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Measuring and assessing capacity in fisheries

1. Basic concepts and management options

PREPARATION OF THIS DOCUMENT

In 1998, FAO organized a Technical Working Group (TWG) to discuss issues related to fishing capacity. Major issues discussed included measurement and control methods for managing and reducing capacity. The FAO meeting also served as a basis for the development of an International Plan of Action (IPOA) for the Management of Fishing Capacity. The FAO Committee on Fisheries adopted the IPOA in February 1999. A subsequent FAO Technical Consultation was held in Mexico City in 1999. The purpose of that meeting was to better define capacity and capacity utilization in fisheries, and to examine methods or develop general guidelines that might be used to estimate capacity and excess capacity in fisheries.

Since the 1988 meeting, considerable activity has been undertaken by FAO in studying fishing capacity. This has culminated in several reports, including:

- Report of the Technical Working Group (TWG) meeting on the Management of Fishing Capacity (FAO Fisheries Report 586, 1998).
- Selected papers from the TWG meeting (FAO Fisheries Technical Paper No. 386, 1999).
- International Plan of Action on the Measurement of Fishing Capacity (1999).
- Report of the Technical Consultation on the Measurement of Fishing Capacity (FAO Fisheries Report No. 615, 2000).
- A review of policy and technical issues involved in managing capacity (FAO Fisheries Technical Paper No. 409, 2001).
- Report of the Expert Consultation on Catalysing the Transition away from Overcapacity in Marine Capture Fisheries (FAO Fisheries Report No. 691, 2002).
- Selected papers from the Technical Consultation on the Measurement of Fishing Capacity (FAO Fisheries Technical Paper No. 445, 2003).

This current report is part of the ongoing commitment to improving methods for assessing and managing fishing capacity. The report is in two volumes, published separately. Volume 1 provides an overview of basic concepts for the assessment and management of fishing capacity and is aimed at managers and policy-makers who need to have an understanding of the key concepts but are not likely to be involved in capacity assessment directly. Volume 2 provides more details on methods for measuring and assessing capacity and is aimed at fisheries economists and scientists who are likely to be involved in the process of measuring and assessing fishing capacity.

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ABSTRACT

This Fisheries Technical Paper provides an overview of the main concepts involved in the assessment and management of fishing capacity. It discusses why capacity management and the problem of overcapacity have become key issues for fisheries management in the new millennium. The paper explains why overcapacity develops in the fishery and the role that fisheries management has played in contributing to this development in the past.

Methods for estimating current and desired levels of capacity are discussed in a non-technical manner, and a range of potential indicators of overcapacity is described. The effectiveness of various capacity management programmes that have been applied in various fisheries around the world is also discussed, along with an explanation as to why many of these programmes have been ineffective. Potential management systems that have proven effective in reducing overcapacity are also presented and discussed.

CONTENTS

List of Tables

List of Figures

1. INTRODUCTION

Excessive levels of harvesting capacity are a serious problem facing fishery managers in the new millennium. Mace (1996) identified “[over]capacity as the single most important factor threatening the long-term viability of exploited fish stocks and the fisheries that depend on them,” requiring a significant reduction in existing global fishing capacity for levels to become commensurate with sustainable resource productivity.

As well as being biologically unsustainable, the level of overcapacity observed in the mid-1990s was also economically unsustainable, relying on subsidies to persist. Garcia and Newton (1997) estimated that world fishing capacity would need to be reduced by 25 percent for revenues to cover operating costs and by 53 percent for revenues to cover total costs.

While some have identified overcapacity as the primary reason for overfishing in domestic and global fisheries, both overfishing and overcapacity are really symptoms of the same underlying management problem – the absence of well-defined property or user rights.

In the absence of management, i.e. free and open access, fishers do not have any right to any particular quantity of fish, nor can they prevent others from harvesting the resource. Limiting their own activity in an attempt to conserve the resource results in no benefits to themselves, as others can increase their activity and benefit immediately. As a consequence, there is no incentive to restrict output even though the combined effect of each individual’s actions results in reduced stock size and future potential yields and profits.

Hence, under free and open access, excessive levels of fishing effort develop that can result in the both total yields and economic benefits falling well below their potential levels. Restrictions on access through the introduction of fisheries management can reduce this problem, but may still lead to the development of excessive levels of fishing effort if the property rights problem is not addressed.

For this reason, fisheries managed through restrictions on global levels of inputs (e.g. basic limited entry schemes) or outputs (e.g. global TACs) are considered to effectively operate as open access and are often termed “regulated” open access.

Property rights have been developed in most primary industries. For example, in agriculture, farmers either purchase or lease the land they farm, and have exclusive access to that land. Mining rights give individuals similar exclusive access to certain areas for the extraction of oil or other mineral resources. In forestry, rights to harvest are generally given to a limited number of individuals who are given exclusive access to particular areas.

As in fisheries, these rights have not always been clearly defined, leading to their unproductive use. For example, farming of common land in eighteenth century England led to lower yields through overexploitation, while gold rushes in the middle of the nineteenth century resulted in the considerable quantities of labour and other resources being used unprofitably. In areas where unrestricted access to forests still exists, unsustainable levels of harvest are observed and the forest resources are becomes overexploited.

If the property rights problem could be corrected, the incentive system under which the fishers would operate should result in increased efficiency of fisheries harvesting and improvements in fish stock abundance as capacity levels decline. However, solutions to this fundamental management problem are not simple for a variety of technical, political and social reasons.

Concerns about food security, and the economic and financial impacts of adjustment on fishers and fishing communities are also important considerations for fisheries managers. These impacts are also not confined to the commercial sector, but affect all consumptive and non-consumptive users of living marine resources, including recreational fishers and the general public. As a consequence of these other concerns, property-rights based management systems are not always considered appropriate, and the problem of overcapacity needs to be addressed using other measures.

In fisheries where property right management systems are deemed not to be appropriate, explicit capacity management systems need to be introduced. In its simplest form, a capacity management system can be considered as a set of policies and tools aimed at apportioning the fleet size in order to achieve some desired level of exploitation so as to achieve the multiple objectives of management.

This requires an assessment of the existing and desirable level of fishing capacity, and decisions as to how this capacity is best utilized to achieve the management objectives. For example, in some instances a lesser quantity of fully utilized capacity may be preferable, while in other cases more capacity that is less utilized capacity may be desired. The mechanisms for achieving these goals also need to be addressed.

Unfortunately, fish harvesting capacity concepts are not as clearly understood as other fisheries management concepts, such as overfishing. The purpose of this report is to present an intuitive overview of the key issues involved with the assessment and management of capacity in fisheries. To maintain simplicity, not all aspects of the capacity management problem are addressed. These problems and issues are addressed in more detail (with consequent greater complexity) in other FAO reports and in Volume 2 of this document.

1.1 Capacity: effort, catch or vessels?

A main factor contributing to the confusion about capacity in fisheries is that different groups of people may have a different intuitive understanding of capacity.

Fishing technologists often refer to capacity in terms of the technological and practical feasibility for a vessel to achieve a certain level of activity, be it days fishing, catch or processed product.

Fisheries scientists often think of capacity in terms of fishing effort, and the resultant rate of fishing mortality (the proportion of the fish stock killed through fishing). Effort is itself a fairly abstract concept, as in theory it encapsulates all inputs employed in the harvesting process.

In practice, it is generally not possible to measure all inputs, so proxy measures (indicators) are used such as total days fished, number of pots deployed or kilometers of nets used. A relationship between the measure of effort and fishing mortality is assumed to exist. If total fishing mortality exceeds the desired target level (generally a biological reference point relating to maximum sustainable yield or some other precautionary reference point), the fishing mortality rate is too high because fishers have produced too much fishing effort. If regulations can be imposed to ensure that effort levels are in line with target fishing mortality rates, then capacity is not considered an issue and the fact that fleet size may be larger than required is somewhat ignored.

Fisheries managers generally have a similar view of capacity, but often link this more directly to the number of vessels operating in the fishery. This view is particularly prevalent where the fishery is managed through the use of input controls as fleet size and effort levels are the main control variables.

To many managers, capacity may be expressed in measures such as gross tonnage, for example, or in terms of total effort (e.g. standard fishing days). Assuming that there are no restrictions on effort, these measures may indicate that too many boats may potentially produce too high a catch, so overcapacity may be considered to exist if the fleet is larger than desired. Thus, a link is somewhat established between existing and target levels of effort and fleet size.

Fisheries managers may also be concerned with the rate of vessel utilization. Underutilized capacity may manifest itself as boats fishing less than their expected "normal" number of days (full use), and thereby catching less than their potential. This situation often occurs as a result of catch or effort restrictions. In this case actual fishing effort (and/or catch) figures underestimate "capacity" and a better indicator will be potential fishing effort, assuming normal use (and corresponding catch). With respect to assessing capacity, this implies that some consideration will be given to cost minimization.

The previous groups tend to think of capacity primarily in terms of inputs (an input perspective). In contrast, **economists** tend to consider capacity as some level of potential output that could be produced if the boat was operating at maximum profits[1] (an output perspective).

Operating at less than full capacity implies, therefore, that boats are not achieving their maximum profits, and that profits could be increased through increasing their output. In the short term, when stock sizes are given, profit maximization implies the full use of the vessels, which requires the application of a target nominal level of fishing effort (e.g. days fished) to achieve a target catch level.

The economic definition of full use incorporates short-term cost-benefit considerations (i.e. the additional revenue derived from an additional unit of output must at least equal, if not exceed, the additional cost of catching it). As a result, the full use level of catch and fishing effort from an economic perspective may be less than is technically possible for the boat to achieve or apply. In the long term, higher catches can be achieved at a lower level of exploitation, with the economic reference point being generally more restrictive than biological reference points.

The implications of the differences in the concepts are most apparent when considering fisheries management responses to the problems of excess capacity. For example, if the vessels fished for fewer days, then the level of effort would decrease and the "problem" of overcapacity would disappear from the perspective of the fisheries scientist. However, the problem would remain for the manager,[2] and be worsened for the economist, as the reduced utilization would result in even lower levels of profitability.

Conversely, reducing the number of vessels in the fishery would result in the effort level also being reduced (satisfying the scientists) and directly reduce capacity from the manager's perspective. As the reduction in the fleet size will allow the remaining boats to operate more effectively, the problem is also reduced from the economists' perspective.

Despite their apparent differences, these different concepts of capacity are not necessarily incompatible and may even be considered complementary. Basic relationships between catch, effort and fleet size exist, although the level of utilization of the vessels may affect these.

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[1] Or maximum benefits if these two objectives differ.

[2] This depends on the objectives of fisheries management. In some cases, a larger fleet that is not fully utilized may be preferable to a small, fully utilized fleet. For example, during stock recovery the full fleet may be required to optimally take the catch when the stock is recovered, but the level of effort is too high to allow stock recovery. Effort limits that reduce capacity utilization in the short term may therefore be an optimal management decision.

In order to try and capture these alternative views of fishing capacity, FAO (2000) developed a definition of fishing capacity that was both input (e.g. effort, boat numbers, etc) and output (catch) based. Fishing capacity was defined as: *the amount of fish (or fishing effort) that can be produced over a period of time (e.g. a year or a fishing season) by a vessel or a fleet if fully utilized and for a given resource condition.* Full utilization in this context means normal but unrestricted use, rather than some physical or engineering maximum.

1.2 Capacity utilization, excess capacity, overcapitalization and overcapacity

The initiative to monitor and manage capacity instigated by the FAO through the International Plan of Action (IPOA) has also resulted in some confusion regarding definitions of key terms (if only because "capacity" is not defined in the IPOA). A distinction needs to be drawn between the concepts of capacity *utilization*, *excess* capacity, over*capitalization* and over*capacity* – concepts that are also often confused.[3]

Capacity utilization represents the degree to which the vessel is fully utilized. From an input based perspective, this may relate to the ratio of the number of days actually fished to the number of days the boat could potentially fish under normal working conditions. From an output based perspective, capacity utilization is the ratio of the actual catch to the potential catch (if fully utilized). This is understood, given prevailing resource conditions. Thus the two approaches will be equivalent only if one assumes that catch rates will remain the same in the short term even if effort expand.

Excess capacity exists when the potential catch or effort level exceeds the actual catch or effort level in a given period. It manifests itself in terms of capacity underutilization, and the existence of capacity underutilization implies the existence of excess capacity. Excess capacity is primarily a short-term[4] phenomenon that can arise for a number of reasons. For example, lower prices or temporarily higher costs (e.g. fuel price increases) may result in boats operating on average for fewer days than expected under more average conditions. Assuming the prices and costs return to normal levels in the future, then this form of excess capacity will be self correcting.

Excess capacity can also be caused by management. For example, stock recovery programmes may impose restrictions on catch or effort that results in the vessels being underutilized during the recovery process, but allows the vessels to be fully utilized when the stocks have increased. In such circumstances, the existence of excess capacity would not be considered problematic.

Excess capacity can also indicate, however, longer term problems in the fishery. If restrictions are imposed that limit catch or effort and these restrictions are likely to persist into the future, then it is likely that excess capacity is an indicator of overcapitalization in the fishery.

Overcapitalization is a longer-term problem for the fishery. In its simplest form, overcapitalization can be considered to exist if the fleet size is greater than that required to

[3] Some of these concepts were introduced in the previous section.

[4] Long-term and short-term do not refer to any specific length or period of time. These terms refer to the ability of an economic agent (such as a fisher) to adjust their use of inputs or outputs. All inputs and outputs can be adjusted in the long term, while at least one input or output cannot be adjusted in the short term. For example, in the case of fisheries, the capital input (the boat) is generally fixed in the short term, while fishing effort can be varied. In the long term, fishers can change their boat as well as alter their fishing activity.

harvest a particular yield (which in many cases may be greater than the current yield). This can be illustrated for the simple case of a single fleet exploiting a single species.

In Figure 1, a yield curve is depicted that relates sustainable yield to fleet size.[5] In the simple fishery used in this example, growth is maximized at half the environmental carrying capacity of the stock. The level of growth is equivalent to the sustainable yield, as this can be removed through fishing indefinitely and will be replaced through natural growth the following year. If we assume a linear relationship between yield and effort for a given level of biomass, then the resultant sustainable catch-effort curve appears as given (Figure 1).

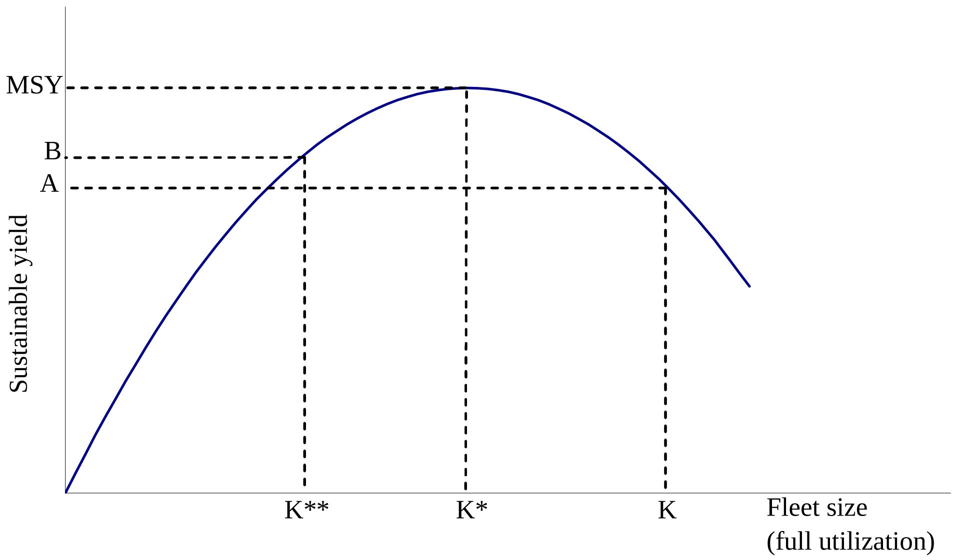

Figure 1. Example of a single species, single fleet fishery

In this simple example, the fishery is assumed to be operating under conditions of free and open access with a fleet size *K* producing a sustainable yield *A*, and the fleet is assumed to be fully utilized for the purposes of the example.

Higher yields could be achieved by reducing the fleet from *K* to *K**. This would result in the generation of the maximum sustainable yield (MSY), a target level generally considered minimal in terms of ensuring sustainability and a point beyond which the stock is generally considered to be *overfished*. When costs of fishing are taken into account, a more desirable fleet size may be *K***, giving a sustainable yield of *B*. In this example, the sustainable yield at *K*** is also greater than at K (i.e. *B>A*), although this is not necessarily always the case.

The difference between *K* and *K** or *K*** represents the level of *overcapitalization* in the fishery.[6] This represents waste in terms of both the use of the resource and the benefits that may be generated from the fishing activity.

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[5] Underlying this yield curve is a relationship between biomass, growth rates and sustainable yield, and also between fleet size, biomass and yield.

[6] The pure economic definition of overcapitalization is the difference between the current level of capital (e.g. fleet size) and that which maximizes economic profits in the fishery. Even at MSY, the fishery is considered to be overcapitalized as greater profits could be earned by employing fewer boats (i.e. less capital).

The additional capital, labour and fuel used in maintaining the fleet at *K* not only reduces the potential revenue that could be realized from the fishery, but also costs more to harvest the lower level of fish than is necessary. Greater catches (and revenue) could be obtained at lower total cost. The cost savings and potentially higher revenues generated with smaller fleet sizes can generate economic profits that can be used for the general benefit of the fishing communities or society as a whole.

The term "overcapitalization" was used in the above illustration rather than "overcapacity" as it related specifically to an input-based measure of capacity based on fleet size.

Overcapacity can be considered the generic term for excessive levels of capacity in th e longer term and relates to some long-term desirable level of capacity (the target capacity). This may be either some long-term target sustainable yield, or some long-term target level of capital employed in the fishery.

The relationship between overcapacity and excess capacity is not straightforward. It is quite possible for overcapacity to exist even in the absence of excess capacity (the short term measure).

For example, at fleet level *K* in Figure 1, all boats were assumed to be fully utilized, with biomass rather than effort being the factor resulting in the lower level of output. In such a case there would be no apparent excess capacity, although the fishery is considerably overcapitalized, and hence overcapacity exists.

In contrast, if the fleet were subject to an effort quota (e.g. days at sea restriction) such that each boat was not fully utilized, it may be possible to achieve MSY even with fleet size *K*. This is illustrated in Figure 2, where fishing effort – the product of both days fished and fleet size – replaces fleet size on the x-axis.

If permissible days at sea are reduced by some proportion so that the total effort level is $\alpha E(K)$ rather than $E(K)$ (where $\alpha<1$), it is possible that MSY could be achieved and maintained in the longer term.[7] However, the fleet size, *K*, is capable of producing considerably greater levels of effort, and could potentially, if not restricted, catch substantially higher catches in the short term (e.g. C) even though the long term sustainable catch at that fleet size is considerably lower (i.e. A).[8]

In such a case, the fishery would have both *excess* capacity and *over*capacity even though the maximum sustainable yield was being achieved.

[7] The mechanism for this is not apparent from Figure 2. Initially, catch levels would fall below the sustainable catch level, allowing the stock to recover. Catches increase as stock size increases until MSY is reached.

[8] The mechanism here is the reverse of the previous footnote. The higher catch level *B* is above the sustainable level of catch. As a result, stock sizes fall. Catches also fall over time with the declining stock size until catches are equal to the sustainable yield level at *A*. In effect, a series of short-term catch curves could be depicted for each level of stock. At the lower stock level, the short-term catch curve would intersect the sustainable yield curve where the yield is *A*.

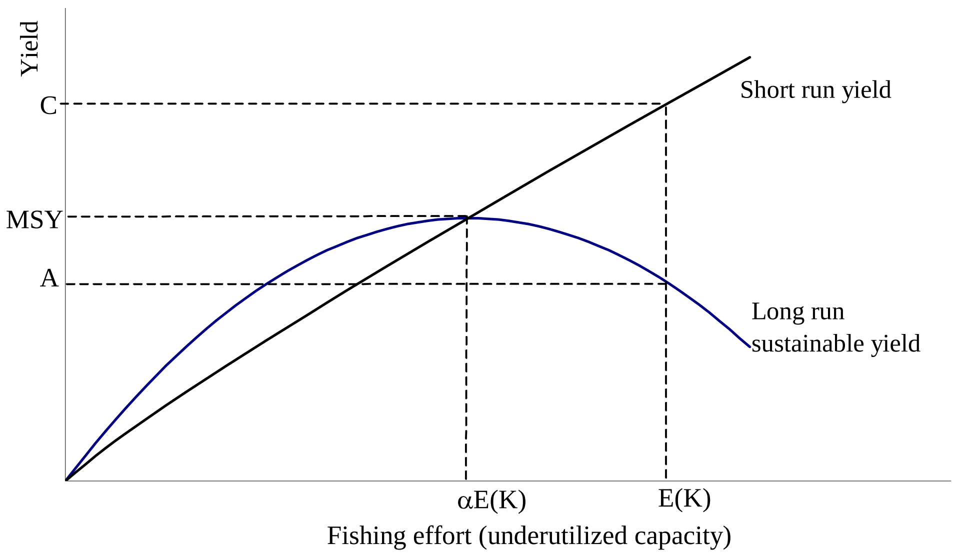

Figure 2. Example of a single species, single fleet fishery with underutilized capacity

As noted previously, excess capacity can exist for reasons other than through the existence of overcapacity. Identifying the cause of excess capacity is therefore important when assessing capacity in fisheries.

1.3 Target capacity and the objectives of management

As noted above, overcapacity is a relative measure, basically indicating that capacity is greater than some desired level. Reduced stock biomass, low yields and unprofitable fleets are not in themselves problems for managers of a fishery if the objective of fisheries management is to maintain or increase employment; then these “problems” are just consequences of achieving this objective. However, when reduced stock size is incompatible with the complete set of management objectives, overcapacity exists, and managers need to address the problem.

The fundamental objective of capacity management is to identify the desired level of capacity and bring the existing capacity into line with this target level. Further, this target level of capacity – either input or output based – also relates to some desired stock size and level of exploitation of the stock, so there is also an implicit (or, in some cases, explicit) target fishing mortality and stock level.

The optimal or target level of capital employed, fishing mortality or yield in a fishery will depend on the objectives of the fisheries policy.

The main goal of most fishery management programmes has been stock conservation. Fishery managers with this objective often use MSY as a target since it also represents the point of maximum production or yield from the resource. Doing this, in effect, captures several objectives: maximizing production from the resource, stock conservation, ensuring food security and enhancing self sufficiency.

Other reference points[9] have since been in use that have been judged more efficient to achieve sustainability objectives, accounting for resource characteristics and precautionary principle.

Unfortunately, MSY and related reference points do not correspond to the point of maximum net benefits in fisheries where positive operating costs exist. In addition, in most fisheries, MSY does not represent a stable equilibrium point in the market for that species except under a certain set of special market conditions. If prices vary with quantity landed, then achieving MSY may result in lower revenues than if lower quantities were landed. In such a case, this target is inappropriate as greater economic benefits could be achieved with either a smaller or larger fleet.

Managers also often have goals other than maximizing yield. Management based on the precautionary principle may result in a desire for higher biomass levels than under MSY, and therefore a smaller fleet may be preferred. Improving the economic efficiency of the fishery is another objective often considered in developing target capacity levels. If employment is a major consideration, then higher fleet sizes and lower sustainable yields may be preferred. Food security, political stability through employment, and international exchange, are among other reasons used to justify choosing a point that maximizes the overall benefits derived from the exploitation of fishery.

Identification of an appropriate target capacity given multiple, and often conflicting, objectives is not a trivial exercise. Ideally, multi-objective bioeconomic models can be used to simultaneously determine fleet sizes and structures, catch levels and exploitation rates that best achieve the set of objectives (see Pascoe and Mardle (2001) for an example). However, the development of such models is not always feasible, requiring alternative methods, and these are addressed in more detail in Volume II of the report (Pascoe *et al*., 2004).

1.4 The need to assess fishing capacity

It could be argued that if a property rights based management system was introduced then there is little need to consider fishing capacity as an issue. In such a case, the costs associated with excess and overcapacity would be internalized (i.e. borne directly by the fishers themselves), and incentives would exist in the fishery for adjustment to take place to remove overcapacity.

In many cases, as mentioned above, property rights based management systems are not considered feasible either for technical (e.g. inability to estimate appropriate allowable catches), social or political reasons. In such instances, management through a combination of input and output controls is required. Under such systems, incentives exist for capacity to increase rather than decrease, so capacity management must form part of the overall management system.

In order to manage capacity, managers need to understand how much capacity currently exists in the fishery and what is the desirable level of capacity (i.e. the target level of capacity) that best meets the set of management objectives. As incentives exist for capacity to increase, managers also need to regularly monitor how capacity is changing over time. Consequently, regular assessments of capacity in the various fisheries for which they are responsible are essential.

Even in the case of property rights based management systems, there are still benefits from monitoring fleet capacity. Imperfect markets may result in some overcapacity persisting, which

[9] Reference points relate to either stock (biomass) levels or yields that are aimed at achieving different objectives. These may be either target levels, such as MSY, or critical levels, such as Bpa (the minimum biomass to ensure recruitment according to the precautionary principle).

may reduce the effectiveness of the system. This is particularly the case during the transition to a property rights based management system, but may also persist after the system has been established. Under such circumstances, capacity management may be considered appropriate in order to correct for market imperfections (i.e. factors that may inhibit trade in property rights) and achieve the management objectives. Similarly, there are benefits in assessing capacity and capacity utilization in order to know what is happening within the fishery, where the overcapacity is going, its impact on other fisheries where rights have not been established, etc.

2. CAUSES AND CONSEQUENCES OF OVERCAPACITY

While excess capacity is often most apparent in a fishery as it is easiest to identify, the fundamental issue for capacity management involves overcapacity. Excess capacity may be an indicator of overcapacity, or may exist for other reasons. In some cases, for example when strict effort controls are imposed on a temporary basis to allow stocks to recover, excess capacity may be a necessary by-product of effective management. In contrast, overcapacity is a persistent problem that, unless addressed, will result in failure to achieve the objectives of management and an inefficient use of the fishery resource.

As illustrated in the previous section, overcapacity develops primarily as a consequence of market imperfections. In the case of the fishery, a major market imperfection is the absence of clearly defined property rights and the incentives this creates. Overcapacity in fisheries leads to several problems, including:

- overinvestment in capital and the excessive employment of labour in the harvesting industry with impact on processing in some cases;
- depleted abundance for both the directed fishery and associated fish stocks; overfishing and, potentially, denigration of habitat;
- reduced returns to capital and labour, and a decline in the quality of life of fishers and their families; and
- increasing political strife in the management process.

In addition, realignment of the management strategy and objective becomes increasingly difficult as the severity of its consequences increase over time. The greater the adjustment necessary to bring capacity into line with the resource, the greater the impact of the change and, consequently, the greater the resistance to change.

In this section, the factors causing the development of overcapacity and the consequences of this development are further detailed.

2.1 The link between markets and capacity

A theoretical construct that describes a market that allocates goods and services perfectly is called the perfectly competitive market. Such a market is characterized by price-taking producers and consumers, homogeneous products, the existence of complete and perfect knowledge, and free mobility of resources (Ferguson and Gould, 1975). When these conditions are met at the long-term market equilibrium, each unit of output is produced at the lowest possible cost and sells for a price that allows “normal” profits to be earned by the producer. These “normal” profits represent the rate of return on the investment that is expected given the returns that could be earned in alternative investments with similar levels of risk. They are also the minimum returns necessary to keep the producer in the industry. With perfectly competitive markets, investment flows into industries that are earning profits above their “normal” level, and flows out of industries that are experiencing less than “normal” profits. It is when these perfect market conditions are *not* met at the long-term market equilibrium that undercapacity or overcapacity can exist in the marketplace. This is known as market failure.

Under- and overcapacity exist in the marketplace when the market fails to allocate economic resources efficiently.

The assumption that the perfectly competitive marketplace consists of price-taking producers and consumers means that the buying or selling behavior of an individual entity does not affect the market price of a good or service. This condition can be met in a marketplace characterized by such a large number of consumers and producers that their individual shares of the total market are so small that any individual decision to buy or sell cannot raise or lower prices.

Alternatively, the product being produced could have such a large number of substitute products available that even a single producer could not influence the price paid by consumers by increasing or reducing output levels. Whether or not there are large or small numbers of producers and consumers, or if in aggregate their decisions do affect price levels, this assumption for a perfectly competitive market to exist requires that individual entities act as if prices are given in the marketplace.

The assumption that the perfectly competitive marketplace consists of homogeneous products means that the product of any one producer is identical to the products produced by all the other producers. This assumption means that consumers are indifferent to the firm from which they purchase the good or service. That is, real or perceived differences in the quality of a good or service do not create price differentials that consumers are willing to pay for.

The assumption that complete and perfect knowledge exists in the perfectly competitive marketplace ensures that a uniform price exists for inputs and outputs. Without perfect knowledge consumers might pay a higher price for

when a lower price is available, labourers might not sell their services to the highest bidder, or producers may not sell their goods at a price that maximizes their profits from production. This assumption also requires perfect knowledge about the future as well as the present. For example, the discovery and exploitation of a new oil reserve would increase the supply of oil on the world market thereby depressing its market price. Without perfect knowledge of the resource base, consumers of oil would overpay prior to the discovery of the new field and the price would not reflect future conditions in the marketplace.

Related to the above is the assumption that all inputs have a price that relates to the marginal value of the input (i.e. the additional value of output given the use of an additional unit of the input). Price is essentially a mechanism for allocating inputs to their most productive use. If the price is incorrect, then the input is either overused if the price is too low, or not used enough if the price is too high. This is particularly relevant for fisheries, as will be discussed below, as a key input into the production process – access to the fish stock – has a zero price.

Of importance also for this discussion is the assumption of free mobility of resources for the existence of perfectly competitive markets. This condition assumes that all resources can move to their best use or highest bidder. That is, each resource can easily move into or out of the marketplace in response to their price signals. Labour, which is assumed to be of uniform quality and skill levels, can move between employment opportunities geographically with no retraining. Also, inputs in the production process are not monopolized by an owner or by a producer. In addition, firms or capital investment can enter or leave the marketplace without difficulty (i.e. capital is malleable).

Freely mobile does not mean that costs do not exist. Individuals cannot become farmers without paying a fair price for the land on which they grow their crops or the acquisition of new skills.

Freely mobile does mean that existing firms can withhold production or new firms can begin production by purchasing the land, labour and capital needed to enter the industry. One requirement underlying the free mobility of resources condition is the existence of clearly defined and enforceable individual property rights for goods and services. Without strong property rights, resources cannot be transferred between economic entities.

If these conditions hold at the long-term equilibrium (and when economic efficiency means that profits will be maximized by individual entities as well as for the marketplace as a whole), the marketplace will allocate inputs and outputs efficiently. In the long term, all inputs and outputs are variable and can be adjusted by economic agents to their best use, which means use by the highest bidder for that resource.

These conditions can still hold in the short term, where one or more inputs or outputs are fixed and cannot be adjusted to their best use or use by the highest bidder, but profits will not be maximized. As a result of this fixed input or output in the short term, insufficient or excess capacity can exist in the market. In the long term, the fixed input or output is variable. The economic agent or entity can adjust its use of inputs or production of outputs to maximize profits at both the individual and aggregate levels in the market.

2.1.1 The link between markets and excess capacity

In general, *excess* capacity may be defined as the difference between what a production facility could produce if fully utilized and what is actually produced by the owners, given the prices of inputs and outputs. Excess capacity is a common phenomenon in all types of industries at different points in time.

For example, a tilapia farm would be constructed by its owners to produce a level of output that, given the price of tilapia, would maximize the owners’ revenue while minimizing operating costs, given the price of feed, tilapia fry, electricity, labour, and any other inputs used in the production process. If the cost of feed increased over time, the farmer would respond by reducing production because operating costs usually decline faster than revenues when production drops. While the lower level of production is efficient given the prevailing input prices, profits are lower as a consequence of the cost of maintaining the fixed assets (e.g. the tanks). The farm is producing less than it is technically capable of producing (i.e. excess capacity exists).

In the long term, the fish farmer will increase their profits for this new level of output by replacing the tanks with either smaller, or fewer tanks, resulting in lower fixed costs and hence lower production costs. Excess capacity will not exist given this new structure. Thus, in this case, excess capacity is considered to be a short-term problem that is self-correcting because of the financial incentives that the market creates for owners of the firm.

In marine capture fisheries, market induced excess capacity would also be expected to be self-correcting over time, assuming the change in market conditions persisted (and were expected to continue to persist). Indeed, as will be discussed in detail later, increasing the cost of fishing has been proposed as one solution to the problem of overcapacity. However, as discussed earlier, not all excess capacity is a direct result of changes in market conditions. For example, excess capacity can result from restrictions on season length. In such cases, purchasing a smaller vessel would be of no benefit, as the season length is beyond the control of the fisher. Instead, the incentive is to purchase a larger vessel so that catch can be increased over the limited season. In such cases, the excess capacity is indicative of overcapacity, while the incentives developed as a result of the management policy are likely to lead to increased overcapacity.

Most marine capture fisheries management plans are based on attempting to control the symptoms of market failure without addressing the real cause of the market failure (i.e. no price for the fish resource). Failure to address this underlying problem has contributed to the expansion of capacity and generation of overcapacity in many fisheries. Indeed, some measures, such as subsidies, have actively encouraged the generation of overcapacity in world fisheries. Other measures, while well intended, have often not achieved the desired results due to the underlying market failure.

2.1.2 The link between markets and overcapacity

Overcapacity can exist in a market if one of the perfectly competitive market conditions is violated at the long-term market equilibrium. The market fails to allocate resources efficiently since individual or industry profits are not maximized.

Open access fisheries have become known as the classic example of market failure as the full costs of production are not realized by the producer (i.e. the stock input is unpriced leading to its overuse). Without strong property rights for the *in situ* resource, the market mis-allocates capital, labour, and the fish stock in the production decisions of the fishers, and profits are not maximized by the industry. Instead, effort continues to increase as new fishers enter the fishery until “normal” profits are realized (that is, the level of profits is equivalent to what might be earned elsewhere in the economy, representing the “opportunity cost” of the investment).

In any other industry, the fact that producers were earning “normal” returns would be considered as an indication that the market was working efficiently in allocating resources. However, in all other industries, all inputs are priced at a level that represents their value in production. As mentioned above, in the cases of fisheries, a key input – the fish stock – is unpriced. Hence, its use (or overuse) is not considered in the production process, and the “normal” profits produced by the fishers do not account for the value of the resource consumed in the production process.

The value of the resource in the production process is the *resource rent*. In other natural resource based industries, this rent is usually extracted by the resource owner, so forms part of the production decision. For example, in agriculture, tenant farmers pay rent to the landowner. Even when purchasing land, the value of the land reflects its future productive value (equivalent to the future discounted resource rent), and this is paid by the new owner to the previous owner. In forestry, usually royalties or fees are paid for the right to extract timber.

The above-normal profits generated by fishers at the start of an open access fishery is, in fact, the resource rent. This rent is being captured by the users of the resource (rather than the owners of the resource). It is this resource rent that attracts new entrants to the fishery, and it is this resource rent that is dissipated through the use of excessive levels of inputs. Hence, not only are yields lower than might otherwise be achieved, a valuable potential source of revenue to society (the effective owners of the resource) is lost through the additional costs (capital, labour, fuel etc) associated with overcapacity.[10]

[10] In practice, effort expansion (and consequent overcapacity) in many unregulated fisheries goes beyond the point of resource rent dissipation. Imperfect information results in greater effort levels than the traditional model would suggest and barriers to exiting the fishery (primarily the difficulty in disposing of fishing boats that have little or no alternative use) often result in profits falling below their “normal” levels, with the effect that the fisheries (and many

2.2 Consequences of overcapacity

2.2.1 Bio-economic consequences of overcapacity

The increase in fish harvesting capacity outlined in the previous section manifests itself as a substantial increase in fishing effort in the fishery. This increase in fishing effort results in a reduction in stock size below that necessary to support MSY in the fishery, eventually reducing yield to levels that are below MSY, and resulting in overfishing of the living marine resource. Such high effort levels can cause reductions in fish stocks to levels where they are threatened with extinction. This is particularly the case if technical advances offset the effects of reduced stock size in the production process, so that it is still profitable to harvest species at very low stock levels.

Increased incidental catch (i.e. bycatch) of non-target species and habitat destruction directly results from excessive fishing effort levels that can develop in fisheries characterized by overcapacity. In many parts of the world, there are now threatened or endangered species whose recovery is jeopardized by their incidental catch in commercial fishing operations (e.g. marine sea turtles). Excessive use of fishing gear in sensitive ecological areas can also reduce the carrying capacity of the environment for fish species. Lost gear can continue to deplete fishery resources through “ghost” fishing and reduce the viability of the entire ecosystem.

The above problems stem from overfishing that arises as a consequence of overcapacity. To some extent, these problems can be reduced by imposing measures that reduce capacity utilization, such as days at sea restrictions that limit fishing effort or quotas that limit the total catch. These measures, however, come at the cost of reduced efficiency in the fishery. For example, in the Adriatic, numerous regulations on fishing activity have been imposed to counter the problem of too much capacity and too much effort, resulting in a rather old and non-dynamic fleet. In addition to imposing considerable economic inefficiencies in the fishery, these measures are usually not completely effective. Where possible, fishers attempt to sidestep these regulations through the increased use of unregulated inputs. Usually, this results in more and more regulations being imposed, further reducing the ability of the fleet to adapt to changing conditions and, thereby, further reducing the efficiency of the fleet.

The reduced profitability in the fishery as a result of overcapacity can also results in some of the overcapacity diverting to adjacent unregulated fisheries. The overcapacity problem tends to move and grow up to a point where most fisheries in an Exclusive Economic Zone (EEZ) and around the EEZ are overfished and over capitalized. For example, overcapacity in the Senegalese EEZ, and the consequent reduction in performance, resulted in fishers moving into the neighbouring EEZs of Mauritania, Guinea-Bissau and Guinea.

2.2.2 Social and political consequences

Another problem with open access management is its impact on fishing-dependent communities. Incomes in many remote, fishing-dependent communities are tied directly to the abundance of fish stocks in the fisheries. Declines in stock abundance as a result of overfishing and overcapacity, and consequently fishing income, will have an impact not only on the fishers

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fishers) are operating at an economic loss. That is, fishers may be covering their running costs and other cash costs (hence making a financial profit), but not covering the full opportunity cost of their investment.

themselves, but other sectors in the local economy that service the industry directly (e.g. fuel suppliers, boatyards) or indirectly (e.g. local stores the provide consumer goods to the fishers and their families).

While the impacts on the local economy are a direct result of localized overfishing, these impacts are also an indirect consequence by the national or regional level of overcapacity. As noted above, overcapacity in one area can lead to fishing capacity diverting to less exploited areas.

While the state of these local economies may be depressed as a result of overcapacity, reducing overcapacity may also have adverse impacts. Reducing boat numbers will reduce the number of fishers employed. Although the incomes of the remaining fishers may increase, partially offsetting the lost income of the fishers who left, the lack of alternative employment opportunities may result in social problems developing in the local communities. Displaced fishers may be forced to leave the area, and the remaining fishing population may not be sufficient to maintain the level of economic activity previously in the community. For example, schools may be forced to close as a consequence of the reduced numbers of school children and banks, post offices, hospitals and other social services may be forced to centralize. These changes will cause further declines in the local economy, pushing it further into depression.

It could be argued that these facilities only existed as a result of the unregulated fishing activity, and if property rights had been established initially in the fisheries they may never have developed. However, the fact that they *do* exist and *are* affected by reduced overcapacity can cause general reluctance to instigate capacity reduction programmes. This reluctance will largely result in the decision to reduce overcapacity becoming a political issue rather than just a fisheries management issue.

While political strife may develop as a result of attempting to redress the overcapacity problem, political strife in the management process can also develop as a direct consequence of overcapacity in a fishery. As fishery resources become increasingly depleted or as total allowable catch is reduced by management regulations to aid in stock rebuilding, recreational and commercial fishers may become increasingly vocal in the management process.

Depending upon the management institution in place in a particular country, political pressure to increase yields from a fishery could outweigh the biological advice to reduce harvest levels to rebuild stocks. In addition, the temptation to violate fishery regulations also increases as stocks recover when excess and overcapacity exist. Since profits or satisfaction from fishing could increase by more than the expected cost of the fine, fishers have an incentive to cheat and land more fish out of season.

3. ASSESSING CAPACITY

Some estimate of the existing level of fishing capacity in a fleet and the corresponding level of overcapacity in the fishery. To this end, many countries have developed a range of capacity indicators, mostly based on physical attributes of the fleet (FAO, 2000). Key indicators of capacity applied in many countries are measures such as gross tonnage (a measure of the volume of the vessel), engine power and the number of boats. In some countries, engineering measures such as vessel units, generally based on a combination of characteristics, have also been developed. More recently, output based measures of capacity have been developed that relate to the potential level of output of a fleet.

Input based measures of capacity involve an implicit assumption that the level of output is related to the level of physical inputs employed in the fishery. If these inputs were fully utilized, then the capacity of the fleet would be a function of these inputs. The level of utilization in this case would relate to the level of activity (e.g. days fished). Hence, the capacity of the fleet is related to the fixed inputs employed, e.g. capacity is assumed to be a function of boat size, engine power, etc., on the assumption that they are fully utilized. As a consequence, changes in effort levels do not change the *potential* output of the fleet, so do not directly affect the capacity (just capacity utilization).

The link between the level of inputs and the level of outputs is generally the basis for management of fisheries using input controls. Changing the level of inputs (e.g. through buyback) or their utilization (e.g. through days at sea restrictions, seasonal closures) is assumed to have a proportional effect on the level of output. However, this relationship is often not proportional, and changes in the distribution of the inputs can have a substantial effect on the output in a fishery even if the total input-based “capacity” is unchanged.

Output based measures of capacity attempt to measure the potential output and/or the level of capacity utilization directly, usually at the individual vessel level. Implicit in the estimation of the output based capacity measure is also a relationship between the level of fixed inputs, their level of utilization and the level of output. However, the methods for estimation do not generally impose the same assumptions that are implicit in the input based measures. As a result, the measures are not affected by the distribution of inputs.

While providing a better estimate of capacity and capacity utilization in fisheries (FAO, 2000), the output-based measures are not as useful for the purposes of many current management schemes. Most fisheries are managed using some form of input control, and if the management system is not changed, the only way to reduce capacity under such a management system is to withdraw some inputs and input-based measurement is necessary. Consequently, there is a need for both types of measures in fisheries management, with identification of the relationship between the different measures an important component of the management information system.

In this section, issues relating to the use of both input and output based measures of capacity are discussed. In some cases, insufficient information exists to develop either measure for the formal assessment of capacity. In these cases, indicators of overcapacity may be required, and some potential indicators of excess and overcapacity are presented.

3.1 Input-based capacity

A single fleet harvesting from a single stock can be used to illustrate the input-based capacity approach. The intent is to find a fleet size that can harvest a targeted level of output. In most fisheries, some long-term potential yield (LTPY) can be identified based on an assessment of the fish stock. This may be the maximum sustainable level of landings (i.e. MSY) that can be produced by a fishing fleet, or alternatively some other sustainable yield that corresponds to the objectives of management. For example, a bioeconomic model can be used to find the maximum economic yield (MEY), where capital investment in the fleet and the abundance level of the fish stock are such that profits are maximized. MEY is less than the MSY and is supported by a higher stock abundance and lower effort level. The larger stock size reduces the cost per fish landed for the same level of fishing effort exerted by the fishing fleet.

Associated with a target yield is a target effort level, and it is this that is used to determine the most appropriate fleet size. This requires assumptions about the level of capacity utilization that is to be employed in the fishery. A given level of effort may be produced by a larger number of underutilized vessels or a smaller number of fully utilized vessels. From an economic perspective, the latter is preferable, but full utilization may not be a realistic objective in some cases. For example, with fluctuating stocks some underutilized capacity may be appropriate under "normal" conditions to take advantage of the peak conditions. Similarly, stock recovery may require vessels to be underutilized during the recovery process, but fully (or at least more) utilized when the stocks had recovered. The use of input based measures of capacity therefore also requires some measure of target capacity utilization.

Seasonality and fluctuating stocks will increase the complexity of measuring overcapacity using input-based measures. When fish stocks are only available during certain times of the year either because they are migratory (tunas, for example) or because of regulations restricting access, measures of overcapacity become more subjective. Larger fleet sizes may be needed to harvest the resource if the fleet or portions of the fleet are restricted to a single or different geographical area. Larger vessels may be needed to follow or intercept the fish stock as it follows its migration route over the fishing season. The more powerful the individual vessels, the fewer vessels are needed in the fishing fleet. Many possible vessel and fleet size combinations are possible to harvest a particular target yield. For a single fleet and stock, the fleet that harvests the target level of output at the lowest possible cost is optimal.

Fluctuating stocks are also a common occurrence in fisheries. Different environmental conditions can cause abundance levels in different year classes, between fishing grounds and stocks of the same species. Likewise, changes in fishing pressure on predator, prey and competitor species can lead to different stock abundance levels over time. As mentioned above, with high variability in stock recruitment, fleet size needs to be larger to harvest the target level of catch during high abundance years than would be needed for a more stable fish stock, resulting in some capacity underutilization in the "average" years.

Another factor that makes input-based measures of overcapacity more difficult to measure is the existence of a single fishing fleet that exploits separately several different stocks or species of fish (i.e. operates in several different fisheries). Individual fishing vessels can move between fishing grounds in response to changes in relative abundance levels and productivity by using the same gear in a different location or by switching fishing gear types to harvest different species of fish. Multiple species of fish are also commonly harvested by single gear types such as long-lines, gillnets, and trawl gear. Regulations designed to reduce overcapacity in a fishery for one species of fish could inadvertently increase overcapacity in a related fishery if the vessels have the capability to switch gear types or fishing grounds.

Determination of the level of overcapacity is also made more difficult if multiple stocks are exploited simultaneously (i.e. a multispecies fishery). In a multispecies fishery, a high valued species could cause the fishing fleet to produce such a high level of effort that any incidentally caught species could be driven to extremely low levels. The economic solution in an open access fishery may be to concentrate fishing effort on the high value species while depleting the lower valued species. This market driven solution may not comply with the precautionary approach of fishery managers.

An additional complicating factor in understanding and measuring capacity is the existence of multiple fleets. When exploiting a single species, each fleet of vessels using different gear types will harvest different amounts of the TAC based on their gear catchability for that species. A sub-allocation of the total TAC for each fleet can be used to measure capacity, but establishing an economically efficient sub-allocation for each fleet depends on relative prices, fleet characteristics such as catchability of each gear type, and relative abundance of the fish stock. In addition, in open access fisheries where overfishing is occurring, harvests by one fleet could impact the operating costs for other fleets. Regulations designed to eliminate overcapacity that reduce the size of one fleet could result in the expansion of the other fleets.

With multigear, multispecies fisheries, identifying a target yield for each individual species becomes a secondary issue. What is more relevant is the total level of fishing effort and the configuration of the fleet that best satisfies the range of objectives faced by managers across the set of species in the fishery. Generally, sustainability is an overriding consideration, as any outcome must be biologically sustainable for each species individually. The optimal yield of each species, however, is determined by the optimal fleet and effort level taking into account the full range of activities. Bioeconomic models can be used to determine the fleet size and structure, effort allocation and resultant yields of each species across the fisheries that best achieve the management objectives. Overcapacity then becomes the difference between the existing fleet and that which is required to achieve the management objectives. In such a complex system, however, the optimal fleet is likely to be sensitive to costs and market conditions, so a robust measure of overcapacity may be unobtainable.

Input-based capacity involves more than just the vessel or boat used to harvest fish. Labour as well as capital and the stock or stocks of fish also need to be considered when developing input-based capacity measures. Identifying a target fleet size to compare to existing fleet size is also difficult when multiple inputs and outputs are being considered and fishing firms have the option to switch species relatively quickly. Seasonality of stocks can also complicate the ability to determine the optimal mix of inputs to use in producing a desired output level per firm. If more than one stock is available on a seasonal basis, the optimal fleet size may depend on the least abundant species availability, and undercapacity may exist for other species that the fleet or fleets exploit. When fish stock abundance fluctuates, optimal fleet size will change from year to year and between species. The most abundant stocks may experience undercapacity if inputs are used to harvest from the least abundant stock. Alternatively, overcapacity may exist for the least abundant stocks if inputs are set to harvest the more abundant species at their target levels.

3.2 Output-based capacity

Alternatively, output-based capacity measures can be estimated and used as the basis for managing a fleet of fishing firms. Output is based on the level of capital invested in the fishery, the amount of labour employed and the abundance of the fish stock. As such, it can be considered an index of capital, labour, and the stock abundance. Rather than treating a mix of inputs in the capacity measurement and management process, one output in the single species fishery can be used to determine overcapacity levels. In addition, most biological stock assessments identify the LTPY for a fishery in terms of a level of harvest that can be sustained over time. This allows comparisons of the firm and fleets' output levels with the target level of output determined to be sustainable by fishery managers.

If the single fleet exploiting a single species fishery, output-based capacity measures are developed as follows. First, the efficient level of output can be determined for inefficient vessels and then the most productive level of output can be selected. This information can then be used to determine both the levels of excess and overcapacity that exist in the fishery. A slightly higher level of excess and overcapacity will exist when stock abundance fluctuates greatly to reflect the increased capacity needed to harvest at the larger MEY level, or when seasonality exists. For example, excess capacity will be larger during years of lower abundance, and insufficient capacity may exist during years of exceptionally higher abundance. The point, however, is that output-based excess and overcapacity levels can be measured without first determining the optimal mix of inputs used in the production process.

In the case where a single fleet of vessels exploits multiple stocks or species of fish with the same or different gear types, output-based capacity measures can still be estimated. In the case of fishers switching between fisheries by changing the type of gear types used, each fleet can be estimated as a separate fishery. For fisheries in which multiple species are landed from different stocks, capacity can be measured in terms of one output level while holding other output levels constant. In both cases, overcapacity for any specific species can be measured relative to the LTPY for that species of fish.

The shortcoming of this approach is that the least abundant fish species could determine the capacity level for the fishery, resulting in insufficient capacity to harvest the more abundant species. If the total cost of production and the price of output is known, the MEY can be determined and used as a target to estimate the optimal capacity level needed in the fishery. This could be used to develop species-specific target levels to maximize net benefits from harvesting from the multiple stocks or species.

Similarly, in the case of multiple fishing fleets harvesting from a single stock as in the case of a multi-gear fishery, capacity measures for each gear type can be made relative to the LTPY from the fishery. Total capacity for the fishing fleet can be determined by aggregating the estimates for each gear type. In the case of multiple fleets exploiting multiple species or stocks of fish, aggregate capacity levels can be determined by aggregating the capacity estimates for each individual stock and gear type combination. However, managing overcapacity in this situation can be problematic since fishermen can usually switch between gear types fairly easily. If information exists to determine the optimal fishing fleet configuration, fishery managers can target vessels for removal to achieve their management objectives.

3.3 Indicators and measures of excess and overcapacity

Both qualitative and quantitative indicators of capacity exist and can be employed to determine the level of capacity in a fishery. While excess capacity may be of less importance than overcapacity to fishery managers, the ability to distinguish between the level of excess and overcapacity to determine appropriate management actions is still necessary.

Several quantitative techniques exist that are available for measuring excess capacity even with limited information, but estimation of overcapacity generally requires detailed information on the fisheries that may not be readily available, including information on the target level of capacity. As a result, subjective measures and qualitative indicators of overcapacity levels may provide useful information to managers who manage fisheries as open access or regulated open access resources.

3.3.1 Quantitative measures of excess and overcapacity

Quantitative measures of excess and overcapacity provide an indication of the extent of the problem, and by implication, the potential reduction in capacity that may be necessary to achieve the longer term objectives of management.

Key quantitative indicators are measures of the current and potential fishing effort produced by the current fleet, and the current and potential catch that could be taken by the current fleet. The immediate difference between these measures (i.e. current and potential) provides an indication of the short term quantity of excess capacity. Similarly, the ratio potential effort or catch to current effort of catch provides an indicator of the relative level of excess capacity.

Quantitative measures of overcapacity require the definition of the target level of capacity (effort, catch or boat numbers). Again, a measure of overcapacity is given as either the difference or ratio of the potential level to the target level. This is more complex to derive as the target level of capacity is usually based on different stock conditions than currently exist, so the potential catch needs to be re-estimated taking this into consideration (see Figure 2).

Given the complexity in estimating potential catch, several techniques have been developed to assist in the quantitative measure of excess and overcapacity. These include data envelopment analysis (DEA), stochastic production frontiers (SPF), and peak-to-peak (PTP) analysis.[11] These are output based measures that estimate levels of capacity utilization in terms of the ratio of current to potential output, from which can be derived estimates of excess capacity. These techniques have been applied to excess capacity in many industries around the world. For example, Garcia and Newton (1997) used the peak-to-peak approach to measure capacity levels in global fisheries.

Overcapacity measures that utilized DEA have been developed to measure overcapacity levels in fisheries relative to a biological target level of yield (Kirkley *et al.*, 2002) or to an economic target level of yield such as MEY.

Bioeconomic models have also been used to estimate input-based measures of overcapacity (in particular, measures of overcapitalization). Using such models, the fleet size and configuration that best conforms to the objectives of management can be estimated. This can be compared with current fleet sizes and configurations to derive an estimate of the level of overcapitalization.[12] The development of bioeconomic models for this purpose requires detailed information on biological and economic relationships in the fishery, and the results are often sensitive to changes in assumptions regarding these relationships. Further work is required in this area to develop robust models for estimation of overcapacity.

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[11] Details on how these measures are estimated are presented in Kirkley and Squires (1999) and in Vol II (Pascoe *et al.*, 2004). Examples of applications using these techniques are also presented in Pascoe and Greboval (2003).

[12] An example of the application of a bioeconomic model for the estimation of overcapitalization is presented in Pascoe *et al.* (2004).

Each of the methods outlined above has both strengths and weaknesses, and the choice of the appropriate method will vary depending on the nature of the fishery, the data available, and the intended use of the capacity measure.

3.3.2 Subjective measures of excess and overcapacity

The use of rapid appraisal techniques and expert knowledge has been used to derive estimates of a wide range of measures when data are not available. These are based on the subjective assessment of individuals who are in a position to provide an informed judgement. This might involve fisheries scientists who have been associated with the fishery for several years, or may involve key industry members who are able to provide information on how the fishery has changed over time.

For example, fishers may be able to provide a picture of how the fishery looked, say, 10 years ago, and how it has changed since then. They may also be able to provide an indication of current capacity utilization by comparing their current activity levels to previous levels.

Subjective measures are most appropriately applied to single species or simple fisheries when information is lacking. However, in some cases, subjective measures may be the only way to derive estimates of overcapacity for more complex fisheries. For example, in the case of a fishery comprised of several fleets harvesting several species, where information on the stocks is either unknown or highly uncertain, such that formal models neither exist nor can be developed.

As with any subjective judgement, the information is subject to bias. However, collecting information from a range of individuals, or the use of semi-formal techniques (e.g. the Delphi technique) may result in consistent trends in the information being detected. In the absence of any other information, the use of subjective expert judgement should not be discounted, although the results should be used with caution.

3.3.3 Qualitative indicators of overcapacity

Qualitative assessments of overcapacity can be based on verifiable indicators, which themselves are based on scientific methods. The fundamental rationale of this approach is to apply common yardsticks to all fisheries, and minimize the role of subjective judgement. At the same time, it is recognized that the judgement, individual knowledge, and experience of the analysts will necessarily play an important role. The indicators approach has important advantages: it makes maximum use of existing information and it incorporates biological, management, and fleet-specific data.

Qualitative capacity indicators can be developed from bioeconomic theory based on existing conditions in or characteristics of a fishery. It should be noted from the outset that some commonly proposed indicators have been omitted for practical reasons. For example, a “good governance” indicator is hard to assess with precision. Purely economic indicators, like profitability, would be particularly insightful, but the current situation of insufficient data on firm operating costs prevents their use. However, other indicators based on the status of the stocks or management-related tests can be used in conjunction with theoretical knowledge of a fishery to assess capacity levels.

Clearly, no one indicator can be sufficient to make a determination of overcapacity in a fishery. A combination of indicators utilizing time trend information is needed to determine qualitative capacity levels in fisheries.

Biological status of the fishery

In many countries, regular stock assessments are undertaken for key species. These assessments generally aim to estimate the stock abundance and level of fishing mortality over recent years, and often predict yields and biomass in the short term based on assumptions about continuing levels of fishing effort. Based on these assessments, advice is often given to fisheries managers about either target catch levels or effort levels, depending on the management system in place. In many cases, the stocks are classified as either overfished, fully utilized or underutilized based on a set of biological reference points.[13]

If the species in a directed fishery are overfished, overcapacity almost certainly exists since overfishing and overcapacity are both symptoms of the same underlying management problem. Further, a fishery that is characterized as fully utilized or that may be approaching a condition of being overfished is also likely to exhibit overcapacity since fewer inputs in the production process could be used to provide the same level of harvest.

The biological status of a fish stock is a reasonable and useful indicator of overcapacity, but must be applied in a careful and qualified manner. The analyst, in using this indicator for the determination of the existence of overcapacity in a fishery, must ensure that the fishing fleet is such a sufficient contributor to this overfished condition that overcapacity does in fact exist. For example, adverse environmental conditions may result in stocks temporarily falling to low levels. In such a case, there may exist excess capacity in the fleet in the short term, but assuming environmental conditions return to normal, then overcapacity may not exist.

Second, this indicator may apply somewhat differently to non-targeted and multi-species fisheries. The general observations noted above relate to directed fisheries. However, many multiple species fisheries include a mix of overfished, fully utilized and developing fisheries. Incidental harvests in a fishery directed at another overfished and/or fully utilized species may or may not indicate overcapacity for the incidentally caught species. Where species are caught together, it is inevitable that the status of the individual stocks will vary, with some being overexploited and others possibly underexploited. The optimal capacity in this case depends on the total mix of activity, not just the status of the individual stocks. In these cases, the individual analyst in each region has to determine capacity levels on a case-by-case basis.

Harvest/target catch ratio

The ratio of harvest levels to target catch (e.g. quota levels) is another management-related indicator of overcapacity. Most managed fisheries operate under harvest guidelines that usually relate to a target catch level – either explicitly through the use of an aggregate quota control or implicitly through effort limitations. Overcapacity may be thought to exist if a harvest level exceeds the target catch on a regular basis. Under this indicator, it is assumed that the target, or optimal, level of capacity is the level that is necessary to harvest the target catch in a single species fishery during a fishing season.

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[13] For example, in the United States, the annual report to Congress entitled "Status of Fisheries of the United States," prepared by the National Marine Fisheries Service, identifies fisheries that (1) are *overfished*, (2) are approaching a condition of being *overfished*, and (3) are subject to *overfishing*. Similarly, stocks in European fisheries are classified as either severely overexploited, overexploited or fully utilized by the International Commission for the Exploitation of the Sea (ICES).

It should be noted that this is not a perfect measure of overcapacity. First, effective enforcement and monitoring of the harvest levels could close the fishery before the target catch is exceeded. In such a case the harvest level would not exceed the target and no apparent overcapacity would be observed. Second, this indicator does not work well in multispecies fisheries, especially if aggregate quotas are imposed. In such cases, discarding of any overquota catch would disguise the apparent overcapacity.

A third difficulty arises if the fishery has been overfished, as the harvest level may be below the target level, especially if the target level is set high for social reasons. As this is likely to be the case in many fisheries in which overcapacity exists, the measure may be misleading as ratios of less than one may also indicate overcapacity. Nevertheless, under most circumstances, a harvest-to-target catch ratio that exceeds one on a regular basis indicates at least the potential for overcapacity to exist.

TAC/season length

Another indicator of overcapacity is the “race for fish” in which fishers harvest the TAC before the end of the fishing season. The ratio of the total allowable catch level to the season length may be used as a qualitative indicator of overcapacity. If the season length declines progressively for a number of years, that may be an indicator of overcapacity. This indicator is not a perfect test of overcapacity for the same reasons as the harvest-to-target catch relationship. However, an increase over time of this ratio could indicate the potential for overcapacity in a fishery.

Conflict

Controversies surrounding the setting of the TAC and its sub-allocation among user groups may also indicate overcapacity in a fishery. Typically, disputes occur between commercial fishers using different gear types or residing in different areas, and/or between commercial and recreational fishermen.

Evidence that the determination and sub-allocation of TACs are accompanied by a meaningful level of political controversy suggests that there may be a potential for the existence of overcapacity in that fishery. Obviously, this is a rough indicator of overcapacity for the simple reason that it is difficult to evaluate objectively the seriousness and intensity of such differences.

Latent permits

Another qualitative indicator of overcapacity is the trend in unused or latent permits. These are permits (or licences) issued to fishers that have either never been used to harvest fish, or have been used previously but are currently inactive.

Applying this definition of latent permits, it follows that the ratio of active permits to total permits (active and latent) may be used as an indicator of overcapacity. A relatively large number of latent permits, or a low ratio of active to total permits, would indicate the potential for overcapacity in a fishery. Further, as this ratio declines the likelihood that overcapacity exists in the fishery probably increases.

This is not a perfect measure of overcapacity since speculators who never intend to harvest fish may hold a permit in the hope of benefiting by selling or leasing the permit if they are made transferable. In addition, fishery managers may decide to purchase or cancel inactive permits. Nevertheless, a relatively low and declining ratio of active to total permits may, under certain conditions, indicate overcapacity in a fishery.

Catch per unit of effort

A decline over time in catch per unit of effort (CPUE) implies overfishing and, potentially, overcapacity.

However, the CPUE indicator of overcapacity must be used with care. Fluctuating TACs under a constant fishing mortality management strategy could mask this effect. The CPUE could remain constant or improve even with overcapacity in the fishery as the TAC increases with recovery of the stock. In addition, CPUE trends could remain constant or increase for schooling species even though overall stock abundance is declining.

In general, in fisheries where TACs and harvest levels are fairly constant, a declining trend in CPUE over time probably indicates overcapacity.

Value per unit of effort

Related to the above, value per unit of effort (VPUE) will decrease as the quantity of fish caught decreases, potentially indicating overcapacity.

However, there are several circumstances where VPUE may decline although catch rates remain relatively constant. For example, an increased proportion of juvenile fish in the catch, which generally attract a lower price on the market due to their smaller size, will result in lower revenue per trip even if total catch weight remains relatively constant. This would be an indicator that the stocks are being overfished and hence excess capacity is likely to exist.

Similarly, changes in the species mix will also affect the VPUE. To the extent that targeting is possible, fishers will attempt to target the most valuable species first (i.e. those with the highest price per kilogram). A fall in VPUE would indicate that these species had been depleted, and that effort had been diverted to the less valuable species.

VPUE is potentially a useful indicator for highly mixed fisheries where recording catch of each species is impractical, but recording the total value of sales is feasible.

Other measures

Other measures that may indicate overcapacity include declining profitability and increased age of the fleet. The former requires information on both revenue and fishing costs. Declining VPUE in some ways reflects declining profitability provided costs are also not changing.

An increased average age of the fleet is an indication of lack of new investment into the fishery. This again is likely to be a reflection of lower levels of profitability than can be achieved elsewhere, and hence is an indicator of overcapitalization.

3.3.4 Use of indicators for assessing capacity

While these indicators have limitations, they reveal whether overcapacity exists in fisheries. Qualitative indicators show if overcapacity exists at a point in time, but do not indicate the magnitude of the problem or the direction of change. In addition, the expertise of the analyst can influence the application of these indicators.

Again, no one indicator would be sufficient to make a determination of overcapacity in a fishery. A combination of indicators is needed to determine qualitative capacity levels. Inevitably, given the indicators' inherent lack of technical precision, different experts may apply them differently.

4. MANAGEMENT AND REGULATORY REGIMES FOR REDUCING OVERCAPACITY

The existence of overfishing, excess capacity, overcapacity and overcapitalization are symptomatic of the same underlying problem – namely the absence of well-defined property or user rights.

A key feature of these rights that can prevent overexploitation is exclusivity of use of the resource (or part of the resource). Instead, fish stocks are common pool resources. In fisheries that are subject to either little or no management, individual fishers are unable to control the activities of other fishers in exploiting this common pool. Attempts to moderate their own use of the resource will only result in benefits flowing to other users. As a result, incentives are created to overuse, rather than conserve, the resource. Fishers have a market incentive to over-invest in capital and other productive inputs in a bid to increase, or at least maintain, their share of the harvest.

Furthermore, the existence of profits in the fishery over and above those that might occur elsewhere in the economy also attract new entrants to the fishery, further increasing the pressure on the resource. The excessive use of capital and labour in a fishery causes biological overfishing to occur, resulting in a decline in sustainable yields as illustrated in Figure 1. With the appearance of overfishing and resulting declines in stock abundance, overcapacity develops in the fishery and the net benefits to the fishing fleet begin to decline.

The problem of excessive levels of fishing effort in the fishery is compounded by technological change. Fitzpatrick (1996) calculated a 270 percent increase in an average fishing technology coefficient between 1965 and 1995, representing, on average, a three percent cumulative annual growth rate. This improvement in technical efficiency resulted in profits being maintained even as stocks diminish, creating further incentives for new entrants to the industry.

The problems associated with unregulated or pure open access fisheries have generally been recognized and relatively few fisheries around the world are subject to no management at all. However, in most fisheries, management has not fully addressed the problem associated with the absence of succinct property rights, and many of the incentives associated with free and open access still exist even if the number of participants is now constrained.

Given that management changes the set of incentives facing fishers, management instruments can be considered either "**incentive blocking"** or "**incentive adjusting"**. Incentive blocking measures attempt to restrict the level of activity in some form, whereas incentive adjusting measures attempt to address the property rights issue and allow the market to assist in reducing overcapacity. A brief overview of the main management instruments shown in Table 1 and that fall under each category is given in the Appendix.

Table 1. Management instruments: incentive blocking and incentive adjusting measures

Incentive blocking instruments	Incentive adjusting instruments
• Limited entry • Buyback programmes • Gear and vessel restrictions • Aggregate quotas • Non-transferable vessel catch limits • Individual effort quotas (IEQs)	• Individual transferable quotas (ITQs) • Taxes and royalties • Group fishing rights (CDQs, etc) • Territorial use rights (TURFs)

Incentive blocking measures are effectively command-and-control measures that restrict the ability of the market to operate. For example, licence limitation programmes, while preventing new participants from joining the fishery, do not reduce the incentive for fishers to increase their individual catches. In contrast, management by aggregate quota, while limiting the total output of the fishery, does not prevent new entrants and generates incentives for existing participants to attempt to increase their share of the restricted catch. In both cases, the fisheries are effectively open access despite the regulations imposed, and in many cases this results in both excessive fishing effort levels and the regulated reduction of fishing seasons.

These market incentives to invest in additional capacity result in command and control regulations becoming increasingly complex and convoluted to control fishing effort levels in the fishery as stocks recover and profits increase. For example, as noted above, aggregate catch quotas encourage a race-to-fish, and therefore incentives to invest in capital that will ensure that individual fishing firms can maintain or increase their share of the resource. This may result in limits being placed on other effort inputs such as days at sea or number of traps. These, in turn, create incentives to increase the use of other unregulated inputs in the fishery, e.g. larger engines to cover more ground per day. This input substitution results in boats operating at a higher cost than they might in the absence of such regulations. Increased regulation in response to these adaptations encourages fishers to use increasingly inefficient mixes of inputs. The end result in many fisheries around the world is economically inefficient fishing fleets characterized by excessive fishing effort levels, overfished stocks of fish, and complex fishery management programmes.

When self-correcting, market incentives do not exist, overcapacity can appear and exist essentially forever in an open access fishery.

Without exclusive access to the resource provided by property rights, no individual fisher has a financial incentive to reduce capacity because cutting production simply increases the profitability of all the other fishers in the fleet.

4.1 Incentive blocking and incentive adjusting mechanisms: an example

An example that illustrates how overcapacity changes in response to the set of incentives embodied in the management measure is the sablefish fisheries off Canada and Alaska. These fisheries – managed separately in Canadian and Alaskan waters – were subject to both inventive blocking and incentive adjusting mechanisms.

Between 1981 and 1988, the Canadian domestic sablefish and groundfish fishery was managed based on a system of fixed-length fishing seasons linked to a target catch level. In the early 1980s, the fishery was open from February to October for a period of 245 days. The simple control on the season length was not sufficient to control fishing capacity, which continued to expand. By 1987, the fishery was only open for a total of 45 days. Despite this significant reduction in the number of open-days, catches per day increased more than 5-fold over the same period. Catch levels were consistently over the target catch during the period (see Figure 3, Source: Pascoe, Tingley and Mardle, 2002) providing an indication of the fishing pressure on the resource.

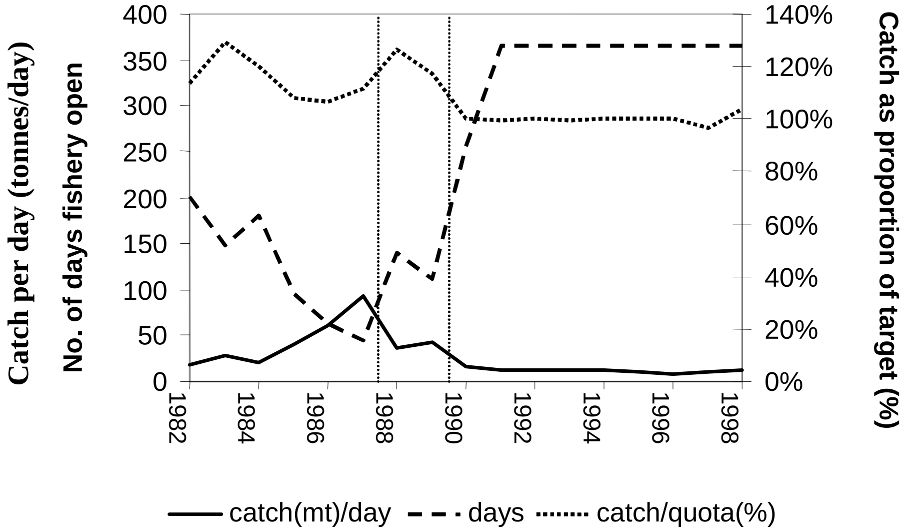

Figure 3. Catch and quota up-take history of Canadian domestic sablefish fishery

In 1990, a new management system was introduced in the form of Individual Vessel (catch) Quotas. By 1991 the fishery was open 365 days per year. Quota catches were consistently at, or very close to, the 100 percent TAC limit and IVQs allowed vessels to fish more consistently throughout the season so removing much of the race-for-fish and thus improving the efficiency of operations.

Management of the adjacent Alaskan sablefish fishery (which is essentially the same stock as the Canadian fishery) developed along parallel lines to that of the Canadian fishery. As with the Canadian fishery, the Alaskan fishery was managed using a fixed-length season with an implicit TAC, but was effectively open-access to all participants. The fishery became known as a “derby” fishery due to the decreasing length of the open season as more vessels entered the fishery each year and considerable overcapacity developed. From 1985 to 1990, the number of active sablefish vessels increased from 371 to more than 800 (Hartley and Fina, 2001).

Individual quotas were chosen as the preferred management method for the fishery in December 1991, although were not implemented until 1995, 5 years after the adjacent Canadian fishery. Eligibility for quota entitlements involved participation in the fishery in the three years prior to the announcement of the proposed scheme (i.e. landings of sablefish at least once in 1988, 1989 or 1990) (Pautzke and Oliver, 1997). The number of initial recipients of quota allocations exceeded the number of participants in the 1990 fishery by more than 50 percent (Hartley and Fina, 2001), suggesting that over 1200 vessels received some quota entitlement. However, by 1999, the number of vessels with quota entitlement had declined to 433 (Hartley and Fina, 2001).

In both the Canadian and Alaskan fisheries, increases in capacity prior to the introduction of the property rights based system typify the problems experienced with incentive blocking approaches to management. Failure to address the property rights problem resulted in increased capacity. The restrictions on activity, while limiting total output, exacerbated rather than reduced capacity.

What is unclear from these examples, however, is where the excess capacity in the fishery went following the introduction of the property rights-based system. Given the open access nature of many North American fisheries, it is possible that the problem was largely transferred to other fisheries rather than eliminated.

4.2 Applying capacity-reducing measures: equity, fairness and displacement

Of particular importance in applying these incentive blocking and adjusting regulations to fisheries is the issue of equity, or fairness. This is especially true for the incentive adjusting regulations because they make an explicit reallocation of wealth in the fishery - in contrast to incentive blocking measures which have implicitly allocate wealth. When establishing incentive adjusting programmes, those who receive the access right to harvest from the stocks of fish capture the resource rent that leads to overcapacity in the fishery. This rent can be substantial, and those who are left out of the initial allocation can be negatively affected.

In an effort to address this issue, in most cases where ITQs have been implemented the initial allocation has generally been based on past fishing activity levels (e.g. individual's catches of the species under quota over the last several years). Even this approach, however, is subject to difficulties as fishers who were less active over the qualification period, who had recently entered the fishery or who had recently replaced their boat with the expectation of higher catch levels were placed at a disadvantage. In some cases, this has resulted in legal challenges and compensation claims. As a result, initial allocation processes more recently have become complex, trying to take these other factors into account.

An alternative to giving away the quota is to auction it. This would allow some of the resource rent to be captured by the owners of the resource (society as a whole). Otherwise, the resource rent gets captured in the quota price, generating a windfall gain for the first generation of quota owners who may subsequently sell their quota. Subsequent quota buyers have to pay this resource rent to the initial quota holders, so do not capture the resource rent themselves.

Capacity reduction in any form results in some fishers having to leave the industry. These excluded fishers will have to find alternative means of generating their income. In communities that are highly fishery dependent, this could mean an increased unemployment for a region or insufficient food supplies to indigenous peoples.

The initial allocation of access rights will determine who benefits from and who bears the costs of incentive adjusting programmes to eliminate overcapacity in a fishery.

Another issue for international fisheries is the existence of overcapacity in shared stocks. Management measures taken to control overcapacity in one jurisdiction can be undermined by another jurisdiction expanding its capacity to harvest from the same stock, such as high-seas fisheries.

It can also be a problem in fisheries managed by regional management authorities. Even though TACs are set for each individual country, the aggregate effect on stock abundance can increase operating costs in countries that are trying to reduce their own capacity. Incentive adjusting management measures for shared stocks need capacity metrics that generate comparable estimates based on common biological and economic reference points.

No single, simple solution to the overcapacity problem in fisheries exists.

Changes in the regulatory institutions that give fishers a market incentive to reduce capacity in the long term are preferred to changes in the regulated, open access fishery management regime that provide only short-term relief from overcapacity. However, specific proposed management regulations must be carefully crafted by fishery managers and tested prior to their adoption to ensure they meet stated goals and objectives, and additional research needs to be completed before the impacts of proposed regulations on fleet capacity levels can be determined.

5. CONCLUSIONS

The process of capacity assessment can be simplified into a series of questions:

- What is the current capacity? and Is there excess capacity?
- If there is excess capacity, is this a problem? Is underutilization a result of the nature of the fishery (e.g. highly variable stocks), the current market conditions (e.g. temporary price or cost fluctuations), or is it indicative of a serious problem of overcapacity?
- What level of capacity is required in the fishery to meet the objectives of management?
- What does this mean in terms of fleet sizes, effort levels and capacity utilization? Do we want a small fully utilized fleet or a larger underutilized fleet? How might this change over time (e.g. as a consequence of stock recovery)?
- How do we move from the current situation to the desired situation?

Answering these questions, however, is more complex, as decisions need to be made how to measure capacity, and more critically, how to manage capacity if overcapacity is perceived to be a problem.

While capacity is a complex management problem, a carefully planned and coordinated research programme can result in comparable capacity estimates and an effective management programme that will reduce and even eliminate overcapacity in global fisheries without undermining, and perhaps even enhancing, other fishery management objectives.

Basic data collection will have to be augmented with economic information if net benefits from fishing are to be enhanced. Even though costly, this is a worthwhile activity since net benefits generated by the fishing industry could increase considerably if managed effectively.

A conceptual framework for management based on a multidisciplinary scientific model should be developed to determine what data need to be collected in each fishery, and second, to determine the direction of change and magnitude of impacts in each fishery from the adoption of fishery management regulations designed to reduce harvest capacity.

Estimates of overcapacity need to be discussed relative to seasonality in fisheries, mobility of fish stocks and fishers, and fluctuations in recruitment, for example, to determine what constitutes a level of overcapacity needing attention by fishery managers.

Capacity needs to be regularly monitored in each fishery of interest to ensure that the capacity levels are not rebounding once management regulations have been put into effect. Managers also need to discuss the steps needed to mitigate undesirable impacts of capacity reduction regulations on commercial and recreational fishermen, subsistence fishers, local communities, and fish stock abundance levels. These discussions are particularly important for shared stocks managed under regional management organizations and for developing nations that wish to have a share in the wealth that capacity management could generate in the future.

In the interim before such capacity reduction research and management programmes can be developed and adopted in global fisheries, steps can be taken to assess capacity levels in fisheries.

Where stock assessment data are available, output-based capacity estimates can be used to determine excess and overcapacity levels in specific fisheries. Where such data are not available, qualitative indicators can be used to determine if overcapacity could potentially exist in a fishery.

If three or more qualitative indicators suggest the existence of overcapacity, a finding of overcapacity for that fishery could be made. These qualitative indicators could be used to support development of a quantitative research and management programme to reduce or eliminate overcapacity in the future.

Since excess capacity and overcapacity in fisheries are essentially economic issues and the costs of correcting overcapacity could be substantial, benefits need to be maximized in any capacity management programme proposed to ensure that those who benefit compensate those who bear its costs. While a long-term potential yield in a fishery ensures the maximum sustainable harvest from a fish stock, it does not necessarily mean that the net benefits generated by the fishery are at a maximum. Developing long-term targets using maximum economic yield would ensure that management regulations that adjust fishers' incentives to conserve fish stocks are chosen to reduce overcapacity in fisheries.

Although such an approach could result in fewer fishers in existing fisheries, alternative fisheries and increased employment could develop, for example, once bycatch levels are reduced. As overcapacity is eliminated, the increased net benefits from fishing could be shared and used to enhance developing countries and local communities.

APPENDIX A: CAPACITY MANAGEMENT PROGRAMMES

Incentive blocking programmes

As the name suggests, incentive blocking measures to control capacity aim to block the incentives that are inherent in an open access fishery and that lead to increased fishing fleet capacity. In broad terms there are six categories of these measures:

- limited entry programmes,
- buyback programmes,
- gear and vessel restrictions,
- aggregate quotas,
- non-transferable vessel catch limits, and
- individual effort quotas (IEQs).

Incentive blocking programmes are only effective in reducing capacity in the short term.

For example, a government funded vessel buyback programme could be used to reduce the fishing effort level resulting in a reduced harvest level in the short term until the stock can grow to its targeted level. The reduction in fish supply as a consequence of the initial reduction in fleet size results in a higher price of fish, since demand has not changed in the fishery. The cost of producing the fish has declined as congestion on the fishing grounds has waned and as landings per firm increase. The consequent higher profit levels create incentives for the individual fishers remaining to increase their effort (i.e. more fully utilize their capacity).

If the initial capacity reduction was successful and stock levels increase, then the resultant higher profits results in further incentives being created for the remaining individuals to increase their capacity through what ever means are possible under the restrictions (e.g. input substitution, capital stuffing).

Restrictions on some inputs to the fishing activity create incentives to increase the use of unrestricted inputs if these can lead to increased individual profits, at least in the short term. This input substitution results in inefficient mix of inputs[14] being used, and can lead to further restrictions being placed on the fishery that locks the fishers into the inefficient combination of inputs (or further exacerbates the problem by encouraging the adoption of even less efficient combinations of inputs).

[14] In this case, “inefficient” is in the context of economic efficiency, as the combination of inputs is not the least cost combination, and catch is therefore being taken at a higher cost than it would otherwise be in the absence of the restriction.

Limited entry

Restricting entry to a fishery is the first step in addressing the open access problem. However, licence limitation is not – by itself – a sufficient management measure to reduce capacity. It requires other mechanisms to control the rate of increase in capacity because increases in capacity can take the form of:

- capital stuffing – where a vessel's horsepower, length, breadth, and tonnage are increased;
- changes in gear;
- changes in fishing periods or areas; and
- the adoption of technological innovations in fishing gear.

Modifications to licence limitation programmes to address capital stuffing include transferability and unitization systems. Transferring of licences allows new entry to occur as existing fishermen exit the fishery. While charges can be imposed for the issuance or transfer of licences that capture some of the rents generated by the stock, this does not prevent capacity from increasing over the long term. The rate of increase of capacity is reduced, but it continues to increase over time.

Unitization (or fractional licence) programmes assign each participant in a limited entry fishery a number of capacity units based on the physical characteristics of the vessel (e.g. length, engine power and fishing gear units). The total number of units in the fishery is capped. Under such programmes, larger boats can only be introduced through purchasing the additional units from other owners. Penalties on upgrading through unit forfeiture may also compensate to some extent the increase in capacity though boat replacement. Consequently, the total number of units may be reduced over time, although the actual capacity of the fleet may remain constant or increase if the forfeiture does not offset the increase in efficiency.

Buyback programmes

A buyback programme buys and removes vessels, licences or vessel capacity units from a fleet to decrease capacity.

Many countries have experience in operating buyback programmes, including Japan, the United States, Canada, Norway, Australia, those in the European Union, and Taiwan. Similar motivations and goals existed in each programme even though the mechanics differed. For example, some programmes purchased licences instead of vessels, and others restricted licence use or participation in commercial fishing.

While the existence of other fishery regulations has made it difficult to determine if buyback programmes have been successful in achieving these goals, Holland, Gudmundsson and Gates (1999) concluded that the buyback programmes' potential to achieve their stated goals seemed very limited in actual practice.

In the short term, capacity may be reduced in a fishery. However, as long as open access fishery incentives remain, improvements in stock abundance will attract additional capacity into the fishery. If the market incentives are corrected, individual fishers are more likely to conserve their resource stocks including the stock of fish. In addition, the buyback programmes would be more effective if the regulatory instrument that grants access to the fishery would also capture the resource rents.

Gear and vessel restrictions

Gear and vessel restrictions attempt to control capacity by controlling the use of inputs in the production of fishing effort.

Minimum mesh sizes, restrictions on the number of pots or traps, limits on the length of longlines, or the banning of gear are methods that have been employed in various fisheries. Regulations specifying physical characteristics of vessels (e.g., hull, hold, and engine sizes) to control capacity also have been used.

In general, fishers circumvent the regulations by substituting other factor inputs or new types of gear for the inputs that have been restricted. For example, regulations restricting the length of a vessel have been circumvented by increasing its beam or by increasing engine power.

Aggregate quotas

Aggregate quotas are used to maintain or rebuild fish stocks by establishing a total allowable catch (TAC) for domestic fisheries to allocate a fish stock between different fishing gears or user groups, and to allocate international stocks between nations. Aggregate quotas are fished competitively rather than allocated to individuals.

TACs used in isolation in virtually all situations are more likely to speed up the growth of fishing capacity rather than reduce it (FAO, 1998). As stocks of fish recover because of reduced fishing mortality, rents appear and attract new capacity into the fishery if entry of new fishers or expansion of existing fishing effort is not controlled. As a result, a race for fish or fishing derby develops that results in increased harvest capacity, shorter fishing seasons, and higher harvesting costs needed to land the same amount of fish in a shorter period of time. When approaching the limits of a binding TAC, sufficient real-time data may be difficult to obtain to use as a basis to close the fishery, resulting in frequent overruns of the TAC.

These large landings over short time periods frequently result in excess processing capacity, such as the peak load problem. This results in overcapacity in the fishing sector and in idle capacity in the processing sector.

Non-transferable vessel catch limits

Individual vessel catch limits are a form of individual quota without transferability between fishers.

As such, they partly address the property rights issue, but do not allow any mechanism for capacity to adjust out of the fishery and, as a consequence, the problem of overcapacity is not addressed – but the growth in overcapacity may be stopped. By restricting the amount of fish each individual fisher may land, the race for fish can be slowed. Staggered or tiered catch limits have been used in fisheries to allow full-time or specialist fishers higher catch limits than part-time or generalist fishers.

As with any form of output control, fishers could circumvent catch limits by landing fish at out-of-the-way docks and ports, or through misreporting actual landings in document based monitoring systems. However, vessel catch limits could have applications in community-based fisheries if widespread adjustment out of the industry was thought to be problematic for these communities.

Individual effort quotas

Individual effort quotas (IEQs) limit the fishing effort that a fishing craft can apply to a fishery. Usually a restriction is placed on trawl time, time away from port, or fishing days that the vessel can employ.

While not addressing the property rights issue directly, effort quotas can have some benefits through creating incentives for self adjustment, and therefore may fall between the categories of incentive blocking and incentive adjusting programmes. Where IEQs are transferable, fishers can purchase them from existing fishers or sell to new entrants. This can allow the consolidation of fishing activity, reducing the level of excess capacity and possibly also the level of overcapacity.

However, as with vessel catch limits, enforcement is difficult since effort is expended away from port and restrictions can be evaded. As with gear and vessel restrictions, capital stuffing is a common occurrence under IEQ programmes.

While days fished or trawl time may remain constant, the fishing power of the vessel can be increased by substituting other factor inputs in the production process for the fixed effort variable, thus causing the effective fishing effort of the vessel to increase. As a result, fleet capacity can increase over the long term, requiring constant re-adjustment of the total allowable effort.

Incentive adjusting programmes

A second management approach designed to reduce overcapacity in a fishery using incentive adjusting techniques is the adoption of a rights-based management regulatory system such as:

- individual transferable quotas (ITQs, also known as individual fishing rights or IFQs);
- taxes and royalties;
- group fishing rights (including community development quotas (CDQs) and other community-based management[15]); and
- Territorial Use Rights (TURFs).

Cooperatives, co-management, individual transferable quotas (ITQ), individual fisherman quotas (IFQ), and community quotas are examples of management regulations that internalize the market failure that induces overcapacity in a fishery into the production decisions of the individual firm or fisherman. (In addition, and although the economic implications have not been fully discussed, an industry-funded buyback programme may also internalize the costs of an open access fishery into the fisher's production decisions.)

What these regulations have in common is that they create a management instrument that captures the value of the resource (resource rent) and causes the fisher to behave as if it is a cost in deciding how much they should produce at a given stock size. Thus, each of these cause the fisher to behave as if their costs of production have increased.

> ***If the management institution is changed to allow a fisher to internalize the social cost of exploiting the resource – by establishing cooperatives, co-***

[15] These management instruments can take several forms including an ITQ or IFQ coupon or share that can be transferred between fishers, a landings tax to repay an industry-funded buyback programme loan, or in the case of a cooperative, a share in the organization or a contract to harvest fish among the cooperative members.

management, or rights-based fisheries – the consequences of overcapacity in the form of overfished stocks of fish should be corrected.

Incentive adjusting measures to control capacity change the regulatory environment and create a market incentive that causes fishers to adjust their fishing capacity. Fishery management regulations eliminate the open access externality by causing fishers to behave as if they own the *in situ* fishery resource. When fishery resources are no longer free to whomever harvests them first, fishers are willing to invest in the future by conserving the fishery resource as well as other resources used in its harvesting.[16] As a result, overcapacity is eliminated in the fishery.

Individual transferable quotas

Individual transferable quotas (ITQs) explicitly limit the fish that a fleet can harvest from a fishery and assign tradable shares of the total catch to the participants in the fishery. ITQs have been found to have been effective at controlling capacity in the fisheries to which they have been applied. A commonly cited example of this is the case of New Zealand's fisheries.

While self-adjusting with regard to capacity, ITQs are not believed to be practicable in all cases. Questions have been raised regarding the application of ITQs to highly variable fish stock – such as shrimp fisheries – owing to the technical problem of determining an appropriate total allowable catch each year.

ITQs have other features that have prompted some individuals to raise objections to their use. In the case of multi-cohort stocks, for instance, concerns may exist about high-grading catch – the discarding of less valuable cohorts when price is greatly affected by the size of the fish. Discarding overquota catch is another issue that has been raised with regard to ITQs that has not been adequately addressed in an empirical manner, although several studies have found that overquota catch (and subsequent discarding) has been reduced in some fisheries as a result of ITQs. A capacity cascade, displacement, or spillover of capacity may occur if ITQs are sequentially adopted in a series of fisheries as fishers move from one fishery to the next.

However, and despite these concerns, which are similarly relevant for many other management measures that are regularly applied, for the fisheries in which ITQs have been applied, substantial long-term declines in capacity have been observed. Three examples in the USA include:

- the pollock cooperative established under the American Fisheries Act;
- the individual transferable quota programme in the southeastern wreckfish fishery; and
- the individual fisherman's quota in the Alaskan halibut/sablefish fishery.

By addressing the open access problem, these programmes have had a positive effect on reducing capacity by either lengthening the fishing season or reducing the number of vessels in the fleet.

Under these approaches, resource ownership remains with the management authority, yet the transferable harvest rights give fishers a financial incentive to reduce capital investment and labour used in harvesting the fish stock in order to increase individual profitability.

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[16] For example, a fisher will produce fish until the cost of producing the last pound of fish is just equal to the revenue it generates. When fish in the sea are free to the fisher, they do not have to pay its value to the owner. This reduces their costs of production. The fisher overproduces fish, because the cost of the next unit of fish produced is less than the revenue it generates.

Taxes and royalties

While a tax on landings is theoretically equivalent to ITQs in reducing capacity in a fishery, little empirical evidence of its actual impacts is available.

A serious problem in developing taxes is determining the optimal tax rate to apply to a fishery at a particular point in time. That is, the amount of capacity in a fishery depends upon the abundance of fish, the ex-vessel price, and the unit cost of fishing effort at each point in time. As costs, prices, and abundance fluctuate, capacity levels need to be adjusted by an appropriate tax adjusted on a timely basis.

With taxes, the governing authority has to determine the appropriate level of tax and has to decide when to change taxes to optimally control capacity. In contrast, with ITQs, these adjustments occur in the ITQ market automatically to determine the optimal capacity level.

In Asian countries, a tax on landings caused widespread protests among small-scale fishers and consumers who expected the taxes to result in higher prices (FAO, 1998). Landings taxes have also been proposed in United States fisheries to offset the costs of loans to fund industry financed vessel buyback programmes.

Royalties have a similar effect on reducing capacity, as they are effectively a form of tax. A fee paid per pound of fish landed or on quota holdings to a managing authority would theoretically reduce the ex-vessel price received by fishers, which would slow the rate of growth in harvest capacity in a fishery.

This method is in many countries for recovering rents in natural resource extraction activities (e.g. offshore oil leases or forestry “stumpage” charges) and could be employed in the management of fisheries.

A related mechanism that is not designed primarily for capacity management is management cost recovery charges. These internalize at least some of the costs imposed by the fishing fleet (e.g. enforcement, monitoring and research) that are otherwise borne by the broader community. Failure to recover these costs amounts to an effective subsidy of the industry, which itself contributes to some of the overcapacity.

Group fishing rights

Community-based and co-management systems have been introduced in several countries with some success at controlling and reducing capacity.

In Australia and New Zealand, involving the industry in the management process has generally been considered successful in devising appropriate management plans that limit or reduce capacity. However, in the United States, the National Marine Fisheries Service (NMFS) and regional Fisheries Management Councils may be considered a co-management framework between the government and fishers that has unsuccessfully controlled capacity in domestic fisheries.[17]

Community Development Quotas (CDQs) instituted for Alaskan native tribes is an example of a potentially effective group fishing rights programme that could reduce capacity substantially since the community can effectively control effort. For group fishing rights systems to be

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[17] However, a number of exceptions to this general result exist, including the wreckfish fishery in the southeastern region, the halibut and sablefish fisheries in the northwest and Alaskan fisheries, and the surf clam fishery in the mid-Atlantic region of the United States.

effective, the group must be able to exclude outsiders; that is, the group right must be enforceable.

Community-based management methods have proven to be effective in some cases (for example, Senegal, Japan, and, in the 1940s and 1950s, the Gulf of Mexico shrimp fishery). However, these methods are not expected to perform well when:

- there is no institution building capability;
- membership cannot be restricted; or
- the ability to enforce rights and rules does not reside with the community.

Furthermore, community-based management may apply any method for governing capacity within a community.

Community-based management is attractive because of the improved proximity of decision-makers to consequences. However, a wide range of potential decisions and outcome exists. If transaction costs[18] are not too great, community-based management may be fully efficient and the outcomes may be desirable.

Territorial use rights (TURFs)

TURFs represent another means to control capacity by causing fishers to behave as if property rights for a fishing ground exist. Access to, and use of, a particular fishing ground or site is restricted to a small group or an individual. This group can determine how to harvest fish from the site and to whom the fish is allocated.

Oyster leases could be considered a form of TURFs, where private ownership was compared to public access and resulted in both a reduction in capital investment and an increase in labour employed to harvest oysters (Agnello and Donnelley, 1976).

[18] Transaction costs are the costs associated with reaching a decision by a group of individuals.

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