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Buyback Programs: Goals, Objectives, and Industry Restructuring in Fisheries

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National Oceanic and Atmospheric Administration Fisheries has conducted several buyback programs to reduce harvesting capacity in fisheries. These programs have attempted to maximize capacity reduction given a fixed budget. However, restructuring issues have not been considered. We explore the possibility of satisfying three different buyback objectives. We examine the black sea bass trap fishery and determine the number of vessels given different allowable catch levels and objectives of maximizing technical efficiency, capacity utilization, and vessels in the fishery. We find considerable variation in the number of vessels allowed to remain in the fishery given the different objectives.

Key Words: capacity utilization, Data Envelopment Analysis, fishery buyback programs, fishing capacity

JEL Classifications: C61, D24, Q22, Q28

Eliminating excess capacity in fisheries has become a global issue. National Oceanic and Atmospheric Administration (NOAA) Fisheries, the Food and Agriculture Organization (FAO), and various member nations have all embarked on an ambitious plan to measure capacity and subsequently determine methods to eliminate excess capacity in fisheries. In the United States, there have been several buyback programs implemented to help reduce excess capacity in fisheries. These programs, however, have been viewed as being only marginally successful (U.S. General Accounting Office). One major problem recognized by the present study was that these buyback programs did not restrict individuals from returning to other fisheries or the same fishery.

In 2002, NOAA Fisheries prepared a report on overcapacity in five federally managed fisheries and the cost of eliminating the overcapacity (Kirkley et al.). The five fisheries examined were the New England and West Coast groundfish fisheries, the large coastal pelagic shark fishery, the Gulf of Mexico shrimp fishery, and the Atlantic swordfish fishery. All fisheries were determined to have substantial excess capacity. It was also determined that nearly $1.0 billion would be required to eliminate the overcapacity in all five fisheries.

In recent years, NOAA Fisheries conducted several buyback programs. The apparent primary objective of these programs was to ensure that capacity was reduced as much as possible, given a fixed amount of funds available for the buyback. None of these programs, however, had goals or objectives other than to reduce as much capacity as possible given a fixed budget. Alternatively, issues such as

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whether or not the reduction should yield the most technically efficient fleet, a fleet consistent with the maximization of capacity utilization, or some alternative objective were not considered in these buyback programs.

We present the results of an analysis of a buyback program that was designed to satisfy three objectives. We selected the South Atlantic trap fishery for black sea bass. The three objectives considered are as follows: (1) maximization of technical efficiency or reducing the fleet such that technical efficiency for the fleet is maximized subject to varying total allowable catch (TAC) levels; (2) maximization of capacity utilization or reduce the fleet such that existing capital stock of the fleet is fully utilization subject to various TAC levels; and (3) maximize the fleet size to harvest the desired sustainable yield or TACs. The third objective may appear to be the most undesirable objective relative to economic concerns, but it is one often under consideration by management councils.

We initially estimated capacity, technical efficiency, and capacity utilization using data envelopment analysis (DEA). Capacity was estimated for all vessels and fleets operating between 1995 and 2001 and, subsequently, relative to average or customary and usual operating procedures (CUOP) between 1995 and 2001. It was determined that the fleet, on average, had the capability to harvest approximately 2.1 times the average annual landings actually harvested between 1995 and 2001.

We then ordered the estimates according to the three objectives (e.g., for the case of maximum technical efficiency, we ordered the estimates from most to least efficient). Next, the various outputs consistent with the objectives were cumulatively summed and compared with stated TACs or desired sustainable yields. We found that, depending on the stated objective, the number of vessels to remain in the fishery substantially varied.

Data

Data about vessel and gear characteristics, such as vessel length and engine horsepower, were acquired from the permits database at the Southeast Regional Office. Data about gear type and number of gear used, along with landings data, were obtained from trip reports in the logbook database at the Southeast Fisheries Science Center and weigh-out files. The analysis assumed vessels' characteristics, gear type, number of gear, and hours fished to be fixed. The vessel characteristics are, in effect, fixed factors of production. The assumption that number of gear and hours fished were fixed was made to estimate capacity given CUOP. Data on days at sea and crew size per trip were also obtained and considered to be variable factors of production (i.e., they could be relatively easily changed by the vessel operator but only within certain bounds). The data covered fishing operations between 1995 and 2001 (Table 1).

The data were subsequently examined for missing information. After a review of the data, we decided to examine capacity only for the trap/pot fishery for black sea bass. This is the primary gear used to harvest black sea bass and had the fewest number of observations with missing information (Table 2).

As is apparent in Table 2, there are considerable differences in the number of vessels landing black sea bass and the number of vessels used to estimate capacity. For example, 370 vessels reported landing some sea bass in 1995, and 75 vessels reported landing some sea bass in the trap fishery. The 370 vessels represent all gear types and vessels reporting landing sea bass in 1995; the 75 vessels represent vessel operators reporting landings of sea bass and participating in the trap fishery. Of the 75 vessels participating in the trap fishery in 1995, however, only 54 vessels had information that could be used to estimate capacity output. Landings by trap gear for vessels having complete information accounted for approximately 60%–73% of the total landings between 1995 and 2001.

Methodology

Ballard and Roberts were among the first to estimate capacity in fisheries. They used the method of Klein, which has become known as the "peak-to-peak" method, to estimate

Table 1. Vessel Characteristics, Landings, and Effort in the Black Sea Bass Fishery, 1995–2001

	1995	1996	1997	1998	1999	2000	2001
Fleet size (no. of vessels)							
Total	370	339	357	339	310	260	243
Trap	75	80	93	77	72	68	57
Used in analysis	54	73	81	71	65	61	51
Vessel characteristics							
Horsepower							
Minimum	130	40	115	120	120	120	175
Mean	310	320	333	348	355	342	360
Maximum	671	800	800	800	735	735	650
Length (feet)							
Minimum	21	22	20	18	18	24	24
Mean	34	38	34	36	35	35	36
Maximum	48	50	50	68	48	50	50
Crew size (no.)							
Minimum	1	1	1	1	1	1	1
Mean	1.7	1.9	1.8	1.9	1.8	1.9	2
Maximum	3	3	4	4	3	3	3
Fishing effort							
Days absent							
Minimum	1	1	1	1	1	1	1
Mean	17.4	18.5	18.1	18.6	17.2	13.5	21
Maximum	85	92	131	107	94	69	149
Hauls per trip							
Minimum	2	1	1	1	1	1	1
Mean	52	52	40	48	46	47	60
Maximum	217	367	270	370	529	638	720
Traps per trip							
Minimum	2	2	2	1	2	2	3
Mean	27	24	25	26	28	25	30
Maximum	100	151	150	101	118	120	117
Landings (lbs.)							
Black sea bass							
Minimum	3	69	21	36	70	30	55
Mean	5,533	6,343	6,095	6,594	7,084	5,470	7,075
Maximum	34,565	48,417	57,046	47,282	44,526	30,715	43,166
Other species							
Minimum	0	0	0	0	0	0	0
Mean	1,219	958	1,105	780	2,132	876	1,189
Maximum	15,569	17,057	16,385	10,917	11,458	12,325	13,139

capacity. It attempts to extrapolate estimates of capacity on the basis of fleet landings divided by the number of operating units adjusted for technical change. Since the publication of Ballard and Roberts's work, numerous methods have been developed to estimate capacity. Kirkley and Squires provided an exhaustive summary of various ap-

Table 2. Summary of Landings and Ex-Vessel Revenue for Black Sea Bass, 1995–2001

Year	Gear	Data (trips)	Trips Included (no.)	Vessels (no.)	Landings (lbs.)	Revenue (no.)	Total Landings (%)	Usable Observations: Trap Landings (%)
1995	All	All	3,307	370	502,028	838,108		
1995	Trap	All	999	75	410,354	693,598	81.74	
1995	Trap	Usable	662	54	298,770	530,421	59.51	72.81
1996	All	All	3,333	339	633,976	1,004,600		
1996	Trap	All	1,153	80	544,330	859,743	85.86	
1996	Trap	Usable	985	73	463,014	737,953	73.03	85.06
1997	All	All	3,883	357	686,801	1,213,586		
1997	Trap	All	1,330	93	562,147	984,512	81.85	
1997	Trap	Usable	1,221	81	493,676	865,005	71.88	87.82
1998	All	All	3,821	339	646,999	1,139,858		
1998	Trap	All	1,199	77	536,880	939,627	82.98	
1998	Trap	Usable	1,096	71	468,163	821,285	72.36	87.20
1999	All	All	3,064	310	666,560	1,358,850		
1999	Trap	All	1,050	72	544,701	1,103,624	81.72	
1999	Trap	Usable	931	65	460,461	935,371	69.08	84.53
2000	All	All	2,496	260	470,669	931,516		
2000	Trap	All	828	68	404,552	798,200	85.95	
2000	Trap	Usable	715	61	333,698	661,063	70.90	82.49
2001	All	All	2,874	243	494,875	908,249		
2001	Trap	All	1,071	57	428,987	788,373	86.69	
2001	Trap	Usable	919	51	360,831	660,531	72.91	84.11

proaches that can be used to estimate capacity in fisheries.

The methods explicitly incorporate economic behavior, stochasticity or noise, and other concerns. For the most part, however, methods that attempt to estimate capacity from a rigorous economic perspective cannot be used to estimate capacity for most fisheries in the United States. This is because the cost and earnings information required to estimate an economic concept of capacity are typically not available.

In the present article, DEA is proposed as a method for estimating capacity. DEA is a nonparametric, mathematical programming approach that has been used to estimate technical efficiency of production. Charnes, Cooper, and Rhodes initially proposed DEA. It has subsequently been expanded to deal with issues other than simply estimating technical efficiency (Färe, Grosskopf, and Knox-Lovell). For example, it can be used to estimate the optimum allocation of inputs or the optimum production of outputs in a multiple product technology. Färe first proposed DEA as a method for estimating capacity. Färe also offered a framework for determining the level of variable inputs (e.g., labor and days at sea) required to produce the capacity output. Färe et al. provided a comprehensive introduction to using DEA to estimate capacity in fisheries.

In addition to being nonparametric and nonstatistical, DEA imposes no underlying functional form of the relationship between outputs and inputs (i.e., the production function or technology). DEA is used to construct a linear, piecewise technology relative to an ideal or best-practice frontier technology. The best-practice frontier technology is a reference technology that depicts the most technically efficient combinations of inputs and outputs. There are three possible orientations of DEA: (1) determine the minimum level of inputs required to produce a given output; (2) determine the maximum level of outputs that can be produced given existing levels of inputs; or (3) determine the maximum expansion of outputs and minimum level of inputs such that production is technically efficient.

For the purpose of estimating capacity in fisheries, an output orientation was used. That is, we desired to estimate the maximum potential output levels that can be produced given existing fixed factors and the potential level of variable inputs. Estimates of capacity are obtained by solving one mathematical programming problem (in actuality, a linear programming [LP] problem) for every observation. This traces out a best practice frontier and permits capacity to be estimated for each observation. The basic LP problem is as follows:

$$\text{(1)} \quad TE_{ocj} = \underset{\theta,z,\lambda}{Max}\ \theta$$

subject to

$$\theta u_{jm} \leq \sum_{j=1}^{J} z_j u_{jm}, \qquad m = 1, \ldots, M,$$

$$\sum_{j=1}^{J} z_j x_{jn} \leq x_{jn}, \qquad n \in F_x$$

$$\sum_{j=1}^{J} z_j x_{jn} = \lambda_{jn} x_{jn}, \qquad n \in V_x$$

$$\sum_j z_j = 1.0$$

$$z_j \geq 0, \qquad j = 1, 2, \ldots, J$$

$$\lambda_{jn} \geq 0,$$

where θ is a measure of technical efficiency (TE; $\theta \geq 1.0$), F is a vector of fixed inputs, V is a vector of variable inputs. z is a vector of intensity variables used to construct the piecewise technology, and u is a vector of outputs. If we multiply the observed output by θ, we obtain an estimate of capacity output. Capacity can also be estimated by solving the same problem without the variable input constraints, which indicates that they are, in fact, decision variables. With either the equality constraint included on the variable inputs or the omission of the variable inputs, the solution to Equation (1) yields values of z that can then be used to calculate the level of variable inputs required to produce the capacity output.

Equation (1) imposes strong disposability in outputs and variable returns to scale. That is, it is assumed that a producer has the ability to dispose of any unwanted commodities without incurring any production cost (strong disposability) or experiencing a loss in revenue, and increasing all input levels by the same proportion will result in a different rate of change in output levels (e.g., if all input are doubled, output levels might increase by a factor of 2, less than 2, or more than 2). The important aspect of variable returns to scale is that it permits different rates of change in output levels given different rates of change in input levels. Alternatively, a technology may exhibit more than one type of returns to scale (e.g., constant returns, decreasing returns, and increasing returns are all possible with variable returns to scale imposed on the technology). The constraint that the sum of $z_j = 1.0$ imposes variable returns to scale.

Equation (1) was initially proposed by Färe, Grosskopf, and Kokkelenberg for assessing capacity when data were limited to input and output quantity information; that is, economic data such as cost and earnings information and information on input and output prices were not available. As such, Equation (1) is a technological engineering concept of capacity. Because estimates are based on actual data, however, estimates of capacity obtained from solutions to Equation (1) implicitly reflect the underlying economics.

In addition to obtaining an estimate of capacity, Equation (1), together with the same problem but including all inputs, may be used to estimate an unbiased measure of capacity utilization (CU). Färe, Grosskopf, and Kokkelenberg demonstrated that the ratio of an output-oriented measure of TE (TE_{oj}), with fixed and variable inputs included, to an output-oriented measure of TE (TE_{ocj}), with variable inputs excluded, yielded a relatively unbiased measure of CU:

$$(2) \qquad CU_j = \frac{TE_{oj}}{TE_{ocj}}.$$

The Färe, Grosskopf, and Kokkelenberg CU measurement permits an assessment of whether or not deviations from full capacity are because of inefficient production or less than full utilization of the variable and fixed inputs. In most calculations of CU, it is determined in a nonfrontier framework (e.g., peak-to-peak methods).

The solution to Equation (1) also may be used to estimate a variable input utilization rate. The *i*th variable input utilization rate is estimated as follows (Färe, Grosskopf, and Knox-Lovell):

$$(3) \qquad \lambda_{jn}^* = \frac{\sum_{j=1}^{J} z_j^* x_{jvi}}{x_{jvi}}, \qquad n \in V_x,$$

where λ^* equals the ratio of the level of the *i*th variable input required to produce the capacity level to the observed usage of the *i*th variable input; the numerator equals the optimal level; and the denominator equals the observed usage of the *i*th variable input. A value of $\lambda > 1.0$ indicates a variable input whose usage should be expanded to achieve capacity production; $\lambda < 1.0$ implies that usage of the variable input should be reduced.

The use of DEA to estimate capacity need not be restricted to the primal or technological engineering concept of capacity. If sufficient data on input or output prices are available, it is possible to estimate TE, capacity, CU, and optimal variable input usage using a cost or revenue-based DEA problem. Färe, Grosskopf, and Kirkley illustrated how TE, capacity, and CU for a multiple product, multiple input technology can be estimated either directly by solving respective revenue maximization or cost minimization DEA problems similar to Equation (1) or by exploiting the properties of duality. It is also possible to estimate capacity from a profit maximizing orientation.

Although DEA has gained widespread recognition as an approach for estimating either technical efficiency or capacity, it does have some limitations. First, it is not stochastic and, thus, the most efficient producers define the frontier. Alternatively, estimates of capacity and TE attribute all randomness or noise to inefficiency. In the case of fisheries, therefore, it would be possible for "high-liners" or the lucky catch of the trip to define the frontier for the entire fleet. Capacity, therefore, could be easily overestimated. Second, if there are large horizontal or vertical sections of the frontier, it is possible to underestimate capacity; Coelli, however, has offered a multistage DEA approach to address this latter problem. Third, the DEA approach that we have used provides a short-term measure of capacity; this should not, however, pose a serious problem, because capacity is a short-term concept.

Kirkley et al. and Walden, Kirkley, and Kitts offered alternatives for addressing the issue of nonstochasticity. Rather than basing capacity strictly on actual observations of outputs and inputs, both studies suggested that it is possible to partially incorporate noise by using mean or expected values of outputs and inputs; this is mostly applicable, however, to very large data sets. Another approach, the one that we have used, is to first form clusters, then estimate capacity output for each cluster, and then base the estimates of capacity on the expected value (means) of the estimates.

Two basic black sea bass fisheries were initially considered. The first fishery is strictly a single-species fishery (i.e., trips for which only black sea bass was reported as being landed). The second fishery is a multispecies fishery but restricted to two categories: black sea bass and all other species. There were a total of 6,529 trips during which black sea bass were landed by trap gear between 1995 and 2001. Of this total, 1,732 trips landed only black sea bass, and 4,797 trips landed black sea bass and some other species.

Each fishery was further disaggregated into five clusters. Cluster analysis is a nonparametric method for grouping similar observations (Kaufman and Rousseeuw). Clustering was done to reduce the possibility of overestimating capacity, which might occur if the estimates of capacity for all trips were primarily determined by high-liners or lucky catches. The partitioning of observations or clustering was accomplished by *K*-means clustering. *K*-means clustering assigns observations to a cluster to reduce the within-groups sum of squares. We arbitrarily considered five clusters for each of the two categories; a total of 10 clusters were thus considered in the analysis. Clustering was based on vessel characteristics, variable input levels (days away and crew size), output levels, and gear usage (e.g., number of traps, effort or number of trap hauls, and hours fished). Trip level information was used to estimate the clusters. It is possible for a boat to appear in more than one cluster. This should not, however, affect the estimates of capacity. Capacity output was calculated by aggregating capacity output over all trips on a per-vessel basis. Capacity was estimated for each trip and each vessel operating between 1995 and 2001. These estimates were subsequently averaged to determine the possible capacity output under customary and usual operating procedures.

For the purpose of estimating capacity, the following variables were considered to be fixed and variable. Fixed factors were vessel length, engine horsepower, number of traps, number of trap hauls (effort), and time fished (fished); variable factors were crew size per trip and days at sea per trip. It would be possible, however, for fishing operations to change the number of traps, hauls, and time fished, which would increase the estimates of capacity output. Without more detailed information, however, it would be difficult to assess the feasibility of individual vessel operators changing the number of traps and time fished. In addition, it was believed that, by restricting the number of traps and hauls and time fished, the analysis would better reflect customary and usual operating procedures.

Estimates of capacity output, however, should be viewed as lower bound estimates. This is partly because the estimates were based on only one fleet, the trap fishery; partly because data were incomplete even relative to the trap fishery; and partly because some of the factors that were assumed to be fixed (such as the number of traps and hauls and time fished) could actually be changed by vessel operators.

Analytical Results

Capacity was estimated using DEA for all years and clusters. In total, the analysis required 10 separate estimations. Trip-level estimates were then summed over individual vessels and years; subsequently, total fleet activity was summarized by year, over all observations, and then relative to mean values over all years (Table 3). We again stress, however, that estimates of capacity output represent lower bound estimates. The data used to estimate capacity represented approximately 73% of all reported landings between 1995 and 2001. In addition, some of the inputs that were assumed to be fixed factors are factors that might possibly be changed by vessel operators (e.g., number of traps).

In general, vessels had the capability to harvest two times the level they actually harvested between 1995 and 2001 (Table 4). Crew size could have been marginally decreased; statistically, however, there was no difference between observed crew size and that required to produce the capacity output. Mean days at sea per year per vessel would have only had to marginally increase to realize the capacity output. The highest mean level of landings per vessel occurred in 1999, when vessels averaged 7,084 pounds per vessel. The highest mean capacity output occurred in 2001, which was estimated to equal 14,361 pounds per vessel. Of 51 vessels operating in 2001, 8, or 15.7% of all 51 vessels, had annual landings more than 14,361 pounds. These eight vessels averaged 66.6 days at sea per year in 2001. Twenty-one vessels, or 41.2% of the 21 vessels operating in 2001, had annual landings in excess of 5,000 pounds. These 21 vessels averaged 40 days at sea per year. On the basis of reported landings, these vessels had a mean level of landings equal to 14,365 in 2001. In contrast, 43 vessels in 2001 landed less than the estimated capacity output of 14,361 pounds. They landed, on average, 3,690 pounds per vessel and accounted for a total of 158,667 pounds or 43.4% of the total landings in 2001. The average engine size was 434 horsepower, the average length per vessel was 36 feet, the average days at sea per year was 13.02, and the average crew size was 1.84.

Buyback Programs: Goals, Objectives, and Industry Restructuring

A major concern about reducing capacity is the potential reconfiguration of a fleet. The reduction of capacity could result in several outcomes, such as increased technical inefficiency or lower fleet profit than is possible. NOAA Fisheries and the various fishery management councils have not offered clear goals and objectives relative to the possibility of downsizing fleets or changing fishing strategies. Thus far, the only clearly stated goal is the maximum reduction of capacity given funding available for reducing capacity.

We examined technical efficiency and capacity utilization that would result from three possible objectives of a buyback program: maximization of technical efficiency, capacity utilization, and the number of boats to allow in the fishery. For comparative purposes, we also considered a capacity reduction program that removes predominantly part-time operators. We imposed arbitrary TAC levels; these are arbitrary because the South Atlantic Fisheries Management Council has not yet determined a TAC for the fishery. We initially estimated the number of vessels required to land the TAC, given that each vessel lands either the mean capacity level or the median capacity level (Table 5).

The next sets of analysis were for each of the three possible buyback program objectives (Table 6). The first considered the number of vessels required to harvest each TAC, given an objective of maximum technical efficiency for the fleet; for this analysis, we used annual estimates of capacity for each vessel averaged over the 1995–2001 period. For this case, technical efficiency scores were ranked from 1.0 (the most efficient) to higher values (the least efficient). The second analysis considered the number of vessels required to harvest each TAC, given the objective of maximizing capacity utilization. For the determination of the number of vessels given an objective of maximizing CU, CU scores were ranked from 1.0 (full capacity output) to lower values (lowest capacity utilization). The third analysis considered the objective of maximizing the number of vessels to remain in the fleet and harvest the TAC. For this analysis, capacity output levels were ranked from lowest to highest and then cumulatively summed and equated to the TAC. The capacity output levels rel-

Table 3. Estimates of Capacity, Capacity Utilization, and Full Variable Input Utilization, 1995–2001

	1995	1996	1997	1998	1999	2000	2001
Capacity utilization measure							
Minimum	0.75	0.55	0.68	0.77	0.41	0.57	0.76
Mean	0.96	0.96	0.95	0.96	0.94	0.95	0.95
Maximum	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Potential capacity output (lbs./vessel)							
Black sea bass							
Minimum	3	90	142	123	127	108	55
Mean	11,803	12,413	13,138	14,767	14,361	10,987	7,573
Maximum	83,056	102,370	137,456	114,907	93,495	72,472	121,358
Sum	637,386	906,182	1,064,153	1,048,482	933,444	670,184	783,399
Other species							
Minimum	0	0	0	0	0	0	0
Mean	1,219	1,996	2,547	2,013	2,132	1,965	3,009
Maximum	15,569	26,124	37,894	22,776	21,846	23,711	29,201
Sum	149,110	145,727	89,517	142,908	138,566	119,858	153,447
Effort requirements to produce capacity output (no./vessel)							
Crew size							
Minimum	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Mean	1.57	1.68	1.61	1.59	1.59	1.63	2.00
Maximum	2.47	3.00	2.25	2.21	2.25	2.00	3.00
Days absent							
Minimum	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Mean	17.3	17.3	20.6	19.6	19.0	15.7	24.0
Maximum	86.0	86.0	131.0	129.0	112.0	89.0	197.0

Table 4. Average and Optimal Values from DEA Results

	1995	1996	1997	1998	1999	2000	2001
Landings (lbs./vessel)							
Black sea bass							
Average	5,533	6,343	6,095	6,594	7,084	5,470	7,075
Capacity output	11,803	12,413	13,138	14,767	14,361	10,987	15,361
Cap./actual output	2.1	2.0	2.2	2.2	2.0	2.0	2.2
Other species							
Average	1,219	958	1,105	780	920	876	1,189
Capacity output	2,761	1,996	2,547	2,013	2,132	1,965	3,009
Cap./actual output	2.3	2.1	2.3	2.6	1.0	2.2	2.5
Effort							
Crew size (no./trip)							
Average	1.7	1.9	1.8	1.9	1.8	1.9	2.0
Optimal	1.6	1.7	1.6	1.6	1.6	1.6	2.0
Days absent (no.)							
Average	17.4	18.5	18.1	18.6	17.2	13.5	21.0
Optimal	17.3	20.1	20.6	19.6	19.0	15.7	24.0

ative to the rankings were then cumulatively summed to develop and overall or fleetwide measure of capacity utilization.

If management desired to reduce capacity, under the assumption of mean capacity over all vessels, to ensure that the fleet could not harvest in excess of a TAC of 250,000 pounds (Table 5), the maximum fleet size would be approximately 19 vessels. Alternatively, if managers desired to match the median capacity to the 250,000 TAC, the maximum fleet size would be approximately 52. Alternatively, if management desired to promote technical efficiency and match capacity to a TAC of 250,000 pounds, the maximum fleet size would be approximately 47 vessels (Table 6). In this latter case, however, management would need to explicitly target the vessels to remain in the fishery. Next, the maximization of capacity utilization and a TAC of 250,000 pounds would require a fleet size of 34 vessels (Table 6); again, however, management would have to explicitly identify those vessels to remain in the fishery. If management desired to maximize the number of vessels in the fleet with a TAC of 250,000 pounds, 81 vessels would remain in the fleet (Table 6).

Table 5. Fleet Size (no. of vessels) Required at Alternative TAC and Capacity Levels

	1995–2001 Capacity Output	
Potential TAC (lbs.)	Mean (13,253 lbs./year/vessel)	Median (4,853 lbs./year/vessel)
250,000	19	52
500,000	38	103
750,000	57	155
1,000,000	75	206
1,250,000	94	258
1,500,000	113	309

A TAC of 1.5 million pounds and vessels operating at the overall mean annual capacity would require an approximate fleet size of 113 vessels. If the objective of management was to maximize either technical efficiency or capacity utilization, the fleet size, respectively, could be as high as 102 or 100 vessels, which represents all vessels operating between 1995 and 2001. A TAC of 1.5 million pounds, however, is more than three times the level of landings reported in any year between 1995 and 2001.

Although it might be anticipated that ranking by technical efficiency would result in the least number of vessels, this is not the case for this fishery. There is no apparent pattern of technical efficiency relative to size. For ex-

Table 6. Results at Alternative TAC Levels Under Maximization Objectives

Max. Obj.	TAC (lbs.)	Fleet Size[a] (no. of vessels)	Mean CU	Mean TE	Ratio of Reported CU to Capacity Landings[b]
Technical efficiency (TE)					
	250,000	47	0.91	1.94	0.59
	500,000	57	0.91	2.20	0.54
	750,000	72	0.91	2.61	0.49
	1,000,000	79	0.91	2.81	0.47
	1,250,000	87	0.90	3.04	0.44
	1,500,000	102	0.90	3.56	0.40
Capacity utilization (CU)					
	250,000	34	1.00	4.92	0.46
	500,000	43	0.99	5.43	0.42
	750,000	64	0.98	5.17	0.41
	1,000,000	83	0.97	5.78	0.39
	1,250,000	91	0.96	5.94	0.38
	1,500,000	100	0.95	6.04	0.36
Fleet Size					
	250,000	81	0.91	5.02	0.40
	500,000	101	0.91	5.42	0.37
	750,000	113	0.91	5.73	0.35
	1,000,000	122	0.90	6.06	0.34
	1,250,000	130	0.90	6.06	0.33
	1,500,000	135	0.90	6.12	0.33

[a] Average annual efficiency scores sorted from 1.0 (most technically efficient) to higher values (least technically efficient) and capacity output cumulatively summed until it approximately equals the TAC.
[b] CU may be calculated using either the ratio of technically efficient output to capacity output or the ratio of reported output to capacity output. Färe, Grosskopft, and Kokkenlenberg suggest that CU should be calculated as the ratio of technically efficient output to capacity output. Many government agencies, however, often use the ratio of observed or actual output to capacity output as a measure of capacity utilization. This column reports the latter concept of CU.

ample, the engine horsepower required to maximize efficiency for the 47 vessels, given a TAC of 250,000 pounds, ranges from 80 to 671; the vessel length ranges from 18 to 68 feet. In essence, small vessels can be as efficient as larger vessels. The same reasoning applies to the determination of the number of vessels to maximize capacity utilization. Simply put, it is possible for many small vessels to more fully utilize their productive capacity than large vessels; thus, a larger number of vessels may be allowed to remain in the fishery for a given TAC.

In recent years, management has tended to promulgate regulations that either address issues related to full-time operators or to promote full-time operations. If a buyback program was designed to primarily eliminate the part-time operators in this fishery, the required number of vessels to remain in the fishery could be extremely low. Using days at sea as an indicator of level of activity in the fishery, and sorting from highest to lowest, the required number of vessels to remain in the fishery relative to each TAC would be as follows: (1) one vessel for a TAC of 250,000 pounds; (2) two vessels for a TAC of 500,000 pounds; (3) three vessels for a TAC of 750,000 pounds; (4) five vessels for a TAC of 1.0 million pounds; (5) seven vessels for a TAC of 1.25 million pounds; and (6) 10 vessels for a TAC of 1.5 million pounds.

Summary and Conclusions

NOAA Fisheries is quite concerned about the possibility that there is excess harvesting capacity in U.S. fisheries. It is recognized that excess capacity typically equates to economic waste and the potential for biological overfishing. NOAA Fisheries, the FAO, and various agencies of numerous foreign nations are seeking ways to measure capacity and, subsequently, reduce excess capacity in fisheries. One way of reducing capacity is the use of buyback programs. At present, the only objective apparently pursued by NOAA in conducting buyback programs is to reduce as much capacity as is possible, given a fixed budget for purchasing vessels.

We present results of an analysis of capacity and the subsequent restructuring of a fleet given different objectives of a buyback program. We selected the trap fishery for black sea bass because it is one of the less complex fisheries of the United States, but it still has many of the problems occurring in other fisheries. The analysis was based on DEA which is a mathematical programming approach that determines technical efficiency and capacity. The analysis required estimating capacity for two basic groupings, which were based on whether or not trip landings were only for sea bass or landings were composed of sea bass and other species. Subsequently, each group was further divided into five groups on the basis of a cluster analysis of vessel performance.

It was determined that there was excess capacity in this fishery in all years between 1995 and 2001. The fleet had the capability to harvest approximately 2.1 times the level of reported landings. The primary reason that the vessels did not operate at full capacity appears to be mostly related to technical inefficiency. The required increase in the number of days to operate at full capacity was quite small, relative to the reported number of days vessels actually operated in each year.

The results, however, reflect lower bound estimates of capacity output in the black sea bass fishery. First, because of inadequate data on vessel characteristics and variable input usage, it was not possible to estimate capacity output for all vessels landing sea bass between 1995 and 2001. Second, the estimates of capacity output pertain only to a subsection of the trap fishery; again, data limitations precluded consideration of all trap-fishing activity between 1995 and 2001. Third, some of the input or productive factors, which were assumed to be fixed factors of production, could be changed by vessel operators (e.g., number of traps and hauls and time fished). It would be expected that increasing the number of traps would increase the productive capacity of vessel operations.

A remaining issue is what should be the goals and objectives of any capacity reduction program. NOAA Fisheries and other agencies have not provided clear goals other than ensuring that capacity cannot exceed desired sustainable levels, and a buyback program should attempt to remove as much capacity as is possible subject to a fixed budget. For example, the capacity of a fleet should be less than or equal to a level to ensure that landings cannot exceed the maximum sustainable yield or some other biological target, and as much capacity as possible should be reduced, given the budget. As our analysis illustrates, different goals and objectives could result in different fleet configurations and the number of vessels remaining in the fishery. For example, if resource managers decided on a TAC of 250,000 pounds for the trap fishery and used the overall mean capacity output per vessel, a fleet size of 19 could be allowed in the fishery. If maximization of TE was of concern, a TAC of 250,000 pounds would require that only 47 vessels remain in the fishery. Alternatively, if managers desired to maximize CU, a TAC of 250,000 pounds would require a fleet size of 34 vessels. An objective of maximizing the number of vessels to allow in the fishery permits 81 vessels to remain in the fishery, given a TAC of 250,000 pounds. Last, if management desired to reduce capacity such that full-time vessels characterized fishing operations, a single vessel could remain in the fishery given a TAC of 250,000 pounds. Given such wide differences in the number of vessels and the associated differences in technical efficiency and capacity utilization, it is thus extremely important that NOAA Fisheries and the Councils establish clearly articulated goals and objectives of capacity reduction programs. Alternatively, they consider the potential ramifications of buyback programs on industry restructuring.

References

Ballard, K., and J. Roberts. "Empirical Estimation of the Capacity Utilization Rates of Fishing Vessels in 10 Major Pacific Fisheries." Washington, DC: U.S. Department of Commerce, National Marine Fisheries Service, 1978.

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

Coelli, T. "A Multi-Stage Methodology for the Solution of Oriented DEA Models." Paper presented at the Taipei International Conference on Efficiency and Productivity Growth, June 20–21, 1997.

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

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

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

Färe, R., S. Grosskopf, K. Kerstains, J. Kirkley, and D. Squires. "Assessing Short-Run and Medium-Run Capacity at the Industry Levels and Its Reallocation." Paper presented at the 10th biennial conference of the International Institute of Fisheries Economics and Trade, Oregon State University, July 2000.

Färe, R., S. Grosskopf, and J. Kirkley. "Multi-Output Capacity Measures and Their Relevance for Productivity." *Bulletin of Economic Research* 52,2(2000):101–12.

Kaufman, L., and P.J. Rousseeuw. *Finding Groups in Data: An Introduction to Cluster Analysis.* New York: John Wiley & Sons, 1999.

Kirkley, J.E., and D.E. Squires. "Measuring Capacity and Capacity Utilization in Fisheries." *Managing Fishing Capacity: Selected Papers on Underlying Concepts and Issues.* D. Grébov-al, ed. Food and Agriculture Organization (FAO) Fisheries Technical Paper 386. Rome: FAO, 1999.

Kirkley, J., J. Ward, J. Walden, and E. Thunberg. "The Estimated Vessel Buyback Program Costs to Eliminate Overcapacity in Five Federally Managed Fisheries: A Preliminary Report." Silver Spring, MD: Division of Fisheries Statistics and Economics, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 2002.

Klein, L.R. "Some Theoretical Issues in the Measurement of Capacity." *Econometrica* 18(1960):272–86.

U.S. General Accounting Office (GAO). "Entry of Fishermen Limits Benefits of Buyback Programs." Report to the House Committee on Resources. Publication No. GAO/RCED-00-120. Washington, DC: U.S. GAO, 2000.

Walden, J.B., J.E. Kirkley, and A.W. Kitts. "A Limited Economic Assessment of the Northeast Groundfish Fishery Buyout Program." *Land Economics* 79,3(2003):426–39.