1,000,000 US)	18.6	18.1	18.2
Total capacity (MT) all vessels	88,717	88,717	88,717
Capacity removed (MT)	8,764	10,124	10,239
Percentage capacity removed	9.9%	11.4%	11.5%
Average capacity per vessel	157	158	148
Average revenue per vessel	361,847	318,861	309,654
Average allocated days at sea	129	128	126
Average days fished	150	153	155
Average efficiency score	1.55	1.64	1.61

V. RESULTS

Based on allocated days at sea, capacity output removed through the expanded buyout program equaled 8,764 mt or 9.9% of the total estimated capacity of 88,717 mt (Table 2). Using historical days at sea, estimated capacity removed was 11,567 mt, or 14.5% of the total estimated capacity of 79,833 mt (Table 3).

The expanded buyout program used the bid-to-average groundfish revenue ratio to determine the purchase sequence for vessels. In this study, we examine two alternative methods for ranking vessels: 1) the bid to total capacity ratio; and 2) the bid to daily capacity ratio. Under both schemes, vessels with the lowest ratio would be purchased first until the funds were exhausted. To compare the levels of capacity removed with that of the expanded buyout program, we assumed that vessels would be "purchased" until the total expenditure equaled that dollar amount actually expended on the expanded buyout vessels.[7]

Using allocated days as an expansion factor, and ranking vessels using the bid-to-total capacity ratio, we estimate that 64 vessels

[7] Because of missing vessel data, only 56 of the original buyout vessels were included in the capacity measure, for a total expenditure of $18.6 million.

TABLE 3
CAPACITY REMOVED USING HISTORICAL DAYS AT SEA AS AN EXPANSION FACTOR

	Alternate Ranking Criteria		
	Expanded Buyout	Total Capacity	Daily Capacity
Vessels purchased	56	60	69
Cost ($1,000,000 US)	18.6	18.2	18.2
Total capacity	79,833	79,833	79,833
Capacity removed (M.T.)	11,567	13,630	12,719
Percentage capacity removed	14.5%	17.1%	15.9%
Average capacity per vessel	207	227	184
Average revenue per vessel	361,847	363,093	309,654
Average allocated days at sea	129	121	126
Average days fished	150	160	155
Average efficiency score	1.55	1.56	1.61

would have been purchased for $18.1 million. Removal of these 64 vessels equates to capacity being reduced by 10,124 mt or 11.4% of total capacity (Table 2). A slightly different mix of vessels was purchased than were purchased under the actual buyout; also, 14 vessels purchased in the buyout program were not selected. Based on the bid-to-daily capacity ratio criteria, 69 vessels would have been purchased for $18.2 million, and thus, 10,239 mt or 11.5% of total capacity would have been removed (Table 2). Using the bid-to-daily ratio criteria, 12 vessels bought out under the expanded program would not have been purchased.

Estimates of annual capacity based on the historical number of days at sea were similar to those obtained using actual days at sea (Table 3). If vessels to be purchased were targeted based on the bid to total capacity ratio, 60 vessels at a cost of $18.2 million would have been purchased, and thus, 13,630 mt of capacity (17.1%) would have been removed. Sixteen vessels purchased under the expanded program would not have been selected. If daily capacity was used to identify vessels to be purchased, 69 vessels would have been purchased. The removal of these 69 vessels would have reduced capacity by 12,719 mt, or 15.9% of the total capacity. Relative to all the preceding ranking criteria, the expanded buyout program resulted in the least capacity being removed. When allocated days at sea were used as the expansion factor, ranking vessels using the bid-to-daily-fishing-capacity ratio as a ranking criterion resulted in the most capacity and greatest number of vessels being removed (Table 2). When historical days at sea were used, ranking vessels based on the bid-price-to-total-capacity resulted in the greatest removal of capacity (Table 3).

Gates, Holland, and Gudmundsson (1996) noted that buyout programs like the Northeast buyout program could lead to ''input stuffing'' because vessels are ranked using revenue measures. In response to using this criteria, if vessel owners anticipate subsequent buyouts with ranking criteria based on average groundfish revenue, they could increase their fishing effort, crew size or other variable inputs in order to raise their earnings and increase their capacity estimate. Using capacity based ranking measures not linked to revenue such as we have done in a DEA framework could mitigate this effect somewhat because vessel capacity is determined by how efficiently each vessel uses its capital compared to other vessels. Simply landing more fish does not necessarily advantage one vessel over another. However, there is a moratorium on entry in the Northeast groundfish fishery, and consequently owners will face pressures to upgrade existing vessels in some manner in order to increase their landings. A buyout program using either approach to rank vessels is unlikely to reduce this incentive. Additionally, over time vessel owners may be able to determine ways to act strategically even if DEA is used to estimate capacity, and thereby gain an advantage in the bidding process.

One important issue, which has not been addressed, is ''latent effort'' or idle groundfish capacity. Our capacity estimates did not include those vessels that had a days-at-sea allocation, but did not fish between 1991 and 1993. Only 863 of 1,762 vessels that had a groundfish permit in 1996 were included in our estimate of total capacity.[8] If we assume that our estimates of average daily capacity are representative of the permitted vessels that had no activity between 1991 and 1993, and extrapolate using their allocated days at sea, total capacity for these vessels would equal approximately 95,000 mt. This would reduce the estimated percent of total capacity removed to 4.8%.

VI. SUMMARY AND CONCLUSIONS

Buyout programs are becoming increasingly popular tools for reducing fishing capacity throughout the world. One possible problem with many of the programs, however, is that administrators managing the programs may have little or incomplete information about the actual level of capacity being reduced. Measurement of capacity in terms of historical landings, number of permits, or physical attributes, which are typical capac-

[8] There were 200 vessels that had zero days allocated and were included in the DEA model.

ity measures used in fisheries buyback or decommissioning programs, may substantially understate capacity or result in inadequate capacity reduction programs. In this paper, we offered definitions and concepts of capacity that are more consistent with the traditional economic concepts of capacity; an approach for estimating capacity when data are limited to only quantity information; and an analysis of the Northeast groundfish buyout program.

Buyback or buyout programs may benefit from having estimates of both vessel and fleet capacity. With such information, an agency conducting a buyout may determine which vessels might be targeted for decommissioning; ensure that capacity is matched to sustained resource levels; and subsequently, implement a cost-effective buyout program (i.e., removal of maximum capacity at least cost). In this study, we proposed data envelopment analysis or DEA to estimate capacity removed by the Northeast groundfish buyout program. The weak version of the Johansen concept of capacity was estimated by using the framework offered in Färe, Grosskopf, and Kokkelenberg (1989).

The primary purpose of the expanded Northeast buyout program was to reduce capacity in the Northeast groundfish fishery. Gates, Holland, and Gudmundsson (1996), however, suggested a buyout program should have three general goals: 1) conservation of fish stocks; 2) improvement of economic efficiency; and 3) facilitate making transfer payments to the fishing industry. Based on analyses presented in this paper, it appears that the Northeast program did not accomplish the first two goals. It did, however, enable transfer payments to be made to the fishing industry.

At the time the Northeast buyout program was initiated, capacity was based on average revenue, and decisions about which vessels to purchase were made based on the bid-to-average-revenue ratio. Preliminary results at the time of the expanded buyout suggested that the purchased vessels represented 20% of the groundfish revenue, with revenue being equated to capacity. Based on the DEA analysis, we estimated that the expanded buyout program, using bid to revenue ratios, reduced capacity by 9.9% of the total estimated capacity of 88,717 mt at a cost of \$18.6 million. This is substantially less capacity than the agency believed it had removed.

If the DEA-derived estimates of capacity had been used to rank or target vessels for decommissioning, 64 vessels could have been purchased at a cost of \$18.1 million; removal of the 64 vessels equates to a reduction of 11.4% of the active groundfish capacity. Additionally, 14 of the vessels removed under the expanded buyout program would not have been purchased using capacity based measures. Using the bid to daily capacity ratio rather than the bid to revenue ratio to rank vessels would have removed more capacity (11.5%) at a lower cost (\$18.2 million) than the actual expenditure of \$18.6 million.

The expanded buyout program was designed to remove the most capacity, defined in terms of revenue, at the least cost, and was restricted to vessels earning 65% of their revenue from groundfish. An advantage of this program was that it was very transparent to the participants. That is, each participant knew the level of their groundfish revenue for the time period used to evaluate vessels, and therefore, could estimate their expected score. This would not be the case if vessels were ranked based on capacity estimated from DEA, unless participants were told their DEA capacity measure before they submitted a bid.

If estimates of capacity derived from DEA had been used to decommission vessels, however, only slightly higher levels of total physical capacity would have been removed. The rules which were in place for the expanded buyout program limited the potential pool to very active vessels, which for the most part were the same vessels identified by the DEA model as having high capacity. This suggests that revenue based proxies can work as well as the DEA methods for choosing vessels where the goal is to remove active vessels and there is a desire to have transparent measures.

There remains a problem, however, about the desired target level of capacity reduction and the need for better estimates of capacity. Because the Northeast buyout program equated revenue with capacity, NMFS apparently believed it was reducing capacity by 20%, when, in fact, the level of reduction was only 4.8% of total capacity, which includes latent permits. If NMFS actually had desired to reduce capacity by 20%, our study suggests that inadequate funds were allocated by the buyout program to achieve the desired reduction in capacity. The initial estimate of a 20% reduction in capacity equates to $1.15 million spent per percentage unit of capacity reduced ($23 million divided by 20%). Based on the active vessels in our study, $1.88 million was spent per percentage unit of capacity reduction ($18.6 million divided by 9.9%), suggesting that considerably more than $23 million would need to be spent to reduce capacity by 20%.

Another problem with the Northeast buyout program was that it did not address latent or idle effort. The GAO report criticized NMFS because the agency did not take steps to prevent idle vessels, or vessels that were relatively inactive, from becoming more active and thereby eroding any conservation benefits that might have been realized by the buyout program. This was a serious problem in the design of the Northeast buyout program as well as other buyback programs. Regardless of how capacity is measured and defined, the possibility that latent or idle vessels can expand their activities in a fishery creates the possibility that a buyback program may not realize the conservation goal. There are currently 132,000 permitted days at sea available to the Northeast fleet, which is believed to be far higher than the level necessary to sustainably harvest the resource. On average, only one-third of the available fishing days are used in any given fishing year. There is a possibility, then, that as stocks recover, the number of days fished per year will increase, and that will undermine the conservation goals currently in place. This leaves managers the choice of either reducing allowable days for all permit holders so the aggregate number does not exceed the level necessary for a sustainable harvest; implementing regulations to reduce the efficiency of vessels; or buying out enough capacity to reduce allowable days down to a sustainable level. The design of a buyback program must, therefore, also include provisions to address the potential problem of latent effort.

A further criticism of the buyout program was that it did not prohibit the migration of human capital from purchased vessels, and the program did not restrict individuals from using the proceeds from the sale of their vessel to purchase relatively inactive vessels and start fishing them harder. The GAO estimated that 5% of the conservation benefits gained through the buyout was eroded due to the transfer of captain and crew skill to other vessels. Regardless of the accuracy of the estimate, the potential migration of more highly skilled captains to other vessels, and the possibility of formerly inactive vessels increasing their activities, presents a serious problem for a buyout program relative to achieving a desired level of capacity reduction, particularly for the purposes of conservation of fish stocks and improving economic efficiency. While it may be difficult to regulate managerial mobility, if a buyback program is to achieve the stated goals of conservation and economic efficiency, it will have to include restrictions to either prevent increased activity by relatively inactive vessels or limit the activity of the remaining vessels.

The Northeast groundfish buyout program was initiated in response to a perceived crisis to help rebuild depressed stocks quicker. As a short term measure, it had the effect of removing some capacity from the fishery, perhaps making regulation of the remaining vessels somewhat easier. However, the failure to restrict fishers from re-entering the fishery and to prevent the activation of latent effort resulted in no real conservation benefit. Additionally, there was no apparent improvement in economic efficiency. Thus, what was left was a very expensive transfer payment program.

If further buyouts[9] are pursued then the both the objectives of the buyout and the funding mechanism need to be clearly speci-

[9] A $10 million buyout using public funds to remove further groundfish capacity in New England is currently being conducted. The buyout will purchase the permit, but not the vessel.

fied. In the case of Northeast groundfish, Congress appropriated the money to pay for the buyout. However, participants in the fishery could choose to buyout vessels or permits themselves. There is also the possibility of mixing public and private financing, as was done in the Alaskan pollock fishery. If public funds are used for the buyout, the amount of capacity removed should be made public, along with the final cost of the program, and other information such as the mix of idle and active capacity purchased. For publicly financed buyouts aimed at improving the condition of the fishery resource, there should be a clear link between conservation benefits and the buyout. Periodic reviews should be made to determine if total capacity is increasing; idle capacity is being activated; and whether any conservation benefits brought about by the buyout are being eroded.

References

Anderson, L. G. 1977. *The Economics of Fisheries Management*. Baltimore: Johns Hopkins University Press.

Berndt, E. R., and M. Fuss. 1989. ''Economic Capacity Utilization and Productivity Measurement for Multiproduct Firms with Multiple Quasi-Fixed Inputs.'' Working paper no. 2932. Cambridge, Mass.: National Bureau of Economic Research.

Berndt, E. R., and C. J. Morrison. 1981. ''Capacity Utilization Measures: Underlying Economic Theory and an Alternative Approach.'' *American Economic Review* 71 (1): 48–52.

Charnes, A., W. Cooper, and E. Rhodes. 1978. ''Measuring the Efficiency of Decision Making Units.'' *European Journal of Operational Research* 2 (6): 429–44.

Coelli, T. 1996. ''A Guide to DEAP Version 2.0.'' Working paper 96/08. Center for Efficiency and Productivity Analysis. Department of Econometrics, University of New England, Armidale, Australia.

Färe, R. 1984. ''On the Existence of Plant Capacity.'' *International Economic Review* 25 (1): 209–13.

Färe, R., S. Grosskopf, and E. Kokkelenberg. 1989. ''Measuring Plant Capacity, Utilization and Technical Change: A Nonparametric Approach.'' *International Economic Review* 30 (3): 656–66.

Färe, R., S. Grosskopf, and C. A. Knox Lovell. 1994. *Production Frontiers*. New York: Cambridge University Press.

Farrell, M. J. 1957. ''The Measurement of Productive Efficiency.'' *Journal of the Royal Statistical Society*, Series A, General 125, Part 2: 252–67.

Food and Agriculture Organization (FAO). 2000. *The State of World Fisheries and Aquaculture, 2000.* Rome, Italy: Food and Agriculture Organization of the United Nations

Gates, J., D. Holland, and E. Gudmundsson. 1996. ''Theory and Practice of Fishing Vessel Buyback Programs.'' A Report prepared for the World Wildlife Fund. University of Rhode Island, Department of Environmental and Resource Economics, N. Kingston, R.I.

Government Accounting Office (GAO). 2000. ''Entry of Fishermen Limits Benefits of Buyback Programs.'' Report to the House Committee on Resources. GAO/RCED-00-120.

Holland, D., E. Gudmundsson, and J. Gates. 1999. ''Do Fishing Vessel Buyback Programs Work: A Survey of the Evidence.'' *Marine Policy* 23 (1): 47–69.

Johansen, L. 1968. ''Production Functions and the Concept of Capacity.'' In *Recherches recentes sur la fonction de production.* Namur: Centre d'Etudes et de la Recherche Universitaire de Namur.

Kirkley, J., and D. Squires. 1999. ''Capacity and Capacity Utilization in Fishing Industries.'' Discussion Paper 99-16, University of California, San Diego.

Kirkley, J., R. Färe, S. Grosskopf, K. McConnell, D. Squires, and I. Strand. 2001. ''Assessing Capacity and Capacity Utilization in Fisheries When Data are Limited.'' *North American Journal of Fisheries Management* 21 (3): 482–97.

Kitts, A., and E. Thunberg. 1998. ''Description and Impacts of Northeast Groundfish Fishery Buyout Programs. Northeast Fisheries Science Center Reference Document 98-12.

Koopmans, T. C. 1951. ''Analysis of Production as an Efficient Combination of Activities.'' In *Activity Analysis of Production and Allocation*, ed. T. C. Koopmans. New York: Wiley.

Morrison, Catherine J. 1985a. ''A Primal and Dual Capacity Utilization: An Application to Productivity Measurement in the U.S. Automobile Industry.'' *Journal of Business and Economic Statistics* 3:312–24.

———. ''On the Economic Interpretation and Measurement of Optimal Capacity Utilization with Anticipatory Expectations.'' *Review of Economic Studies* 52 (2): 295–310.

National Marine Fisheries Service. 1999. ''Federal Fisheries Investment Task Force Report to Congress.'' Silver Springs, Md.: National Marine Fisheries Service.

———. 2001a. ''Report of the National Task Force for Defining and Measuring Fishing Capacity.'' Silver Springs, Md.: National Marine Fisheries Service.

———. 2001b. ''Report to Congress on the Northeast Multispecies Harvest Capacity and Impact of Northeast Fishing Capacity Reduction.'' Woods Hole, Mass.: Northeast Fisheries Science Center.

Northeast Fisheries Science Center. 2001. ''Status of the Fishery Resources off the Northeastern United States for 2000.'' ⟨http://www.nefsc.nmfs.gov/sos/index.html⟩ (9/20/01).

Russell, R. R. 1985. ''Measures of Technical Efficiency.'' *Journal of Economic Theory* 51: 255–67.