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Excess capacity and sustainable development in Java Sea fisheries

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ABSTRACT. Excess capacity and overfishing are problems in the open-access, common-pool fisheries of the Java Sea. Data development analysis is used to estimate excess fishing capacity and the number of vessels to decommission in three Java Sea fisheries of Indonesia, the purse seine, mini purse seine, and longline. First- and second-best policy measures are discussed to reduce the excess capacity and give sustainable management and development. The importance of incentive design, asymmetric information, and the regulator's principal–agent problem are emphasized in license limitation programs.

1. Introduction

Indonesia, like many developing countries, has long followed a fisheries development policy aimed largely at expanding fishing capacity, and this

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is particularly evident in the Java Sea. Fisheries development frequently focused on the harvesting sector and pursued resource development through expanded fishing capacity, catches, and productive efficiency rather than sustainable resource management and development policies intended to match capacity with target sustainable yields from the resource stock (Sarjono, 1980; Bailey, Dwiponggo, and Marahudin, 1987; McElroy, 1991; Bailey, 1997; Priyono and Sumino, 1997).

A number of factors contributed to the expansion of fishing capacity in the Java Sea. Policy emphasis placed on production credit, infrastructure development, fishery training programs, and dissemination of more advanced fishing technology all contributed to the build up of fishing capacity. Unimpeded construction of purse seine vessels, backed by publicly provided credit, and conversion from trawlers to the purse seine gear helped counter capacity reduction from the trawl ban. An increasing number of new entrants into the fishery, the result of the high population growth rate in the coastal areas, also expanded fishing capacity for the fleet as a whole. Open access and the largely laissez-faire policy on access rights, albeit the latter restricted by vessel size in a zone radiating from shore, did little to limit fishing capacity. The weak and limited enforcement of the zones and no restrictions on access effectively attenuated any capacity-reducing impacts. Moreover, Licenses for 5–30 GRT vessels can be issued in any province and used by boats to fish in waters in other provinces. Many fishing vessels are believed to be operating on copies of licenses issued to single vessels.

The capacity-expanding development policies have led the Java Sea fisheries to a point of excess capacity in the harvesting sector. These policies are not sustainable, and have largely driven most resource stocks and harvest rates to below those corresponding to maximum sustainable yield (McElroy, 1991). Sustainable resource management is intertwined with sustainable development in fisheries since resource stocks must be harvested at sustainable target harvest rates and overfished stocks coaxed back to target stock levels.

In short, excess capacity and overfishing plague the Java Sea fisheries, and resource management and development policies are in order to redress this excess capacity and place these fisheries squarely on the path of recovery and sustainable development. Pareto-improving policies are required to sustainably regulate fishing capacity or to address the ill-structured property rights. As it currently stands, each vessel does not possess an exclusive catch or area right which is fully specified and transferable, nor are there well-defined groups in a form of regulated common property. Consequently, individuals and groups do not face incentives to harvest in a socially efficient manner.

The purpose of this paper is to address these issues. The paper assesses the likely excess capacity in three of Indonesia's Java Sea fisheries, the purse seine, mini purse seine, and lineline fisheries, and suggests policy alternatives for sustainable management and development of these fisheries. Catch or area rights or regulated common property may be the first-best regulatory approach, but for a variety of reasons are not feasible. A restricted access program, and area license limitation in particular, is a

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second-best regulatory option and the most likely regulatory tool to reduce excess capacity and relieve overexploited fish stocks in multispecies tropical fisheries of developing countries such as in the Java Sea. An assessment of excess fishing capacity in the Java Sea of Indonesia and the minimum number of vessels required to harvest the target sustainable yield helps gauge the extent of the excess capacity and helps facilitate design of any restricted access program to tackle this issue. Incentive design and principal–agent and asymmetric information problems that arise in license limitation are also discussed.

To measure fishing capacity, we adopt the approach of Kirkley and Squires (1999a, b), the 1998 FAO Technical Working Group in La Jolla, California (FAO, 1998) and the 1999 FAO Technical Consultation in Mexico City (FAO, 2000). This approach, stemming from the standard microeconomic theory of capacity initially developed by Klein (1960), Klein and Long (1973) and others is the technological-economic method of measuring fishing capacity, and corresponds to the full-input point on a production function (the maximum production given the fixed inputs) provided that it is sustainable. We employ the data envelopment analysis approach (DEA) proposed by Färe (1984) and Färe, Grosskopf, and Kokkelenberg (1989), which employs linear programming to envelop the best-practice production frontier corresponding to the technological-economic method. This framework lacks the comprehensive capability of a fully developed bioeconomic model, in which population dynamics of the resource stocks are fully incorporated, but it can be applied when the population dynamics are little understood or not well developed and biological and economic data are limited. As such, the approach offers great promise due to its ease of applicability and can be used by Indonesia and other nations to meet their commitment to FAO's International Plan of Action to reduce fishing capacity.

We first measure the fishing capacity by DEA. We next adopt an approach about the likely sustianable target harvest level in the absence of reliable stock information (Restrepo *et al*., 1998) as one possible biological reference point, and then we measure the likely minimum level of excess capacity and corresponding minimum number of vessels required in each of the three fisheries. We subsequently examine restricted access as a policy measure that addresses this excess capacity.

2. The Java Sea purse seine and longline fisheries

The fisheries in the Java Sea are regulated open access in that there is no exclusive ownership or use right. Access to the fishery is limited by zone and vessel size, but not vessel numbers, through an area licensing systems. This system specifies a series of parallel coastal zones 0–3 miles, 3–7 miles, 7–12 miles, and greater than 12 miles from the shoreline, and trawlers are banned. Vessel numbers from other gear types are not limited and there are not any industry quotas, such as Total Allowable Catches, on any species. Most vessels harvest a number of different species depending on weather conditions and seasonal variability. Medium- and large-scale fishers are able to fish throughout the year.

Three classes of Java Sea purse seine vessels can be distinguished, mini,

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medium, or large (Widodo, Potier, and Sadhotomo, 1997). The medium and large purse seiners are powered by diesel engines, but the mini purse seiners are powered by outboard engines fixed laterally or at the stern. Vessels are usually of wooden construction. The mini seiners fish along the coastline within a 30 mile distance, and, similarly, land their catch along the coast. Their target species include anchovies sardinellas, mackerels, scads, and some tuna-like fish, landed fresh. The medium seiners, which did not exist until 1989, are based at the Nusantara Fish Harbour at Pekalongan, Juwana, and to a lesser extent, the port of Tegal. Their fishing grounds are the offshore waters of the Java Sea, where they catch mainly small pelagic species especially scads and mackerels. The large seiners mainly fish for d*ecapterus macrosoma* far offshore, up to the Makassar Strait in the east and the southern tip of the South China Sea in the west.

The longline vessels harvest demersal (bottom dwelling) spcies, some tunas, and the small coastal tuna-like fish 'tonkol'. The longliners predominately harvest coastal fishing grounds. The purse seine and longline gear do not harvest shrimp, which are largely found in nearshore beds and are primarily accessible only to the artisanal sector.

The purse seine was introduced to Indonesia and the Java Sea in 1968 at Pekalongan (McElroy, 1991). With the ban on the use of trawlers in 1980, purse seiners came to dominate medium-scale landings (Bailey, Dwiponggo, and Marahudin, 1987; McElroy, 1991). With the trawl ban, the Government of Indonesia made credit available to encourage expansion into the pelagic (surface-dwelling) fisheries, particularly purse seining. At that time pelagic fish stocks were relatively underexploited, especially compared to demersal (bottom-dwelling) fish resources. A number of trawlers were converted and a number of new purse seiners, designed to fish farther offshore, were constructed.

The fishery resources consist of highly diverse, multispecies complexes (Silvestre and Pauly, 1997). Both small pelagaic and demersal species are harvested. The demersal fishing grounds of the Java Sea, including shrimp grounds and small pelagic fish, are found in the shallow parts of the continental shelf (Sunda Shelf), usually down to 50 m. depths (Martosubroto, 1996). Increasing age and size is found with greater depth and distance from short. Nearshore areas frequently serve as nursery grounds (Silvestre and Pauly, 1997). Many species, especially the small pelagics, are fished sequentially by different gears as the species age and grow and move to deeper, offshore grounds (Silvestre and Pauly, 1997; McElroy, 1991). This generates a technological resource stock externality that is both symmetric and asymmetric—reciprocal on the inshore harvesters of young fish but also asymmetric on the 'downstream' exploiters of older fish, which inhabit waters farther offshore.

The demersal fish species in the Java Sea are relatively abundant and still underexploited, particularly in the northern half of the Java Sea (McElroy, 1991). The level of exploitation of the offshore demersal stocks may remain moderate as long as trawling remains banned from these waters. Shrimp are probably at the level of their long-term sustainable yield (McElroy, 1991).

The small pelagic species are overexploited throughout the Java Sea

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(McElroy, 1991); Priyono and Sumiono, 1997). Total effective fishing effort (measured by days spent at sea per year) has most likely exceeded maximum sustainable yield since at least 1985, and this measure of effort has continued to increase. As the accumulated year classes of small pelagic fish are fished down in previously moderately fished stocks, catches will increasingly depend on the relative strength of just one or two year classes of the main small pelagic fish stocks (McElroy, 1991). Increasing fishing effort on small pelagic stocks will no longer give rises in catches and may indeed cause the stocks to decline further. This situation is aggravated by the natural variability of most pelagic species resource stocks.

Beyond the direct effects of overfishing the resource, the destruction or degradation of coastal habitats, such as mangrove forests and coral reefs, has contributed to the depletion of the fishery resources. Urban and industrial pollution run-offs into rivers, estuaries, and the sea further degrade the ecosystem and lower the environmental carrying capacity. This degradation of the ecosystem and loss in ecosystem services create a second type of technological externality. The subsequent reductions in biomass and sustainable yields increases the excess capacity for any given level of fishing capacity.

Monsoons affect fishing, fish availability, and capacity, making most Indonesian fisheries seasonal. The inclement weather makes fishing both more difficult and dangerous. Heavy rains, rough seas, and strong winds hinder transit to and from fishing grounds and deploying and retrieving nets. Indonesia lies well within the tropics, where oceanic primary and secondary production does not show strong seasonal fluctuations. Nonetheless the biological production of small pelagic fishes is highly seasonal, influenced by environmental conditions, most notably by monsoon winds (Pauly and Navaluna, 1983). Ocean mixing can also increase during monsoons due to the wind forcing. During and immediately following monsoon periods some species of fish may concentrate closer to the shoreline. During periods of calm, which coincide with reduced river discharge, nutrient levels drop and the fish may disperse over a wider area to forage.

3. Capacity and capacity utilization

Capacity is a short-run concept, where firms and industry face short-run constraints, such as the stock of capital or other fixed inputs, existing regulations the state of technology, and other technological constraints (Morrison, 1985). Capacity is defined in terms of potential output. This potential output can be further defined and measured following either a technological-economic approach or an economic optimization approach directly based on microeconomic theory (Morrison, 1985).[1] What distinguishes the two notions of capacity is how the underlying economic aspects are included to determine the capacity output.

[1] In the economics approach, cost-minimizing capacity is defined as the output level at which the short-run average cost curve is tangent to the long-run average cost curve (Klein, 1960; Morrison, 1985). Squires (1987) developed an approach based on the short-run profit function that allows endogenous rather than fixed inputs and establishes capacity as the output level where marginal cost equals output price.

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In both the economic and technological-economic approaches, the most widely used measure of capacity utilization (CU) is simply actual output divided by capacity output (Morrison, 1985). In the technological-economic approach, a CU value less than one implies that firms have the potential for greater production without having to incur major expenditures for new capital or equipment (Klein and Summers, 1966).

This paper, Kirkley and Squires (1999a, b), the 1998 FAO Technical Working Group, and the 1999 FAO Technical Consultation (FAO, 2000) focused upon the technological-economic measures of capacity, because the paucity of cost data in most fisheries militates against estimation of cost or profit functions to derive economic measures of capacity and capacity utiliiztion. Similarly the technological-economic approach is the one used by the US Federal Reserve Boar (Corrado and Mattey, 1998) and in most other countries to monitor capacity utilization throughout the economy.

The technological-economic capacity of a firm can be defined following Johansen's (1968, p. 52) definition of plant capacity 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'. Färe (1984) provides a formal proof and discussion of Johansen's definition of plant capacity.

Capacity output thus represents the maximum production the fixed inputs (the capacity base) are capable of supporting. This concept of capacity conforms to that of a full-input point on a production function, with the qualification that capacity represents a realistically sustainable maximum level of output rather than some higher unsustainable short-term maximum (Klein and Long, 1973). In practice, this approach gives maximum potential output given full utilization of the variable inputs under normal operating conditions, since the data used reflect normal operating conditions and existing market, resource stock, and environmental conditions.[2] This approach gives an endogenous output and incorporates the firm's *ex ante* short-run optimization behavior for the production technology given full utilization of the variable inputs under normal operating conditions.

The definition and measurement of capacity in fishing and other natural resource industries face a unique problem because of the stock-flow production technology, in which inputs are applied to the renewable natural resource stock to produce a flow of output. For renewable resources, capacity measures are contingent on the level of the resource stock. Capacity is, therefore, the maximum yield in a given period of time that

[2] Klein and Long (1973, p. 744) state that 'Full capacity should be defined as an attainable level of output that can be reached under normal input conditions—without lengthening accepted working weeks, and allowing for usual vacations and for normal maintenance.' The US Bureau of the Census survey uses the concept of practical capacity, defined as 'the maximum level of production that this establishment could reasonably expect to obtain using a realistic employee work schedule with the machinery and equipment in place' and assuming a normal product mix and down-time for maintenance, repair, and cleanup.

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can be produced given the capital stock, regulations, current technology, and the state of the resource (FAO, 1998; Kirkley and Squires, 1999a, b). Nonetheless, annual climate-driven ocean variability at local and regional scales is clearly the dominant force that affects local fisheries (Sharp, 1997). The monsoon and El Niño-Southern Oscillation (ENSO) events provide a clear example. As a consequence, and due to annual changes in the size and species and age mix of the resource stocks, the target level and capacity output from the stock-flow production process can vary annually and even seasonally when there are strong seasonal effects such as monsoons.

In fisheries and other renewable resource industries excess capacity should ideally be defined relative to some biological or bio-socioeconomic reference point, which accounts for sustainable resource use and a target resource stock size. Excess capacity, in a technological-economic approach, can be defined as the difference between capacity output and the target level of capacity, such as maximum sustainable yields of the catch rate corresponding to the fishing mortality of an alternative harvest strategy (FAO, 1998). The target level of capacity was defined by the 1998 FAO Technical Working Group as (FAO, 1998, p. 11), 'Target fishing capacity is the maximum amount of fish over a period of time (year, season) that can be produced by a fishing fleet if fully utilized while satisfying fishery management objectives designed to ensure sustainable fisheries.' The 1999 FAO Technical Consultation of measuring fishing capacity reached a similar conclusion (FAO, 2000).

The target fishing capacity is often specified as maximum sustainable yields (MSY) in many fisheries. Estimates of MSY are often imprecise, simply unavailable, or not current in many instances, especially with complex multi-species fisheries in the tropics. In the Java Sea fisheries, the small pelagic fisheries exploited by the medium and mini purse seine vessels are overexploited, harvested at a level beyond MSY. The demersal finfish stocks of the Java Sea as a whole may not yet be at MSY levels. However, the demersal finfish stocks harvested by the longline vessels lie in the accessible inshore waters that receive heavy fishing effort from many gear types and are thus also likely to be at less than MSY levels.

We select the observed catch levels for each fleet as the maximum possible bounds to MSY, and there is both overfishing and overfished resource stocks (McElroy, 1991). The current exploitation rates do not correspond to MSY. The fisheries are far past any drawing down of virgin resource stocks (i.e., the fisheries are not in an initial drawing down of an unexploited resource at high rates), so that the unsustainable exploitation rates are below those corresponding to MSY in equilibrium. Resource stocks are below those corresponding to MSY, and the stocks are likely not in an equilibrium due to the continued fishing pressures. Hence, the difference between total capacity and total catch gives at best a minimum value of excess capacity *vis-à-vis* MSY. The application of the Precautionary Principle (FAO, 1995), which implements conservation measures even in the absence of scientific certainty that fish stocks are overexploited, reduces MSY (and increases resource stock levels) so that that minimum

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value of excess capacity we use is certain overstated.[3] Thus, the excess capacity prolbem *vis-à-vis* MSY is certainly larger than we have measured.[4]

Measuring capacity using data envelopment analysis

We apply data envelopment analysis (DEA), a mathematical programming technique, as a practical approach to determine the maximal or capacity output per vessel. The DEA approach derives a deterministic production frontier describing the most technically efficient combination of outputs given the state of fishing technology, the fish stock, and unrestricted variable inputs. Kirkley and Squires (1999a) proposed DEA to assess harvest capacity in fisheries. The DEA approach distinguishes between variable and fixed factors and allows for multiple outputs and variable returns to scale.

The DEA approach calculates capacity output given that the variable factors are unbounded and the fixed factors, environmental parameters such as the resource stock and oceanic conditions, and state of technology constrain output. Capacity corresponds to the output which could be produced given full and efficient utilization of variable inputs and given the constraints imposed by the fixed factors, the state of technology, and resource stock. In practice, because the data reflect both technological and economic decisions made by firms, the variable inputs correspond to full and efficient utilization under normal operating conditions.

The Färe, Grosskopf, and Kokkelenberg (1989) model posits that

[3] A common element in the application of the precautionary principle to fisheries management worldwide is the definition of 'limits' intended to safeguard the long-term productivity of a stock. Several international agreements and documents that deal with the precautionary approach identify MSY levels as a minimum standard for defining management limits. Another common element in the application of the precautionary approach to fisheries management worldwide is the specification of 'targets' that are safely below limits. Under the precautionary approach, the target should be set below the limit, taking uncertainty and other management objectives into consideration, because of the high probability of exceeding the limit year after year. Restrepo *et al.* (1998) provide further discussion.

[4] Capacity, a short-run concept, is conditional upon both the stock of capital and the resource stock. An anonymous referee observed that MSY, a long-run concept, assumes an equilibrium stock level, so that given the overexploited resource stock, capacity output is less than that which might be achieved with the same fleet with a higher stock level that might be consistent with MSY. In practice, the long-range target, such as MSY and the corresponding capacity and capital stock levels, may be difficult to estimate, so that the most important objective is to develop a management strategy that moves in the correct direction—especially so with the volatile and climate-sensitive small pelagic species. New short-run positions correspond to intermediate stages along some approach path to the long-run target. As the fleet moves along the adjustment path towards a current target estimate, accumulation of knowledge and a better indication of changes in technology and other factors may result in continual updating of the ultimate target. Hence, the issue at hand becomes determining the minimum fleet required to take the existing catch level. The authors are grateful to Serge Garcia for extensive observations on this issue.

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capacity at the plant (vessel) level can be estimated by partitioning inputs according to whether they are fixed (F_x) or variable (V_x) and then solving an output-orientated, DEA problem in which only fixed factors bind production. Assume that there are $j = 1, \ldots, J$ vessels producing M outputs (Catches of different species) by means of both fixed and variable factors. Let u_{jm} equal the quantity of the mth output produced by the jth producer, and x_{jn} be the level of the nth input used by the jth producer. Equation (1) gives the DEA problem to be solved, where θ is an output-oriented measure of the extent to which capacity output can increase and $\theta \geq 1.0$. Outputs expand in fixed proportions, since the expansion is radial. Multiplying the observed output by θ gives an estimate of capacity output.

The DEA problem to asses capacity is written following section 10.3 of Färe, Grosskopf, and Lovell (1994)

$$TE_{ocj} = \max_{\theta,\lambda,z} \theta$$

Subject to

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

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

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

$$\sum_{j=1}^{J} z_j = 1$$

$$z_j \geq 0,\ j = 1, \ldots, J, \quad \text{and} \quad \lambda_{jn} \geq 0 \tag{1}$$

The vector of intensity variables z defines the reference technology given the observed inputs and outputs. These variables comprising z join the observed inputs and outputs to form the piecewise linear best-practice reference technology relative to which capacity is measured (i.e. the technology constructed by DEA). That is, the intensity variables are the (variable) weights given to each activity or observation to which observed input and output points are being compared (Färe, Grosskopf, and Kokkelenberg, 1989; Färe, Grosskopf, and Lovell, 1994). The z vector allows us to radially decrease or increase observed production activities (input and output levels) to construct unobserved but feasible activities, such as capacity or optimal variable input use. Capacity utilization is the ratio of observed output to capacity output, given by $1/\theta$. The parameter in equation (1) is the variable input utilization rate.

The output constraint given by the third line of equation (1), $\theta u_{jm} \leq \sum_{j=1}^{J} z_j u_{jm}$, $m = 1, \ldots, M$, states that capacity output is less than or equal to the piecewise linear best-practice reference technology relative to which capacity is measured. The fixed input constraint given by the fourth line of

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equation (1), $\sum_{j=1}^{J} z_j x_{jn} \leq x_{jn}, n \in F_x$, states that optimal usage of the fixed factor must be less than or equal to actual usage (since the optimal usage of the fixed factor may differ from actual usage (Färe, Grosskopf and Kokkelenberg, 1989). The variable input constraint given in the fifth line of equation (1), $\sum_{j=1}^{J} z_j x_{jn} = \lambda_{jn} x_{jn}, n \in V_x$, allows the variable inputs to be unconstrained (Färe, Grosskopf and Lovell, 1994). The term $\lambda_{jn} \geq 0$ allows the bounds on the variable inputs to vary since the intensity vector z is not restricted in $\sum_{j=1}^{J} z_j x_{jn}$ by this constraint. The next-to-last line of equation (1), $\sum_{j=1}^{J} z_j = 1$, is a convexity constraint which allows variable returns to scale. Global constant returns to scale, a highly restrictive assumption, is imposed without this convexity constraint. Variable returns to scale is more general and is determined by the data rather than *a priori* assumed and imposed, which would otherwise be the case for constant returns to scale. The constraints in the last line of equation (1), $z_j \geq 0, j = 1, \ldots, J$, and $\lambda_{jn} \geq 0$, are non-negativity constraints.

This DEA problem to assess capacity differs from that for output-oriented technical efficiency, because all variable inputs are assumed fully utilized, and hence are not binding on the DEA problem given in equation (1). Thus the variable inputs to not restrict the intensity vector z. Estimating capacity without binding variable input constraints indicates that the variable inputs are in fact decision variables, in line with the Johansen definition that assumes input fixity combined with unlimited access to the variable input dimensions.

In the technological-economic approach to capacity, observed output may differ from capacity output due to technical inefficiency or low levels of variable inputs (Färe, Grosskopf and Kokkelenberg, 1989). Thus, in equation (1), the parameter θ, which measures the extent to which output must increase to reach the 'best practice' full capacity, includes the effects of both low variable input usage and technical inefficiency. In fisheries, technical efficiency corresponds to fishing skill (Kirkley, Squires, and Strand, 1998; Squires and Kirkley, 1999). In addition, the technological-economic approach to capacity is predicated on 'normal practice' or 'normal operating conditions' among the vessels, which involves a range of efficiency in the fleet.

To remove the effects of differences in technical inefficiency (fishing skill) and solely focus on the level of variable inputs, an alternative measure of capacity output can be constructed by purging θ in equation (1) of technical inefficiency (fishing skill), so that θ only reflects low levels of variable inputs. This new problem is found by considering both the variable and the fixed inputs in the analysis (i.e. allowing variable inputs to potentially bind) and estimating a new variable θ_2, where technical efficiency is $1/\theta_2$. In equation (1), the variable input constraint becomes $\sum_{j=1}^{J} z_j x_{jn} \leq x_{jn}, n \in V_x$ (i.e. $=$ becomes $\leq$). The new capacity utilization rate is estimated by $\theta_2 // \theta$, which purges the capacity indicators of the amount

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that is due to technical inefficiency (Färe, Grosskopf and Kokkelenberg, 1989), i.e. the effects of differences in fishing skill. Dividing the observed output by $\theta_2//\theta$ gives an estimate of capacity output in which deviations from full capacity are solely due to low variable input usage and do not include the effects of technical inefficiency or mis- or un-measured production conditions, such as adverse weather, mechanical breakdowns, or other standard operating limitations. This second capacity output which we call case 2, will be lower than the first approach, which we call case 1.

The best-practice capacity frontier is comprised of piecewise linear segments for each gear type. Hence, capacity is estimated separately for different sized vessels, since different linear segments of the reference frontier correspond to different sized vessels.

We specify a single output, total catch, rather than the individual species landed because the data were originally collected and used for another purpose and were only available in their aggregate form (see Susilowati, 1998). Total catch was constructed as the geometric mean of all species landed where revenue shares served as weights. Total catch constructed in this manner assumes homothetic output separability and corresponds to aggregate measures of capacity typically derived for most industries (Segerson and Squires, 1990). Vessel size, measured by vessel gross registered tonnage, represents the fixed factor—the capital stock. Variable inputs are fishing time (hours per trip) and numbers of crew members (including captain). Ideally a measure of resource stock abundance would be included as a non-discretionary input or technological constraint, but such measures are not available and hence are excluded. In any case, because the data are for a single year, abundance is not expected to change appreciably. Table 1 summarizes the data. The capacity analysis did not include any other variables, such as the qualitative variables in table 1, as inputs.

Alternative methods for measuring capacity and capacity utilization have been proposed in the literature, most notably duality-based measures using cost (Morrison, 1985), profit (Squires, 1987), or revenue (Segerson and Squires, 1995). Unlike cost, profit, or revenue functions, DEA does not impose an underlying functional form, so that estimation is not conditional upon the functional specification. Unlike the cost function approach, DEA estimates capacity in a multiple-product environment without imposing separability assumptions on the outputs (Segerson and Squires, 1990), although in this study, separability in outputs has been *a priori* specified as discussed above. DEA can be used when prices are difficult to define, or behavioral assumptions such as cost minimization or profit maximization, are difficult to justiy, or cost data are unavailable.

The DEA approach has limitations. First, it is a non-statistical approach, which makes statistical tests of hypotheses about structure and significance of estimates difficult to perform. Second, because DEA is non-statistical, all deviations from the frontier are assumed to be due to inefficiency. Third, estimates of capacity and capacity utilization are sensitive to random errors in the data that can be attributed to measurement errors and unobservable shocks such as climatic changes.

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Table 1. *Summary statistics of the data*

	Medium purse seiner				*Longliner*				*Mini purse seiner*			
	mean	*max*	*min*	*std*	*mean*	*max*	*min*	*std*	*mean*	*max*	*min*	*std*
Average ton catch/trip	47.1	200	2	31.4	2.6	18	0.1	3.7	26.5	80	3	19.4
Vessel tonnage (GRT)	98.8	300	10	48.5	11.9	6	03	9.5	71	126	15	27.9
Vessel-ton-hours	2,604.3	12,000	150	1,956.3	292.5	2,400	39	35.3	1,611.5	4,275	75	1,103.2
No. of men in boat/trip	37.2	50	20	5.8	6.7	13	4	1.9	31.7	40	23	4.1
No. of men-hours per boat/trip	956.0	3,420	175	467.2	151.8	480	50	97.3	684.8	1,600	125	361.5
No. of hours/trip	581.8	1,080	100	260.1	508.1	1,440	120	222.4	496.3	1,080	120	234.8
Years experience as fisher	18.2	50	2	7.6	15.9	40	1	7.3	20.0	50	4	9.4
Age	35.5	62	24	7.7	33.9	93	19	9.7	35.3	65	22	8.5
Boat ownership	1.0	1	0	0.1	0.9	1	0	0.3	1.0	1	1	0.0
Schooling experience	0.4	1	0	0.5	0.6	1	0	0.5	0.6	1	0	0.5
Household size	3.7	8	0	1.8	3.9	9	0	1.8	3.5	11	0	2.2
No. of family members working	0.5	4	0	0.8	0.3	6	0	0.9	0.7	5	0	1.1
No. of children schooling	1.7	7	0	1.5	1.4	5	0	1.2	1.5	5	0	1.4
Peak Season												
No. of hours/trip	390.8	720	160	139.8	450.1	840	120	169.4	346.8	600	120	121
Catch/trip (kg/trip)	65,898	2,000	6,000	31,683	3,191.2	18,000	300	3,951.8	38,153	80,000	7,500	20,097
No. of men in boat/trip	38.3	50	23	5.7	6.76	13	4	1.9	32.3	40	23	3.9
Of season												
No. of hours/trip	772.8	1,080	100	206.7	566.1	1,440	225	253	645.9	1,080	168	225
Catch/trip (kg/trip)	28,165	75,000	2,000	15,946	2,045.9	15,000	100	3,472.6	14,775	37,500	3,000	8,862
No. of men in boat/trip	36.1	50	20	5.8	6.66	12	4	1.9	31.2	40	23	4.3

Notes: Schooling experience = 0 if no schooling, = 1 if schooling. Boat ownership = 0 if boat owner, = 1 otherwise.

4. Empirical results

Capacity was separately estimated, with (case 1) and without (case 2) the effects of technical inefficiency (fishing skill), for each season for which we had full data (off and peak seasons) and gear type by DEA using the vessel-level data. Excess capacity was calculated as the difference between capacity output and observed catch for each vessel per season by gear. CU was calculated as the ratio of observed catch to capacity including the effects of both technical inefficiency (fishing skill) and low levels of variable input usage for the first approach (case 1) and after purging the effects of technical inefficiency for the second approach (case 2). Fleet measures of capacity, excess capacity, and CU were obtained by summing over all vessels of a gear type. Summing over both seasons, after calculating individually by season, gave the annual measures by gear.

Capacity output, excess capacity, and CU for all gear types and seasons differ considerably whether or not the effects of technical inefficiency—fishing skill—in case 1 are included, where purging capacity output of technical inefficiency in case 2 reduces capacity output as expected (table 2). Fishing skill clearly provides a large contribution to capacity and excess capacity. Cardinal orderings remain the same.

The longline and mini and medium-scale purse seine fleets display considerable excess capacity, especially when the capacity output includes the effects of technical inefficiency (table 2). At the individual vessel level, capacity is largest for the largest vessels, the medium purse seiners, the smallest for the smallest vessels, the longliners (table 2). Medium purse seiners made the longest fishing trips, which also contributes to capacity, while the longliners and mini purse seiners make trips of comparable length. Individual vessels for each gear type display a wide range of capacity (table 2).

Capacity and excess capacity display marked seasonal variation for all three gear types in both cases 1 and 2, highlighting the importance of climatic and oceanographic forcing (table 2). For example, mean capacity for case 1 for medium seiners increases about 240 per cent from the off to peak season, by about the same for mini purse seiners, and by about 195 per cent for longliners. The smaller seasonal increase for longliners compared to purse seiners is due to the comparative biology of demersal and small pelagic fish. Oceanographic conditions that vary with monsoons affect surface dwelling and migratory small pelagic fish more than the bottom-dwelling demersal fish.

Annual CU per vessel over both seasons for case 1 (case 2) a rate, averages 0.40 (0.80) for medium purse seiners, 0.53 (0.86) for mini purse seiners, and 0.31 (0.75) for longliners (table 2). Mean CU per vessel, with and without the effects of technical inefficiency (fishing skill), varies much less by season (table 2). Even though catch declines considerably from the peak to off-seasons, capacity output does as well, so that mean CU per vessel remains remarkably stable; this result demonstrates an adaptation to climatic variability. The comparatively low mean values for CU per vessel with case 1 indicate that investment incentives are minimal when both variable input usage and fishing skill are considered.

The low CU rates under case 1 can be attributed to several factors. When

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Table 2. *Vessel-level summary statistics of catch, capacity, excess capacity, and capacity utilization by vessel type*

			Capacity output		*Excess capacity*		*Capacity utilization*	
		Catch	*Case 1*	*Case 2*	*Case 1*	*Case 2*	*Case 1*	*Case 2*
(a) Medium purse seiner (observation = 64)								
Peak	mean	65,898	167,676	89,522	101,778	23,623	0.393	0.747
season	max	200,000	200,000	200,000	194,000	108,818	1.000	1.000
	min	6,000	100,000	9,800	0	0	0.030	0.088
	stdev	31,683	24,576	37,308	32,527	24,195	0.179	0.196
Off	mean	28,166	69,204	34,471	41,038	6,305	0.405	0.854
season	max	75,000	75,075	75,000	71,400	62,516	1.000	1.000
	min	2,000	60,000	3,136	0	0	0.031	0.031
	stdev	15,947	3,540	17,431	15,412	12,905	0.227	0.236
Annual	mean	94,064	236,880	123,993	142,816	29,928	0.399	0.800
	max	250,000	275,075	268,158	265,400	153,638	1.000	1.000
	min	9,600	160,000	13,625	0	0	0.039	0.087
	stdev	44,828	28,080	51,023	43,936	33,100	0.189	0.197
(b) Mini purse seiner (observation = 49)								
Peak	mean	38,153	69,703	41,521	31,550	3,368	0.545	0.920
season	max	80,000	80,097	80,000	63,597	56,770	1.000	1.000
	min	7,500	14,000	7,701	0	0	0.196	0.209
	stdev	20,098	17,787	19,734	17,263	9,169	0.239	0.170
Off	mean	14,776	28,907	18,388	14.131	3,613	0.514	0.808
season	max	37,500	37,594	37,500	32,594	19,164	1.000	1.000
	min	3,000	7,000	3,862	0	0	0.133	0.223
	stdev	8,862	9,438	9,182	8,160	4,609	0.258	0.219
Annual	mean	52,929	98,610	59,909	45,681	6,981	0.530	0.864
	max	112,500	117,597	112,500	92,594	75,934	1.000	1.000
	min	12,500	21,000	12,701	0	0	0.192	0.216
	stdev	27,231	26,409	22,798	12,599	0.225	0.176	
(c) Longliner (observation = 74)								
Peak	mean	3,191	10,600	4,628	7,409	1,437	0.306	0.678
season	max	18,000	18,007	18,000	17,347	15,486	1.000	1.000
	min	300	2,000	618	0	0	0.017	0.139
	stdev	3,952	5,010	4,489	4,564	2,125	0.261	0.210
Off	mean	2,046	5,450	2,437	3,404	391	0.309	0.817
season	max	15,000	15,007	15,000	11,000	4,536	1.000	1.000
	min	100	300	100	0	0	0.040	0.044
	stdev	3,473	3,371	3,447	2,318	924	0.310	0.247
Annual	mean	5,237	16,051	7,065	10,813	1,828	0.308	0.747
	max	33,000	33,010	33,000	26,486	16,998	1.000	1.000
	min	700	2,300	1,085	0	0	0.034	0.179
	stdev	7,235	8,184	7,488	6,665	2,435	0.268	0.192

Notes: Case 1 = capacity output including one fixed input, full utilization of two variable inputs and allowing for technical inefficiency.
Case 2 = capacity output including one fixed input, less than full utilization of two variable inputs, and purging effects of technical inefficiency.
Annual values for catch, capacity output, excess capacity are added from those of peak and off-seasons, separately for each gear type, while those of capacity utilization are average values.
One way to compare table 2 and table 3 is: for the purse seiner mean catch (94064)*obs(64) = 6020096 (and table 3 shows 6020100).
For the mini purse seiner: 52929*49 = 2593521 (table 3, 2593500).
For the longliner 5237*74 = 387538 (table 3, 387550).

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less than full capacity utilization is due to both low levels of variable inputs and technical inefficiency (case 1), the best-practice frontier, which determines capacity output, is established by vessels with the most appropriate combination of high technical efficiency and variable input usage. These vessels are likely to have found the densest concentrations of fish, so that a given input bundle yields a high capacity output. For most vessels, however, the low levels of the resource stocks limit catches, and hence CU, in this stock-flow production technology. When capacity is due to only low levels of variable input use (case 2), CU rates climb considerably (table 2).

The fleet excess capacity in case 1 (case 2) ranges from 86 (113) per cent for the mini purse seiners to 152 (32 per cent for the medium purse seiners to 207 (35) per cent for the longliners (table 3). The excess capacity in both cases in undoubtedly even higher since the capacity outputs were compared to observed catches (which were assumed to represent the largest possible estimate of MSY).

Policy makers are often interested in the number of vessels that can be removed to eliminate excess capacity. We start with the point estimate of annual fleet excess capacity (i.e. we do not account for the variation in excess capacity that could well occur over different years and stochastic events). To determine the minimum fleet size, the number of vessels that could be decommissioned to eliminate the excess capacity gap can then be

Table 3. *Fleet capacity, excess capacity, and number of vessels potentially decommissioned*

	Purse seiner	*Mini purse seiner*	*Longliner*
fleet total catch	6,020,100	2,593,500	387,550
Under Case 1			
fleet capacity output	15,164,618	4,831,410	1,188,277
excess capacity	0,144,518	2,237,910	800,727
percentage excess capacity	151.90%	86.29%	206.61%
total No. of vessels	64	49	74
No. of vessels removed	36	20	35
remaining No. vessels	28	29	39
Under Case 2			
fleet capacity output	7,935,523	2,935,565	522,806
excess capacity	1,915,423	342,065	135,256
percentage excess capacity	31.82%	13.19%	34.90%
total No. of vessels	64	49	74
No. of vessels removed	9	4	5
remaining No. vessels	55	45	69

Notes: Case 1 = capacity output including one fixed input, full utilization of two variable inputs and allowing for technical inefficiency.
Case 2 = capacity output including one fixed input, full utilization of two variable inputs and purging effects of technical inefficiency.
Number of vessels potentially decommissioned is the number of vessels that could be removed to match fleet total catch with fleet capacity, where the vessels with the greatest capacity were first removed.

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estimated by ordering vessels from highest to lowers capacity. Vessels are removed starting from those with highest capacity until total annual fleet capacity (summed over both seasons) matches total annual fleet catch (the proxy variable for MSY). Alternative approaches, such as ordering from lowest to highest capacity, are also possible.[5]

To the extent that vessels first removed are those with highest capacity and the estimate of excess capacity is a minimum estimate, the number of vessels removed represents a minimum estimate. To the extent that the remaining vessels would not necessarily produce at excess capacity or that the DEA approach does not overestimate capacity (due to its deterministic specification), the number of vessels removed is overstated. The number of vessels removed could also be overstated to the extent that excess capacity can vary annually, especially in small pelagic species fisheries with their highly variable biomasses. Hence, excess capacity might be retained to harvesting years with high levels of biomass—a 'peak load' issue comparable to electric utility industries. To the extent that the Precautionary Principle (FAO 1995) is followed to account for uncertainty in both the biomass and the estimates, more vessels would be removed than otherwise.

The excess capacity and overcapitalization problem in the Java Sea fisheries is severe under case 1, when both inappropriate variable input usage and technical inefficiency (fishing skill) determine capacity output, but relatively modest under case 2, when only variable input usage determines capacity output. A large number of vessels of all gear types must be decommissioned to eliminate excess capacity in case 1 but not in case 2 (table 3).

The decommissioned vessels in case 1 have lower average products of capital (catch per GRT), are more technically efficient, and display higher rates of CU (table 4). With case 2, the decommissioned vessels display higher average products of capital but lower technical efficiency for all gears and lower CU for both purse seiners but higher CU for longliners (table 4).

While, as noted, the specific number of decommissioned vessels may be subject to uncertainty, the large numbers under case 1 nonetheless suggest the severity of the excess capacity and overcapitalization if technical inefficiency (fishing skill) is considered. (Excess capacity includes variable inputs and capital stock while overcapitalization refers only to the capital stock.)

A policy issue arises about whether or not to base capacity policy and vessel decommissioning upon capacity measures that include the effects of

[5] Vessels can be removed to generate minimum or maximum fleet sizes in terms of vessel numbers. Removing the boats with the highest capacity first would involve the minimum decommissioning (in terms of boat numbers) and leave the largest fleet size that could take the target catch. Removing the lowest capacity boats first would require the largest number to be decommissioned, and leave the minimum number of boats that can take the catch. Thus, to find the minimum fleet size necessary to take the catch, the boats are ordered from largest to smallest, but boats are removed starting from the smallest to largest, i.e. the smaller fishing capacity, not the larger capacity vessels are removed.

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Table 4. *Number of vessels decommissioned*

		Capacity utilization		*Annual catch/ton*	
Gear type		*Case 1*	*Case 2*	*Case 1*	*Case 2*
Purse seiner	remove	0.426	0.699	922	1,365
	staying	0.363	0.817	1,695	1,243
Longliner	remove	0.309	0.989	389	853
	staying	0.307	0.730	421	373
Mini purse seiner	remove	0.597	0.762	746	889
	staying	0.483	0.873	800	768

both low variable input usage and technical inefficiency (fishing skill)—case 1—or only low variable input usage—case 2. If technical inefficiency is expected to remain constant and hence latent, then the capacity problem is not severe and the second approach is valid. If technical inefficiency can be reduced, i.e. fishing skill improved, through improved fishing practices, fishery development programs, or other means (which could be concomitant to, but not part of the vessel decommissioning) then this 'latent capacity' due to technical inefficiency is meaningful and should be addressed by vessel decommissioning using case 1 results.

5. Policy implications

Pareto-improving policies to address the excess capacity, overfishing, and Pareto inefficiency in the Nash equiplbrim found in the Java Sea fisheries would, in a first-best solution, directly address the incomplete property rights that underlie the mixed symmetric–asymmetric and rivalrous technological resource stock and ecological externalities for these regulated open-access, common-pool resources. A properly specified property right, whether private or regulated common property, provides the desired set of Pareto-improving incentives.

The inherent variability of small pelagic species' abundance and the many different species help make a first-best property right solution through individual transferable quotas (transferable ownership of a share of the total catch) problematic (Grafton, Squires, and Kirkley, 1996). Such a solution is typically based on species-by-species catch histories rather than population and community ecological composition and multi-species interactions. Well-defined private property rights for the open-access common-pool resources can also have serious distributional consequences, particularly in the form of disenfranchisement of the crewmembers and their families. Several factors limit a property rights solution based on catch: the large number of fishers, difficulties in even initially assigning the rights without an accurate census and catch histories, and limited infrastructure (biological to make population assessments for the total allowable catch and informational to establish well-functioning quota markets with minimal transactions and information).

Even if property rights to catch could be assigned and a well-functioning market established, external costs may remain. The property right pertains

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to a harvest right (resource flow) not a right to the overall resource stock, so that use is not entirely exclusive and some elements of open access remain (Scott, 1993). The harvest right focuses on population size and not on the population structure and its age-based spatial distribution. Important ecological externalities remain, especially pertaining to the coastal littoral where an important local public good in ecosystem services is generated.

License limitation

The second-best solution of limited access through a license limitation program remains. This approach, which limits the number of vessels and hence overall access to the resource stocks, leaves an incompletely specified property right since use is not exclusive to each vessel or fishing firm, entitlements and responsibilities are not fully specified, and divisibility of the right is absent. Enforcement and duration of the right, however are not fundamentally problematic. The limited use right in turn does not fully establish the desired set of Pareto-improving incentives, which leaves rivalrous exploitation of the resource stocks by remaining vessels and the mixed symmetric–asymmetric technological resource stock externality.

License limitation focuses on the capital stock in the form of overcapitalization and capital utilization rather than excess capacity, the latter, which involves both variable and fixed factors. To reduce overcapitalization, license limitation limits the capital stock along with the utilization of capital through restrictions on variable inputs or fishing time, such as crew size and fuel. Fishers often respond by increasing the capital stock or substituting unregulated for regulated inputs to increase capital utilization (Pearse and Wilen, 1979).

The problem of trying to control capacity through the control of the capital stock and its utilization is imprecise and limited (Kirkley and Squires, 1999a, b). This occurs because capacity and capital stock, and capacity utilization and capital utilization, coincide only when there is a single stock of capital, all variable inputs are in fixed proportions to the fixed factor, and there are constant returns to scale (Berndt, 1990). In fisheries, a constant resource stock is also required

Setting the appropriate number of vessels must allow for the high variability in population sizes of small pelagic species, recognizing the effects on population variability of climate forcing in the short-run (monsoon and ENSO events) and any decadal-scale climatic and environmental changes. Too large a fleet gives permanent excess capacity and too little leaves resource stocks above the targets, with an opportunity cost. The uncertainty over a stock-recruitment relationship for small pelagic species and inability to distinguish between the effects of fishing mortality and climate forcing on recruitment and population sizes further obscures the picture. Nonetheless, to the extent that the number of vessels corresponds to a longer-term sustainable target level of catch, short-term, annual variations are not expected to present a problem.

A number of conditions complicate license limitation. Unless the program keeps the fleet size small, there remains a relatively large number of vessels and competition among gear types and between artisanal and

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industrial fishers over the same species, albeit in different areas (especially distance from shore and water depth) and at stages of the life cycle; the 'downstream' stock externality remains. This heterogeneity of the industry, large numbers, and fishing over a wide area and landing of harvest in different ports, coupled with the limited use right, leaves non-cooperation as the strictly dominant strategy for each vessel; a Pareto-inefficient Nash equilibrium and overexploitation of the resource stocks remain the expected outcome.

Other problems arise when Pareto-improving policies are second- rather than first-best. One of the most serious factors affecting the choice, design, and enforcement of license limitation is the Pareto-adverse incentives and asymmetric information between the regulator (the principal) and the vessel owner (the agent). This moral hazard problem, contributing to the market failure and Pareto-diminishing incentives found in fisheries of the Java Sea, occurs because the fishery managers (principal) cannot easily and at low cost monitor and enforce the number of vessels, the zones they fish in, gear conflicts, levels of harvest and the species composition, and the like. In turn, the fishers (agents) face incentives to shirk through avoiding license registration, payment of license, ignoring gear regulations and other requirements for monitoring, enforcement, and regulation. These adverse incentives arise because fishers would otherwise bear these and other costs of limited access but receive only a share of the benefits due to the remaining incomplete property right (and hence the remaining technological stock externality) under license limitation.

An inappropriate level of managerial (skipper) effort, an important component of fishing skill (technical inefficiency), also remains due to the moral hazard problem in this principal-agent problem. A first-best property rights policy is more likely to give a Pareto-improving level of managerial effort.

To deal with the problem of asymmetric information between the regulator and fisher, and the resulting moral hazard problem, the license limitation scheme should be designed to minimize the costs of monitoring and enforcement. Given the high costs of monitoring and enforcement, restrictions on the capital stock and its utilization might best be those that are readily monitored and enforced, such as limits on vessel numbers and vessel length although capacity is not fully controlled. The outright banning of trawling provides a corner solution. Kuperan and Sutinen (1998) and Susilowati (1998) discuss this issue in considerable detail.

As an alternative to simply licensing vessels by size and area—with larger vessels required to fish areas father offshore, areas might instead be delineated according to regions defined by groups of home ports without regard to vessel size (along with prohibition of inshore fishing) and vessel numbers capped. This form of area management could enhance monitoring and enforcement, since tracking vessels by regions would be easier than by distance from shore and vessel size. Area management might also reduce the asymmetric ecological externalities and asymmetric quality of the resource stock externality, since fish are not evenly distributed by demographic structure, disproportionately affecting different gear groups. However, many small pelagic species are highly migratory, so that if the

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areas do not adequately encompass these movements, the extant asymmetric trans-boundary resource stock externality would persist.

Sufficiently small areas with vessels under area licenses, and even more so under area property rights, might help promote cooperative solutions among industry participants by transforming the open access property rights structure into a set of regulated local commons (Wilen, 1988; Ostrom, 1990; Baland and Platteau, 1996; Seabright, 1997). Such a program effectively creates a regulated common property in the form of TURFs (Christy, 1983). This approach provides a well-defined group with clearly defined boundaries, utilizes the local knowledge of sustainable yields, provides user groups of sufficiently small numbers to promote cooperative behavior and enhance reliance upon moral norms, trust, and mutual obligations, and allows ready monitoring by both group members and the state. The enhanced possibility for Pareto-improving incentives and self- and group-monitoring mitigates the moral hazard and asymmetric information problem, and is especially important given the limited public resources available for enhancement and monitoring.

6. Concluding remarks

In many fisheries of developing nations a first-best property rights solution to the problems of excess fishing capacity, overfishing, and the Pareto-inefficient Nash equilibrium under regulated open access in the form of individual transferable quotas may simply be infeasible. The second-best, Pareto-improving policy of license limitation only indirectly tackles excess capacity by limiting the capital stock and its utilization through an incomplete use right for access, but may be the most feasible policy. Area management, perhaps in the form of fully specified private or common property for specific areas, deserves further consideration as a return to a first-best Pareto-improving policy.

The longline, mini and medium purse seine fleets of the North Java Sea display considerable excess capacity. A large number of vessels of all three gear types must be decommissioned to eliminate the excess capacity. License limitation may be the preferred regulatory option to remove vessels and reduce excess capacity, although the access right is limited and the problem of asymmetric information between the regulatory body and the fishers can be expected. Moreover, as long as investment in harvest capacity is in excess of that required for efficient attainment of fisheries objectives, effective regulatory efforts will be frustrated at the levels of both rule making and enforcement (Stone 1997).

Whatever form license limitation or any other major regulatory program takes, a choice has to be made between those who can fish and those who cannot, which carries with it the dilemma of allocating participation among industrial and artisanal fishing sectors, gear types, and areas. There are no objective criteria upon which to base an allotment decision. Some efficiency may have to be sacrificed for equity. For example, artisanal fishers and mini purse seiners harvest inshore waters where younger, sometimes sexually immature fish are. These equity-efficiency trade-offs and distributional decisions leave hard choices ahead for policy makers (Priyono and Sumiono, 1997).

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Finally the current form of licensing system creates a classic dual industry structure of small-scale and large-scale producers. The danger of such a dual structure, if frozen over time, is that of a permanent inshore group mired in poverty juxtaposed against a wealthier offshore sector. While beyond the scope of this paper, it should be noted that the inshore artisanal fishery sector requires special attention of its own to prevent a permanent two-tiered structure and poverty trap in the Java Sea fisheries.

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