CAPACITY AND CAPACITY UTILIZATION IN THE MEDITERRANEAN SMALL-SCALE FISHING FLEET: THE CASE STUDY OF THE NORTH SARDINIA

IDDA LORENZO (1) – PULINA PIETRO (1) – MADAU FABIO ALBINO (2)

(1) University of Sassari, Via E. De Nicola 1, 07100 Sassari (ITALY)

(2) National Institute of Agricultural Economics, Via E. De Nicola 1, 07100 Sassari (ITALY)

Abstract

As recognized by some authors, overcapacity is a problem that generally afflicts small-scale fisheries just much as any other. This study aims to estimate fishing capacity, technical efficiency, scale efficiency and capacity utilization in a particular segment of the Mediterranean small-scale fishery, i.e. the Northwest Sardinian fleet in Italy. To be more precise, our analysis was focused on a sample of 30 trawls that operate in the National Park of Asinara coastal seawaters. A non-parametric approach using a Data Envelopment Analysis (DEA) model was applied to estimate capacity and related measures. Furthermore, capacity and efficiency outputs were calculated under two different scenarios.

Keywords: small-scale fleet, fishing capacity, capacity utilization, technical efficiency Data Envelopment Analysis

---

1. Introduction

As well known, many of the fishery resources of the world are currently overexploited. For this reason, excess harvesting capacity is universally recognized as a major problem for fisheries throughout the world. Since the late 1990s – when the Food and Agriculture Organization of the United Nations (FAO) involved capacity issue as a priority into the political agenda - several institutional agreements and/or policies have been focused on reducing the overall fleet capacity.

Corresponding author: Fabio A. Madau Phone: (+39) 079 229259 Fax: (+39) 079 229356
E-mail: famadau@uniss.it

As highlighted by several authors, in order to manage fishing capacity and to reduce excess capacity, policy makers need to first evaluate the level of any overcapacity in a fleet (Kirkley and Squires, 2003; Pascoe, 2004; Ward *et al.*, 2004; Ward *et al.*, 2005). It means that information about the current and desired levels of capacity assumes a strategic relevance as to designee rational management regulations.

With reference to the European Union (EU), a sustainable balance between resources and the fishing capacity is today one of the main objectives of the Common Fisheries Policy (CFP). In order to promote this finality, EU introduced the Multi Annual Guidance Programmes (MAGPs) where capacity reduction goals are based on a long-term and measured in terms of fishing-effort; *i.e.* trough gross tonnage (GT) and engine kilowatt power (Kw) of the vessels.

Since January 2005, the CFP Reform has removed subsidies for modernisation and renewal of the fleet as to discourage an overcapacity increase. Furthermore, the new European Fisheries Fund (EFF) grants more attractive premiums into the fishing vessels decommissioning scheme and supports equipment and the modernisation of vessels only under reducing-capacity conditions [1].

Remanding to Lindebo (2003; 2005) for more details about capacity policies into the CFP and their inefficiencies, it is common opinion that historically CFP measures designed to reduce or eliminate overcapacity not achieve their goals because not fully targeted. According to Vestergaard (2005) and Lindebo (2005), among the others, a significant cause of this inefficiency is that since its institution CFP has focused policies on *capacity base* reduction. In other terms, capacity target has been estimated through the measurement of certain, relatively straightforward, physical characteristics of a fleet (GT and Kw). The rationale underlining at the basis of this criterion is the supposed linear relationship between fishing mortalities and the size of different fleets. In reality, in most fisheries this relationship is not linear due to presence of non constant returns of scale (Pascoe, 2004).

Substantially, CFP does not recognize distinction between *capacity base* – that is a physical measure of capacity – and *capacity output*, *i.e.* the maximum potential harvest that can produce a fleet if fully utilized. *Capacity output* is a technical and economic concept that reflects ability of vessels to catch fish. Related to this measure is *capacity utilization* that is the ratio between the observed output on capacity output and it could represent a measure of overcapacity in a fleet. Not recognizing capacity output and capacity utilization as parameters for calibrate reduction capacity policies implies that programmed reduction in capacity (base) could be not targeted towards the fleet segments with highest overcapacity.

[1] These supports serve to improve gear selectivity, fish quality, safety for employers, etc.

In the light of these considerations, Vestergaard (2005) affirms that "*…understanding the measurement and definitions of capacity are necessary conditions for designing an effective capacity management plan* (pag. 323)". It means that more research in the field of capacity estimation would be useful to better address CFP decisions.
On the other hand, assessment of capacity cannot be solely sufficient to guide policy to monitor excess capacity. Other measurers related to capacity can be useful in order to support policy decisions. In the last years, estimation of capacity utilization (*e.g.*, Dupont *et al.*, 2002; Kirkley *et al.*, 2002; Kirkley *et al.*, 2003a; Felthoven and Morrison Paul, 2004a), technical efficiency (*e.g.*, Kirkley *et al*., 1998; Alvarez, 2001; Kirkley *et al.*, 2002; Pascoe and Coglan, 2002), scale efficiency (*e.g.*, Guyader and Daures, 2005) productivity (*e.g*, Felthoven and Morrison Paul, 2004b), and variable inputs utilization rate (*e.g.*, Kirkley *et al.*, 2003b) have been becoming research topics among fisheries economists. For example, conjoint estimation of capacity utilization and technical efficiency enables to separate out two different effects that could contribute to not achieve the potential output: presence of a not fully utilized capacity and ability of individual fishers in using inputs in their disposability, respectively. A measure of capacity utilization less than one (capacity under-utilization) could represent the existence of overcapacity in the fishery, while a measure of technical efficiency less than one reflects a certain degree of inefficiency by part of fishers. In other terms, estimation of technical efficiency in a fleet consents to catch also the role of farmer's ability in determining a lack between observed and optimal output.
An important research issue is capacity and efficiency estimation when dealing with multi-species and small-scale fisheries (Kirkley and Strand, 1988; Alvarez and Orea, 2001; Dupont *et al.*, 2002; Kirkley *et al.*, 2002; Felthoven and Morrison Paul, 2004a). Since the fisheries economics literature on the theme already contains many capacity analyses on multi-output fisheries we shall not give an in-depth discussion about managing multi-product situations [2]. In this context, our specific attention is focused on modelling small-scale fishing capacity and efficiency.
As recognized by Cunningam and Greboval (2001), overcapacity is a problem that generally afflicts small-scale fisheries just much as any other. The "artisanal" (low revenues) and high labour intensive nature of this activity could generate a latent use of capacity. Indeed, when faced with very limited alternative employment, some conditions – *e.g.*, new vessels that operate in an open access area – could leads to reduce the days-at-sea and, therefore, to under-utilize capacity. Furthermore, often labour represents a non-elastic input as well as capital and

[2] For more details about literature on multi-outputs capacity and efficiency estimation, see Alvarez and Orea (2001).

fishers may find it relatively easy to begin fishing, but difficult do leave it. In other cases – where profitability is scarce and some employment alternatives exist – small-scale fishers tend to do contextually other activities and quickly switch to fishing if economic conditions warrant it (Cunningam and Greboval, 2001). It is a consequence that capacity tends to be only partially utilized.

A typical case of multi-output and small-scale fisheries into the EU is represented by the Mediterranean fisheries. About 80% of the EU Mediterranean fleet is composed by little vessels (length of hull ≤ 12 metres) that practice a multi-specific activity (European Commission, 2002). Managed prevalently in an artisanal way, however in many Mediterranean areas fishery plays an important role into local communities by an economic and social point of view [3].

On the other hand, despite the weight of Community Mediterranean fisheries, its peculiar characteristics and presence of *ad hoc* CFP instruments for managing excess capacity and natural resources, capacity and other related measures have been scarcely investigated in this small-scale fleet (Sabatella and Piccinetti, 2004; Coppola *et al.*, 2004; Signorello *et al.*, 2004).

This study aims to estimate fishing capacity, technical efficiency, scale efficiency and capacity utilization in a particular segment of the Mediterranean small-scale fisheries, *i.e.* the Northwest Sardinian fleet in Italy. To be more precise, our analysis was focused on a sample of trawls that operate in the National Park of Asinara coastal seawaters.

A Data Envelopment Analysis (DEA) model was used in order to evaluate 1) what is the maximum amount of output that the fleet can produce given available fixed inputs stocks and when the variable inputs are fully utilized; 2) the ability of fishers to obtain the best practice output from a given set of fixed and variables inputs; 3) the role of scale in conditioning technical efficiency; 4) the capacity utilization measure with respect to the observed output (biased measure) and to the efficient output (unbiased measure).

Capacity and efficiency outputs are also calculated taking into account an hypothetic scenario in which vessels would utilize the maximum number of days-at-sea allowed by Sardinian regulations and by climatic and other conditions not under fishers control.

Section 2 provides to briefly recall definitions of capacity and its some related measures. Section 3 illustrates the DEA model utilized in the analysis. Section 4 is focused on description of collected data and on used variables. Results and discussion are reported in Section 5, while some concluding remarks are illustrated in Section 6

[3] Many of the regions individuated by EU as strongly dependent on fishery are sited in the Mediterranean basin (European Commission, 2000).

2. Definition of capacity and related measures.

In 1999, the FAO organized an international technical conference in Mexico to discuss methods for the measurement of fishing capacity. The meeting was concluded with implementation of the International Plan of Action for management of Fishing Capacity in which capacity was defined as: *"…the maximum amount of fish over a period of time (year, season) that can be produced by a fishing fleet if fully utilized, given the biomass and age structure of the fish stock and the present state of the technology*" (FAO, 2000).

Substantially, FAO (2000) definition is equivalent to the definition provided by Johansen's (1968) about capacity in an production system, intended as "…*the maximum amount that can be produced per unit of time with existing plant and equipment, provided the availability of variable factors of production is not restricted*" (Johansen, 1968: p. 52) [4]. According to this definition, capacity reflects fishers ability to produce the maximum output with constraints in terms of the resources stock, technology and use of fixed inputs (Kirkley *et al.*, 2002). Thus, capacity is a short run concept because measures can change with stock fluctuations in a stock-flow production technology [5].

Capacity utilization is a primarily and output-oriented measure determined as the ratio between the observed output to the potential output (or *capacity ou*tput, *i.e*. the output attainable by fully utilization of inputs). Consequently, it represents the proportion of available capacity that is utilized by a fleet (Morrison, 1985; Kirkley and Squires, 2003; Kirkley *et al.* 2003a,b). Using the capacity definition reported above, capacity utilization cannot exceed unity (with full capacity equal to one). It implies that a value less than one indicates that trawls have the potential for greater production without having to incur major expenditures for new capital or equipment. As underlined by Pascoe (2004), capacity under-utilization can be taken as a "rough" indicator of problems of excess capacity in fisheries, because it may imply existence of excess capacity [6].

[4] Kirkley and Squires (1999) provide a discussion and listing of various approaches on capacity in fisheries.

[5] Because of its inherent nature, capacity reduction programs may be needed in the short run to control harvesting capacity, but they could not be fully functional to regulate excess capacity in a long run perspective (Ward *et al*, 2005). In a long run, presence of market incentives could force fishers to adjust their use of inputs to eliminate excess capacity. On the contrary, in a short run, capacity reduction measures are useful for eliminating overcapacity because of market does not provide the financial incentives aimed to induce fishers to alter their production process.

[6] Nevertheless, as already explained, normally excess capacity has to be considered in a long run perspective.

By an output-oriented perspective, *technical efficiency* is defined as the measure of the ability of a vessel to obtain the best production from a given set of inputs subject to the production technology, resource levels, weather conditions, and other technological constraints (Kirkley *et al.*, 1998; Pascoe and Coglan, 2002). The difference with respect to the capacity definition is that efficiency output is the maximum amount of output given a constrained disposability of both fixed and variable inputs [7].

Finally, *variable input utilization rate* measures the ratio of optimal variable input usage (*i.e.*, the level that gives full technical efficiency) to actual variable input usage (Kirkley *et al.*, 2003b).

3. Methodology

A multi-output and non-parametric approach using a Data Envelopment Analysis (DEA) model was applied on the collected data.

DEA is a *non-parametric* approach to estimate efficiency originally proposed by Charnes *et al.* (1978) and based on the Farrell's model (1957). It consents the estimation of efficiency in multi-output situations and without assuming *a priori* functional form for frontier production (Roland and Vassdal, 2000). Solving a linear programming problem, DEA calculates efficiency by comparing each production unit against all other units. The best practice frontier is represented by a piecewise linear envelopment surface. Therefore, efficiency scores arisen from DEA are invariant to technology, because obtained trough comparisons among an observation and each others and not with respect to an estimated frontier [8].

Given the nature of the research question, an output-oriented model was used to estimate capacity and efficiency (Alvarez, 2001; Kirkley *et al*, 2002).

Adopting the Johansen's (1968) definition of capacity output, capacity can be estimated by partitioning inputs according to whether they are fixed (F_x) or variable (V_x). We assumed that are J fishers that produce M outputs.

The DEA model derives a production frontier for a general technology, with variable factors unconstrained but the fixed factors, the state of technology, and environmental parameters constraining outputs. In other terms, the model holds fixed inputs constant and determines the maximal output that can be produced for any given level of fixed input (ad unconstrained variable factors).

[7] See Juliussen and Vassdal (2000) and Alvarez (2001) for more information about literature on technical efficiency estimation in fisheries.

[8] Use of DEA has been individuated as a possible tool to estimate capacity by the FAO (2000) and the International Plan of Action for management of Fishing Capacity (Lindebo *et al.*, 2007).

Capacity. The linear programming model for capacity (θ_1) estimation is described as follows (Pascoe *et al.*, 2003):

$$(1) \qquad \text{Max}_{\theta,z,\lambda} \quad \theta_1$$

$$\text{subject to:} \quad \theta_1 u_{jm} \leq \sum_{j=1}^{J} z_j u_{jm} \qquad \forall m$$

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

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

$$z_j \geq 0 \qquad \forall j$$

$$\lambda_{jn} \geq 0 \qquad n \in V_x$$

where θ_1 is a scalar measure of capacity, u_{jm} is the amount of output produced by vessel j, x_{jn} is the quantity of input n used by vessel j, z_j is the intensity variable for vessel j, and λ_{jn} is the input utilization rate by vessel j of variable input n.

The capacity score ($\theta_1 \geq 1.0$) reflects the percentage by which the production of each vessel's output can may be increased. The measure is the reciprocal of an output distance function and, therefore, it can be taken as indicator of the distance between the observed output and the maximum possible output, *i.e.* under fully utilization of fixed factors [9].

The linear programming model (1) describes a production function that operate under *constant returns of scale* (CRS), i.e. assuming that vessels operate on an optimal scale. This would assume that there is a linear relationship between inputs and outputs, *i.e.* a doubling of inputs results in a doubling of catches (Lindebo *et al.*, 2007). As already discussed above, in reality we have to take into account that in a short run trawls can operate under *variable returns to scale* (VRS).

Imposing the convexity constraint $\sum_{j=1}^{J} z_j = 1$ to (1), we can calculate a capacity score under a *variable returns of scale* (VRS) hypothesis (Guyader and Duares, 2005).

[9] For example, a value of 1.30 indicates that the capacity output equals 1.30 times the current observed output.

Technical efficiency. A technical efficiency score (θ_2) was obtained considering a frontier function with both fixed and variables factors as constrained inputs. Färe *et al.* (1989) suggest that technical efficiency of the firm (boat) *j* - imposing a *constant return of scale* (CRS) condition - may be obtained as a solution to the linear programming problem:

$$\text{(2)} \qquad \text{Max}_{\theta,z,\lambda} \quad \theta_2$$

$$\text{subject to:} \quad \theta_2\, u_{jm} \le \sum_{j=1}^{J} z_j\, u_{jm} \qquad \forall m$$

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

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

$$z_j \ge 0 \qquad \forall j$$

The DEA model (2) adds an additional constraint with respect the model (1). Because of the nature of linear programming, it implies that if the additional constraint is binding it should reduce the value of the solution (*i.e*, $\theta_2 \le \theta_1$).
Adding the convexity constraint to (2), a VRS technical efficiency can be estimated.

Scale efficiency. Scale efficiency (SE) is calculated as the ratio between the two CRS and VRS technical efficiency radial measures (Cooper *et al.*, 2000):

$$\text{(3)} \qquad SE = \frac{1}{\theta_2^{CRS}} / \frac{1}{\theta_2^{VRS}} = \frac{\theta_2^{CRS}}{\theta_2^{VRS}} \qquad SE \le 1$$

SE measures the role of scale in conditioning inefficiency. A SE measure close to unity indicates that scale slightly affects inefficiency.

Capacity output. As consequence of (1) and (2), capacity output (Y_C) and efficient output (Y_{TE}) are equal respectively to:

$$\text{(4)} \qquad Y_C = \theta_1 \cdot u$$

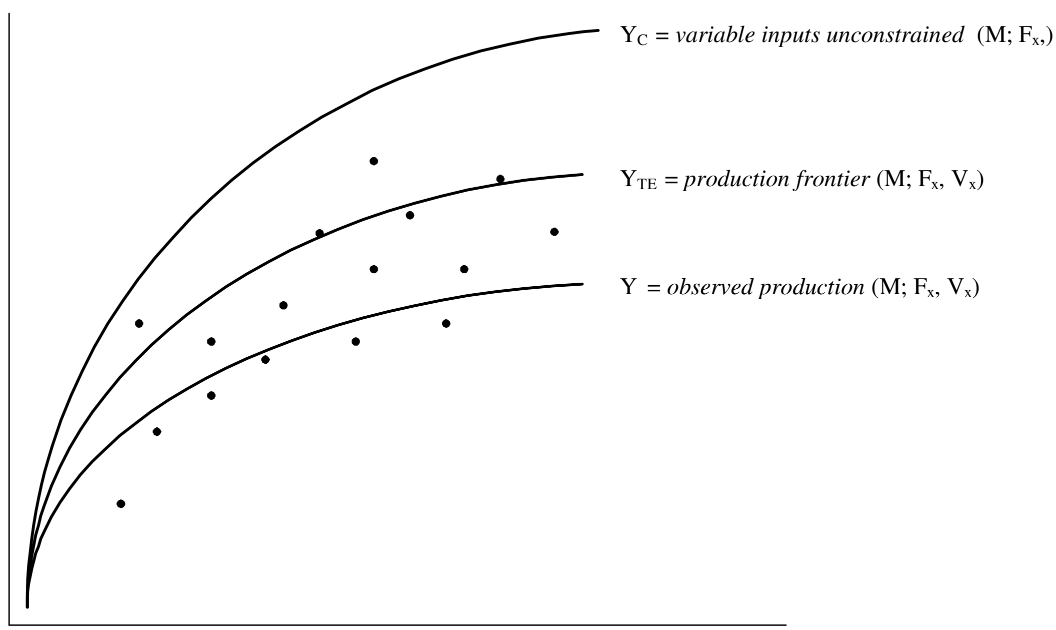
$$\text{(5)} \qquad Y_{TE} = \theta_2 \cdot u$$

where u is vector of output that indicates the observed production (Y).

Capacity utilization. Figure 1 illustrates the observed (Y), efficient (Y_{TE}) and capacity (Y_C) production curves. Capacity utilizations (CU) represents the proportion of available capacity that is utilized, which is measured by the ratio of actual output to capacity output (Morrison, 1985). Following this definition a CU measure can be derived as:

(6) $$CU = \frac{Y}{Y_C} = \frac{u}{\theta_1 \cdot u} = \frac{1}{\theta_1} \qquad 0 \leq CU \leq 1$$

Figure 1 – Actual, Efficient and Capacity production functions



A shortcoming of this measure is that problems that originate in the measurement of Y_C (*e.g.*, measurement errors or distortions due to presence of exogenous variables as such weather), also carry over into the resulting CU estimates. According to Kirkley *et al.* (2002), one way to minimize the impacts of these problems is to compute "unbiased" estimates as suggested by Färe *et al.* (1989), as follows:

$$(7) \qquad CU' = \frac{Y_{TE}}{Y_C} = \frac{\theta_2 \cdot u}{\theta_1 \cdot u} = \frac{\theta_2}{\theta_1} \qquad 0 \leq CU' \leq 1$$

that represents the proportion of available capacity that is utilized, if vessels operate under a full technical efficient condition (*i.e.*, without technical inefficiency).

Input utilization rate. Finally, the variable input utilization rate (U) measures the ratio of optimal variable input usage (best practice frontier) to observed input usage (Kirkley *et al*., 2003b):

$$(8) \qquad U = \frac{x_n^{TE}}{x_n}$$

where x_n^{TE} is the efficient level of usage for input *j*. The coefficient can exceeds 1.0 in value and it implies a shortage of the variable input *n* currently employed and the fisher should expand use of that input. On the other hand, if the ratio is less than 1.0, there is a surplus of the input and the fisher should reduce its use.

4. The Sardinian fleet and the data.

4.1 Characteristics of Sardinian small-scale fisheries

The Sardinian fleet is mostly composed by “artisanal” trawls. More exactly, about 78% of the vessels are small-scale boats that operate close to the coastal seawaters (IREPA, 2007). By an economic point of view, small-scale fisheries is characterized by a scarce capital endowments, a few number of crew by vessel and a not adequate profitability (Idda and Pulina., 2004).

Despite importance in terms of number of vessels, contribute of this small-scale segment in Sardinian fisheries production is not satisfying. Indeed, only the 45% of total fisheries revenue is generated from small-scale fleet (IREPA, 2007). On the other hand, in some areas small-scale fishery plays a significant role into local communities. In some localities of the Northwest Sardinia, for example, a not marginal quota of residents are employed in small-scale activity.

With regards to the number of annual days-at-sea, generally a day-at-sea corresponds to a trip, and each boat practices activity for, on average, 135 annual days-at-sea (Idda *et al*., 2004).

Since 1991 (Regional Law n. 25/91) Sardinian Administration has introduced some regulatory measures in order to limit the fishing effort. More specifically, Sardinian government has forced fishers to temporary interrupt their activity trough two measures that provide cessation for 160 days during the year (Idda and Madau, 2004):

- a continuative and obligatory 45 days temporary cessation (the period can vary in accordance to fishing system, nature of the stock, biological and territorial reasons);
- an interruption of the activity during the weekends (total of 115 days) [10].

In the light of these measures and of other physiologic interruptions (due to weather, availability of work, etc), actually the maximum number of days would amount to about 165-175 for vessel.

4.2 The data

Analysis is focused on the small-scale fisheries practiced in the National Park of Asinara coastal seawaters. The Park is sited in the Northwest of Sardinia and it represents a natural environmental area extended around the Asinara island. In this area, the fleet operating close to the coasts is totally composed by small-scale boats (55 vessels).

During the 2003, we carried out a questionnaire survey on 30 small-scale fishers as to obtain information about of vessels and activity. Collected data contain information about technical characteristics of each vessel, socio and economic characteristics of fishers, accountability data and annual catches for each species. As a consequence, despite a few number of observations, it enables to describe relationship between (fixed and variable) inputs and outputs. Availability of these data - especially data on capital investments and monetary value of inputs and outputs - should permit to (partially) overall one of the most typical problem that affect frontier production analysis and capacity and efficiency estimation in fisheries, *i.e.* the limitation of useful economic data directly linked to production function (Kirkley *et al.*, 2003a; Lindebo 2005).

The variables involved into the analysis are reported in table 1.

Seven outputs were involved in the analysis and catches were measured in terms of euros of landed fish or other species landed per day-at-sea. According to Alvarez (2001), value should be the logical measure for outputs when a multi-output approach is applied in the fisheries. In fact, if the basic assumption is that fishers take decisions regarding catch composition, as consequence production in capacity and efficiency analysis should be measured in terms of value[11]. On the other hand, as to reduce distortion among observed vessels due to prices fluctuations over the 2003, we utilized fixed prices, calculated as the annual average value for

[10] The temporary cessation program is supported by compensatory aids that serve to reward fishers for interruptions.

[11] Alvarez (2001) underlines "*The fact that fishers obtain species of different value when they lift the nets or line is not very different from the farmer who plants cherries and obtains fruits of different sizes, which carry different prices in the market (*p. 10)".

each output. However, this procedure appears consistent with assumption of a primal approach for estimation of frontier production.

Fishes are subdivided in four categories according to their inherent product quality. The first class involves the most appreciated kind of fishes (*e.g.*, gilthead), while by contrast the fourth class regards the worse category by the commercial point of view. The other three outputs represent catches of molluscs, crustaceans (except for lobsters) and lobsters, respectively.

Table 1 – Description of analysis variables – Annual values

Variable		Description	Mean	Min	max
OUTPUTS (7)					
I Class fishes *(euros)*	Y_1	Value of high quality fish	4,256	*619*	*13,802*
II Class fishes *(euros)*	Y_2	Value of medium-high quality fish	3,429	*299*	*18,923*
III Class fishes *(euros)*	Y_3	Value of medium-low quality fish	575	*205*	*1,897*
IV Class fishes *(euros)*	Y_4	Value of low quality catch fish	380	*17*	*1,927*
Molluscs *(euros)*	Y_5	Value of squids, octopuses, etc	1,628	*17*	*9,429*
Crustaceans *(euros)*	Y_6	Value of crayfishes, shrimps, etc.	6,300	*12*	*17,541*
Other species *(euros)*	Y_7	Value of lobsters	6,328	*26*	*50,107*
FIXED INPUTS (4)					
Length of hull (*metres*)	X_1	-	9.46	5.06	11.85
Gross tonnage (*tons*)	X_2	-	5.59	1.38	9.99
Engine horsepower (*HP*)	X_3	-	146.17	18	550
Fixed capitals on boat (*euros*)	X_4	Annual depreciation quote of capital	4,128	760	17,497
VARIABLE INPUTS					
Crew	Z_1	Number of crew	2.03	1	5
Nets	Z_2	Annual expenditure for nets	1,693.47	270	5,286
Fuel	Z_3	Annual expenditure for fuel	3,061.77	245	11,698
DAYS-AT-SEA			140.5	75	170

Regarding inputs involved in the analysis, the production function was explained by four fixed and three variable factors. The formers were represented by the length of the hull (x_1), the gross tonnage (x_2) and the engine power (x_3) of the vessels. Furthermore, we involved also the value of the capital (x_4) – measured in terms of annual depreciation quote – as to take into account also the monetary value of investments on the boats. The variable inputs were defined as the number of crew (z_1), the expenditure for nets (z_2) and the expenditure for fuel (z_3).

In our analysis, days-at-sea is not treated as a variable input, because capacity and efficiency estimation was conducted with respect to a single day-at-sea.

According to Kirkley and Squires (2003) and Kirkley *et al*. (2003a), some of the possible reasons for the differences in the number of days-at-sea (or trip) among vessels that are relatively homogeneous in terms of characteristics derive from factors that are not under the control of fisher (*e.g.*, weather). Using a DEA approach, it implies that presence of some conditions that obstacle practice could affect capacity estimation for a certain vessel. Capacity estimation refereeing to catches and inputs usage for a single day-at-sea would allow to overcome this eventual shortcoming.

For this reason, in a first step, we calculated capacity and efficiency on single day-at-sea and, in a second step, we estimated capacity and efficiency output with respect both to: 1) the observed number of days-at-sea for each vessel; 2) the maximum possible number of days-at-sea that small-scale fishers can make in accordance to Sardinian regulation and other factors.

In the light of survey responses, the upper limit was fixed at 170 days-at-sea.

5. Results and discussion

Table 2 reports shows finding about capacity, technical efficiency, scale efficiency and capacity utilization arisen from empirical analysis.

Table 2 - Capacity and efficiency measures in the Northwest Sardinian fleet

	Capacity (θ_1)	**Efficiency (θ_2)**	**Scale Efficiency (SE)**	**Capacity Utilization (CU)**	
				biased CU	***unbiased CU'***
			CRS		
Mean	**1.432**	**1.243**	-	**0.783**	**0.908**
s.d	*(0.651)*	*(0.386)*		*(0.219)*	*(0.144)*
			VRS		
Mean	**1.253**	**1.163**	**0.901**	**0.865**	**0.964**
s.d	*(0.531*	*(0.258)*	*(0.133)*	*(0.182)*	*(0.109)*

Capacity and efficiency. Results indicate that estimated capacity is equal to 1.432 and 1.253 if measured under CRS and VRS hypothesis, respectively. Since in this study capacity scores are calculated as an output-oriented measure, it suggests that vessels could increase, on average, catches by about 25.3% if they were operating at full capacity (under a VRS condition).

As consequence, it means that there is a sensitive room of not utilized capacity in the small-scale fleet that operate in the National Park of Asinara seawaters. This margin corresponds to 13.5% (unbiased CU = 0.865).

In the short run, this result suggests that the Northwest Sardinian small-scale fleet shows a certain degree of overcapacity. Indeed, a CU sensitively less than one should indicate that small-scale fishers have the potential for grater production (catches) without having to increase expenditure for new capital or for enhancing capacity base of their vessel. Estimated overcapacity could represent an indicator for the presence of excess capacity in a long-run perspective. On the other hand, lack of data on fishing stock in the investigated area does not permit to evaluate significance of this risk.

Technical efficiency amounts to 1.163 (1.243) under VRS (CRS) hypothesis, indicating that fishers would be able to increase output by 16.3% (24.3%) with the present state of technology, using their disposable variable and fixed inputs more efficiently.

Biased capacity utilization lies close to full (CU' = 0.964) and it implies that only a slight quota of capacity (3,6%) would result not utilized when fishers operate at full efficiency.

Since the CU scores measured on the actual output and on the best practice output are sensitively different, it suggests that technical inefficiency affects significantly capacity.

Table 3 – Single inputs utilization rate

	Crew	**Nets**	**Fuel**
U	0.933	0.876	0.932
d.s.	*(0.101)*	*(0.195)*	*(0.143)*

Therefore, improvement of efficiency would move to increase the quota of utilized capacity.

Regarding this problem, estimation of scale efficiency suggests that achievement of an optimal scale should reduce technical inefficiency by about 6% (SE = 0.901).

Imposing a *non-increasing return of scale* (NIRS) condition in the DEA model - *i.e.* changing the convexity constraint in the VRS DEA model – we calculated that more that 40% of the observed vessels operate in an increasing return of scale area, while the scale would be optimal for the 50% of the boats. The good incidence of vessels under increasing return of scale is an expected result in a small-scale fishery, but SE score indicates that efficiency in the sample depends weakly by this problem.

Variable inputs utilization rates estimation gives supplementary information about inefficiency. As reported in table 3, both U_{crew} and U_{fuel} amount to 0.933, implying that there is a surplus of crew and fuel employed by 6.7%.

Table 4 – Single outputs VRS capacity and efficiency scores

	I Class	II Class	III Class	IV Class	Molluscs	Crustaceans	Lobsters	TOTAL
Capacity	1.188	1.439	1.187	1.266	1.531	1.196	1.225	**1.253**
s.d.	*(0.225)*	*(0.348)*	*(0.210)*	*(0.280)*	*(0.370)*	*(0.230)*	*(0.253)*	***(0.531)***
Efficiency	1.130	1.385	1.140	1.220	1.479	1.180	1.217	**1.163**
s.d.	(0.163)	(0.339)	(0.187)	(0.263)	(0.371)	(0.212)	(0.255)	**(0.258)**

Table 5 – Observed, efficient and capacity outputs – per single day-at-sea (euros)

	I Class	II Class	III Class	IV Class	Molluscs	Crustaceans	Lobsters	TOTAL
Observed output	31.76	26.04	4.32	2.80	12.13	42.64	46.92	**166.61**
min.	*6.50*	*1.99*	*1.74*	*0.23*	*0.10*	*0.10*	*0.21*	***37.22***
max.	*98.59*	*135.57*	*14.05*	*13.76*	*67.35*	*135.65*	*357.91*	***657.85***
Efficiency output	34.39	30.29	5.04	3.18	13.30	50.46	48.35	**185.41**
Min.	*6.50*	*2.26*	*1.74*	*0.27*	*0.18*	*0.10*	*0.21*	***37.22***
max.	*98.59*	*135.57*	*14.05*	*13.76*	*67.35*	*135.65*	*357.91*	***657.85***
Capacity output	36.47	31.57	5.30	3.30	14.09	51.15	48.42	**199.32**
min.	*6.50*	*2.26*	*1.74*	*0.27*	*0.18*	*0.10*	*0.21*	***41.72***
max.	*98.59*	*135.57*	*14.05*	*13.76*	*67.35*	*135.65*	*357.91*	***657.85***

Table 6 – Observed, efficient and capacity outputs – per observed days-at-sea (euros

	I Class	II Class	III Class	IV Class	Molluscs	Crustaceans	Lobsters	TOTAL
Observed output	4,256	3,429	575	380	1,628	6.300	6.328	17,661
min.	619	299	204	17	17	12	26	3,945
max.	13,802	18,923	1,897	1,926		17,541	50,106	69,661
Efficient output	4,644	3,934	662	432	1,823	7,722	6.467	19,653
min.	747	299	244	35	17	12	26	3,945
max.	13,802	18,923	1,897	1,926	9,429	18,988	50,106	69,661
Capacity output	4,895	4,366	704	457	1,913	7,818	7,153	21,128
min.	747	339	244	36	27	12	26	4,422
max.	13,802	18,923	1,897	1,926	9,429	19,149	50,106	69,661

Table 7 – Observed, efficient and capacity outputs – per 170 days-at-sea (euros)

	I Class	II Class	III Class	IV Class	Molluscs	Crustaceans	Lobsters	TOTAL
Observed output	5,400	4,426	734	476	2,062	7,248	7,975	28,323
min.	1,105	338	296	38	17	17	35	6,327
max.	16,759	23,046	2,388	2,339	11,449	23,061	60,844	111,834
Efficient output	5,846	5,149	856	540	2,261	8,578	8,219	31,519
min.	1,105	384	296	45	30	17	35	6,327
max.	16,759	23,046	2,388	2,339	11,449	23,061	60,844	111,834
Capacity output	6,199	5,366	900	560	2,395	8,695	8,231	33,884
min.	1,105	384	296	45	30	17	35	7,092
max.	16,759	23,046	2,388	2,339	11,449	23,061	60,844	111,834

The surplus of nets is higher than estimated for the former inputs (U_{nets} = 0.876). In other terms, fishers should reduce use of that inputs as to improve efficiency.

Capacity and efficiency outputs. Table 4 reports the capacity and efficiency scores for single outputs. Findings indicate that fully utilization of capacity should increase catches of each output (margin varies form 18,7% of III Class fish to 53,1% of molluscs).

On the basis of these scores we calculated the capacity and efficiency outputs for a single day-at-sea (table 5).

Empirical evidence suggests that the total value of the catches should shift from EUR 166.61 to EUR 185.41 per day-at-sea if small-scale fishers were operating using efficiently inputs in their disposability. Furthermore, full capacity utilization should increase catches until about EUR 200 per single day.

According to our results, small-scale fishers should be able to enhance their annual production by about, on average, EUR 2,000 (from EUR 17,661 to EUR 19,653) using efficiently their resources and without increasing the number of days-at-sea (as reported in Table 1, the number of observed days-at-sea in the sample is equal, on average, to 140.5). Capacity output at annual level corresponds, on average, to EUR 21,128, implying a possible growth of catches equal to EUR 3,467.

Multiplying capacity and efficiency scores by the maximum estimated number of days-at-sea that fishers can operate in the coastal waters of Northwest Sardinia (170 days-at-sea) we obtained a value of capacity and efficiency output that take into account eventuality that each vessel can make every day allowed by regional normative and other climatic or not specific unforeseen events. In this way, we minimize the risk that capacity output measure can be affected by some external factors (not under the control of fishers) that, in a certain time, obstacles some fishers to practice activity.

In this scenario, observed output amounts, on average, to EUR 28,323. Full efficiency could rise catches until to 31,519 (+11.2%), while full utilization of capacity should switch catches until to EUR 33,884 (+19.4%).

In our opinion, the last estimated capacity output can be an useful information in supporting *policy makers* in the decision process in order to better calibrate regulatory measures on capacity control for small-scale fisheries. Indeed, this measure reflects the maximum output that a fleet can produce given certain disposable days-at-sea. Specifically, in the case of Sardinia it could serve in a short run to verify efficacy of the temporary cessation measures and, especially, to estimate potential capacity output according to different levels of provided day-at-sea interruptions.

On the other hand, also in the light of these findings, in order to designee efficient policies and to address efficiently measures it becomes a priority to individuate the underlying causes that are at the basis of overcapacity and inefficiency in the small-scale segment.

6. Conclusions

The present case study was focused on estimate capacity and efficiency in a segment of the Northwest Sardinian small-scale fisheries. Among the others, results arisen from analysis suggest that capacity is not fully utilized by fishers and technical inefficiency contributed the most to determine a not fully utilization.

Obviously, this analysis reflects only a case study and more research needs to have good information about capacity and efficiency in Sardinia and in the Mediterranean sea, especially in order to have more in-depth data for address management regulations.

References

Alvarez A., Orea L. (2001): *Different Approaches to Model Multi-species Fisheries Using a Primal Approach*, Efficiency Series Paper 3/2001, Università di Oviedo.

Alvarez A. (2001): *Some Issues in the Estimation of Technical Efficiency in a Fishery*, Efficiency Series Paper 2/2001, Università di Oviedo..

Charnes A., Cooper W.W., Rhodes E. (1978): Measuring the Efficiency of Decision Making Units, *European Journal of Operational Research,* Vol. 2: 429-444

Cooper W.W., Seiford L.M.., Tone K. (2000): *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-solver Software*, Boston, Kluwer Academics Publishers.

Coppola G., Gambino M., Spagnolo M. (2004): *Alternative Approaches to Evaluating Mulitspecies Fishery Efficiency*, paper discussed at the XII Biennal Conference of the International Institute of Fisheries Economics and Trade (IIFET), Tokyo, July 2004.

Cunningam S., Greboval D. (2001): *Managing Fishing Capacity: A Review of Technical and Political Issues*, FAO Fisheries Technical Paper 409, Rome, FAO

Dupont D.P., Grafton R.Q., Kirkley J., Squires D. (2002): Capacity Utilization Measures and Excess Capacity in Multi-Product Privatized Fisheries, *Resource and Energy Economics,* 24 (3): 193-210.

European Commission (2000): *Regional Socio-Economic Studies on Employment and the Level of Dependency in Fishing*, Final Report Lot. No. 23, Brussels.

European Commission (2002): *A Community Action Plan for the conservation and sustainable exploitation of fisheries resources in the Mediterranean Sea under the Common Fisheries*

Policy, Communication from the Commission to the Council and the European Parliament, COM (2002) 535 final, Brussels.

FAO (2000): *Report of the Technical Consultation on the Measurement of Fishing Capacity*, FAO Fisheries Report 615, Rome, FAO.

Färe R., Grosskopf S., Kokkelenberg E.C. (1989): Measuring Plant Capacity, Utilization and Technical Change: A Non-parametric Approach, *International Economic Review*, 30 (3): 655-666.

Farrell M.J. (1957): The Measurement of Productive Efficiency, *Journal of the Royal Statistical Society*, A 120 part 3: 253-290.

Felthoven R.G., Morrison Paul C.J. (2004a): Multi-Output, Nonfrontier Primal Measures on Capacity and Capacity Utilization, *American Journal of Agricultural Economics*, 86 (3): 619-633.

Felthoven R.G., Morrison Paul C.J. (2004b): Directions for Productivity Measurement in Fisheries, *Marine Policy*, 28 (2): 161-169.

Guyader O, Daures F. (2005): Capacity and Scale Inefficiency: Application of Data Envelopment Analysis in the case of the French Seaweed Fleet, Marine Resources Economics, 20 (4): 347-365.

Idda L., Madau F.A. (2004): *Il quadro normativo nazionale e regionale*, in Idda L. (ed.): *Pesca e Acquacoltura in Sardegna: Competitività, sostenibilità, politiche, strategie*, Sassari, Tipografia Editrice Giovanni Gallizzi.

Idda L., Pulina P. (2004): *I risultati economici delle imprese della piccola pesca*, in Idda L. (ed.): *Pesca e Acquacoltura in Sardegna: Competitività, sostenibilità, politiche, strategie*, Sassari, Tipografia Editrice Giovanni Gallizzi.

Idda L., Pulina P., Rubino C. (2004): *Il comparto ittico in Sardegna: uno sguardo d'insieme*, in Idda L. (ed.): *Pesca e Acquacoltura in Sardegna: Competitività, sostenibilità, politiche, strategie*, Sassari, Tipografia Editrice Giovanni Gallizzi.

IREPA (2007): *Osservatorio economico sulle strutture produttive della pesca marittima in Italia 2005*, IREAPA ricerche, Milano, Franco Angeli.

Lindebo E. (2003): *Fishing Capacity and European Union Fleet Adjustments*, in Pascoe S., Greboval D. (eds.): *Measuring Capacity in Fisheries*, FAO Fisheries Technical Paper 445, Rome, FAO.

Lindebo E. (2005): Role of Subsidies in EU Fleet Capacity Management, *Marine Resources Economics*, 20 (4): 445-466.

Lindebo E., Hoff A., Vestergaard N. (2007): Revenue-based Capacity Utilization Measures and Decomposition: The Case of Danish North Sea Trawlers, *European Journal of Operational Research*, 180 (1): 215-227.

Johansen L. (1968): *Production Functions and the Concept of Capacity*, in Reserches recentes sur la function de production, Namur, Centre d'Etudes et de la Recherche Universitaire de Namur.

Juliussen V.., Vassdal T. (2000): *Measuring of Productive Efficiency in Commercial Fisheries in the European Economic Area*, in Pascoe S., Fousakis P., Herrero I., Juliussen V., Mardle S., Roland B.E., Vassdal T. (eds.): *Technical Efficiency in EU Fisheries: Methodological Report*, TEMEC Working Paper I, University of Portsmouth.

Kirkley J., Strand I.E.. (1988): The Technology and Management of Multi-species Fisheries, *Applied Economics*, 20 (10): 1279-1292.

Kirkley J., Squires D., Strand I.E. (1998): Characterizing Managerial Skill and Technical Efficiency in Fishery, *Journal of Productivity Analysis*, 9 (2): 145-160.

Kirkley J., Squires D. (1999): *Measuring Capacity and Capacity Utilization in Fisheries*, in Greboval D. (ed.): *Managing Fishing Capacity; Selected Papers on Underlying Concepts and Issues*, FAO Fisheries Technical Paper 386, Rome, FAO.

Kirkley J., Squires D. (2003): *Capacity and Capacity Utilization in Fishing Industries*, in Pascoe S., Greboval D. (eds.): *Measuring Capacity in Fisheries*, FAO Fisheries Technical Paper 445, Rome, FAO.

Kirkley J., Morrison Paul C.J.M., Squires D. (2002): Capacity and Capacity Utilization in Fishing Industries: Definition, Measurement and a Comparison of Approaches, *Environmental and Resource Economics*, 22 (1): 71-97.

Kirkley J., Färe R., Grosskopf S., McConnell K., Squires D., Strand I. (2003a): *Assessing Capacity and Capacity Utilization in Fisheries when Data are Limited*, in Pascoe S., Greboval D. (eds.): *Measuring Capacity in Fisheries*, FAO Fisheries Technical Paper 445, Rome, FAO.

Kirkley J., Squires D., Alam M.F., Ishak H.O. (2003b): Excess Capacity and Asymmetric Information in Developing Country Fisheries: the Malaysian Purse Seine Fishery, *American Journal of Agricultural Economics*, 85 (3): 647-662.

Morrison C.J.M. (1985): Primal and Dual Capacity utilization: an Application to Productivity Measurement in the U.S. Automobile Industry, *Journal of Business and Economic Statistics*, 3: 312-324.

Pascoe S. (2004): *A framework for capacity appraisal in fisheries*, in *AdriaMed Seminar of Fishing Capacity: Definition, Measurement and Assessment*, AdriaMed Technical Documents n. 13, Termoli (Italy).

Pascoe S., Coglan L. (2002): The Contribution of Unmeasurable Inputs to Fisheries Production: An Analysis of Technical Efficiency in Fishing Vessels in the English Channel, *American Journal of Agricultural Economics*, 84 (3): 585-597.

Pascoe S., Kirkley J., Greboval D., Morrison Paul C.J.M. (2003): *Measuring and Assessing Capacity in Fisheries. Issues and Methods*, FAO Fisheries Technical Paper 433/2, Rome, FAO.

Roland B.E., Vassdal T. (2000): *Estimation of Technical Efficiency using DEA*, in Pascoe S., Fousakis P., Herrero I., Juliussen V., Mardle S., Roland B.E., Vassdal T. (eds.): *Technical*

Efficiency in EU Fisheries: Methodological Report, TEMEC Working Paper I, University of Portsmouth.

Sabatella E., Piccinetti (2004): *Example of Capacity Assessment of a Mediterranean Fisheryand Relevant Bio-economic Indicators*, in *AdriaMed Seminar of Fishing Capacity: Definition, Measurement and Assessmen*t, AdriaMed Technical Documents n. 13, Termoli (Italy).

Signorello G., De Salvo M., Maietta O.W. (2004): Stima non parametrica dell'efficienza produttiva e della capacity della pesca nel Basso Ionio, Rivista di Economia Agraria, 59 (2): 207-231.

Vestergaard N. (2005): Fishing Capacity in Europe: Special Issue Introduction, *Marine Resources Economics*, 20 (4): 323-326.

Ward J.M., Kirkley J., Metzner R., Pascoe S. (2004): *Measuring and Assessing Capacity in Fisheries. Basic Concepts and Management Options*, FAO Fisheries Technical Paper 433/1, Rome, FAO.

Ward J.M., Mace, P., Thunberg E. (2005): The Relationship of Fish Harvesting Capacity to Excess Capacity, *Marine Resources Economics*, 19 (4): 525-529.

Nome file: Idda_Pulina_Madau
Directory: C:\Documents and Settings\admin\Documenti\DESA\Pesca\EAFE 2007\def
Modello: C:\Documents and Settings\admin\Dati applicazioni\Microsoft\Modelli\Normal.dot
Titolo: CAPACITY AND CAPACITY UTILIZATION IN THE MEDITERRANEAN SMALL-SCALE FISHING FLEET: THE CASE STUDY OF THE NORTH SARDINIA
Oggetto:
Autore: fabio
Parole chiave:
Commenti:
Data creazione: 20/09/2007 12.32
Numero revisione: 2
Data ultimo salvataggio: 20/09/2007 12.32
Autore ultimo salvataggio: fabio
Tempo totale modifica0 minuti
Data ultima stampa: 20/09/2007 12.34
Come da ultima stampa completa
Numero pagine: 21
Numero parole: 6.655 (circa)
Numero caratteri: 37.938 (circa)