# GREAT LAKES FISHERY COMMISSION

## 1992 Project Completion Report[1]

# Economic Values and Policy

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# ECONOMIC VALUES AND POLICY

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## *1. Introduction*

### Initial Comments and Objectives

One of the most controversial issues currently faced by fisheries managers is the allocation of fishing rights amongst competing users. One controversy that arises frequently involves the division of quotas between commercial and recreational users. We will concentrate on this issue and examine how economic analysis can be used to better understand the problem and to offer solutions. As the reader will see, there are many complex economic questions of efficiency and distribution that must be addressed and resolved. Matters are made even more difficult by the convincing 'common sense' analyses that have been contributed to the debate. The arguments contained in these analyses typically 'sound' correct but, on closer inspection, turn out to be false. As part of the introduction to the analysis presented in this paper and further as a reference point for much of our discussion, we begin by presenting a stylized version of one of these analyses. The numbers that appear are for purely illustrative purposes and not intended to describe any particular fishery. The example is presented in a way that gives the reader an opportunity to be swayed by the (incorrect) arguments. In fact, the reader can reasonably expect to be convinced by the arguments. A measure of the success of this paper will be its ability to get the reader to begin questioning the reasonableness of the incorrect arguments.

Once the stylized valuation example has been presented, the paper will proceed as follows. First we will present a theoretically ideal setting where inter-user quota allocation problems can be described and resolved. We will show and explain how a competitive market allocation of quota rights (which currently does not take place) can resolve the problem in a fashion that is optimal from the perspectives of both the individual user and society. We explain why the quota allocation proposed in the stylized example will not in general be consistent with the optimal allocation. Finally, we search for a practical method of determining and implementing a socially optimal quota allocation. We suggest that applied valuation analysis provides a useful approach. This approach would, however, require a considerable amount of information about commercial and recreational fishermen that is not currently available. The third paper in this series describes some statistical techniques that can be used to obtain this information.

The issues addressed in this paper tend to become complex very quickly and, further, involve many subtle aspects of economic theory. The topics range from individual and social economic efficiency to the distribution of economic gains. Every effort had been made to keep the discussion at a nontechnical level in the sense that no mathematical formulae or diagrams enter the body of the report.

## *2. A Stylized Example of Quota Allocation Arguments*

### The Setting

We will begin with a lake containing a fish population that follows a well-defined biological growth law. Two sets of users harvest the fish resource. One group is comprised of a fixed number of commercial harvesters (hereafter referred to as fishermen) each of whom has a quota describing his or her (hereafter referred to as his) maximum extraction. The other group is made up of recreational anglers. Each angler faces a quota in the from of a maximum daily harvest. We will suppose that licenses limit the number of sports fishermen at the lake. Without entering into too much detail, we simply assume that the government has determined a total quota for the lake and has allocated it to recreational and commercial fishermen (perhaps at historically determined levels). To make the example concrete we will assume that the total annual quota is 5 units of fish: 2 are distributed to recreational fishermen and 3 go to commercial fishermen.

## The Arguments

A controversy has developed. Recreational fishermen claim that their quota should be raised to 5 fish units and that the total commercial quota should be 0. The recreational fishing lobby (which contains both recreational anglers as well as guides and fishing lodge owners) has supplied the following information in support of their claim.

First, total expenditures by recreational anglers over the year have equaled $24. This includes expenditures on travel, accommodation (including fishing camps and resorts), guides, gas and rental of equipment and boats. As well, the anglers' lobby argue that this should be considered an underestimate because the $24 will result in further expenditures as the money enters the economy and multiplies its effect. That is, positive secondary impacts will arise from the initial expenditures when, for example, lodge owners spend their revenues on good and services.

Secondly, and following from the first point, the anglers argue that each fish unit caught by recreational anglers has a 'value' of $12. This value is calculated as the total expenditures made to catch the fish ($24) divided by the number of fish units caught (2, assuming that the entire quota is harvested).

Thirdly, the recreational fishermen point to published figures which (we will suppose) show that each fish unit caught in the commercial fishery sells for $1. We will assume that there is a well developed competitive market which establishes the price of output from the commercial fishery.

The recreational lobby concludes that, on the basis of available information, the commercial fishery should be closed and the quota should be transferred to the recreational fishery. They argue (and provide 'witnesses' to substantiate the point) that the fish resource should be allocated to the use where is has greatest value. According to the lobby, society would experience a net gain of at least $33 if the commercial quota was given to sports fishermen. This value represents the difference between the value of the commercial quota were it in the hands of recreational fishermen ($36 = $12 · 3) less the value of the commercial quota in the hands of commercial fishermen ($3 = $1 · 3). The recreational lobby further suggests that $33 is an underestimate of the gains that could be realized. First, it ignores the secondary impacts. Second, it ignores the costs of landing the commercial harvest and looks only at revenue from sales.

## Discussion

The presentation of the arguments in the example was purposefully simplified. The intent is to focus ideas on the principal issues. Many will find the arguments in the stylized example convincing. Much of the remainder of this paper aims at showing that the reasoning in the example is not sound from an economic perspective. In order to accomplish this, it is necessary to introduce some economic structure. This structure extends beyond the standard supply and demand paradigm. Indeed, the economic analysis of what seems to be a straightforward issue quickly becomes complex. We will take the following steps as we move from the origins of the quota allocation problem, through an understanding of an ideal resolution and finally to proposals for resolving the problem:

1. First, we will examine why the quota allocation problem arises in the first place. Why is it necessary for the government to be in the business of setting and enforcing quotas? The problem is traced to one of ownership of the resource. Unless property rights are enforced, private economic incentives are inconsistent with collective or social economic goals.
2. Second, we introduce an ideal ownership setting where a government manager sells quota units to demanders (recreational or commercial fishermen or both) to the point where the total quota is exhausted. In this idealized setting, demanders buy temporary rights to harvest a given number of fish. Thus, this ideal market for quota units is much like the markets for standard goods such as cars or houses. Throughout this discussion we assume that the total quota has been determined in advance. Our results describing the efficient allocation of quota units amongst users is therefore conditional upon this assumption.
3. Third, we consider how the results from the ideal setting can be transferred to a more practical setting. We discuss the conditions whereby it would be socially efficient to deviate from an observed (and perhaps historically determined) quota allocation. In this discussion we draw on our previous discussion of economic values and compensation. We suggest that these conditions could be investigated empirically.

In the sections that follow we will examine issues using the basic tools of economic analysis. Our coverage is not exhaustive. At the same time, we feel that it contains sufficient detail to explain the important stylized facts.

### *3. Free Access and Tragedy*

The tragedy of the 'commons' (common property resources) appears to have been first discussed in an agricultural setting. The 'common' was a piece of land to which all townspeople had unrestricted free access but was not owned by a specific individual. The land was typically used to graze animals. Since the common grass was essentially free, each townsperson had an incentive to use it as intensively as possible. The commons quickly became barren patches that were no longer suitable for grazing. Not only the fresh growth of grass but the grass plants themselves had been consumed or trampled and killed by the large numbers of grazing animals.

A similar phenomenon has occurred with fish. Whales are a standard example but the discussion ultimately applies to all species of fish that are harvested. If there are no restrictions on access, fishermen will tend to treat the fish as a free resource. They will extract another unit of the resource whenever the cost of extraction is less than the revenue received from selling this unit. That is, harvesting will continue whenever there is profit (revenue in excess of cost) to be made from the next unit. With free access, fishing firms will enter the commercial fishery and harvest until there is no profit to be made from any further extraction. This often means that resource stocks are fished down and maintained at very low levels. At these low levels of abundance harvest costs are higher because, amongst other things, it takes fishermen longer to locate the fish, especially towards the end of the fishing season.

What is the economic problem with this industry? Individual harvesting firms appear to be acting efficiently. If one of the inputs that enters your production process has a price of $0, it seems reasonable that you would want to make as much use of it as possible.

The problem is that today's overharvesting activities impose a cost upon tomorrow. Fewer and fewer animals can be grazed on the common pasture next period. Similarly, fewer and fewer fish are available to be harvested in subsequent periods and the cost of harvesting what is there increases as the fish become more scarce. If one person (perhaps a commercial fisherman) owned the fishery, he would take intertemporal concerns into account and moderate today's harvest so that some of the resource remained for future periods. Given that the individual lives more than one period, this would be individually rational.[1] However, if no one can exercise property rights over the resource it is not individually rational to postpone harvesting. If you don't harvest the resource today, somebody else will and there still won't be any left for you to harvest next period.[2]

As the foregoing discussion suggests, the basic issue is one of property rights. When there are no enforced property rights, harvesters (both recreational and commercial) find it best to follow a policy of immediate harvesting that would be suboptimal if they owned the resource. Society suffers to the extent that too many scarce resources are allocated to the task of searching for and harvesting a depleted resource stock. One interesting feature of the common property problem is thus that what is optimal behaviour from the point of view of a society of individual economic agents is not also socially optimal.

Governments, acting on behalf of society, define property rights over resources such as fish populations. Access to the resource is often limited by quotas. Economists argue that the total quota should be set at the socially most desirable level. The determination of this optimal quota level and how it should be adjusted through time is a complex problem in resource economics which blends both biological and economic considerations. The optimal total quota is not a principal focus of this

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[1]The term 'individually rational' is economic jargon. It translates to 'rational for an individual to do'.

[2]Although we do not pursue the issue here, it is reasonable to expect that a sole owner would also want to take account of the fact that the fewer fish there are, the more expensive it is to find one.

study. As described above and as is implicit in the stylized example, we will take up the difficult and related problem of finding the best allocation of a given fixed quota amongst groups of users who benefit from access to the resource. In the next section we examine the inter-user allocation problem from what can be thought of as an ideal economic perspective. A benevolent (in a sense to be determined) manager is given rights to the quota by the government and sells it to recreational and commercial fishermen at a fixed nondiscriminatory price per unit. The scheme results in an allocation of the quota that is both individually and socially efficient.

## *4. Inter-User Quota Allocation with a Price Mechanism*

### Introduction

We begin by supposing that the government gives control over the predetermined total quota to a manager. This manager is benevolent. He has no interest in discriminating against either recreational or commercial fishermen. His goal is to raise revenue by selling units of the quota. All quota units must be sold at the same price to all individuals who wish to buy. In addition, the manager is not allowed to take advantage of the fact that he is the sole supplier of quota units. That is, he must not exercise any monopoly power. If an individual buys one unit of quota then he has purchased the right to harvest one unit of the resource. The method of harvesting (for example, angling or netting) is determined by the purchaser. The manager does not wish to disappoint any potential purchasers at a given price. Nor does he want to be left with unsold quota units. Thus, a price per unit of quota must be found so that the total number of quota units that individuals wish to purchase is just equal to the total amount of quota that has been made available by the government.

It is useful to consider more carefully how this price that equalizes demand and supply would be established. As a preliminary point, we should note that it is reasonable to expect that such a price might exist. If a price for quota units is set very low then more quota units will be demanded than are available. Alternatively, if a price is set too high, quantity demanded at that price will fall short of the amount of the total quota. Between these extremes it is reasonable to suppose that a price can be found such that total requests for quota units just equal the total fixed supply.

## Demand for Quota Units

How is total demand for quota units determined for a given price? We divide this question into two parts: one relating to recreational anglers and the other to commercial fishermen.

### Recreational Demand

Recreational demand is just a Marshallian demand curve for quota units as described in general terms in the companion paper as economic value. Once a price is stated for units of the quota, an individual can calculate his budget set (the group of affordable and available bundles). The individual chooses his most preferred bundle from that set. The number of units of fish quota in the most preferred bundle represents the individual's demand for quota units at the stated price.[3] The total demand by recreational fishermen at the stated price is just the sum of the desired quota units

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[3]The reader will note that we are using a simple model of a recreational angler. In particular, we suppose that the angler can determine ex ante how many fish he wishes to catch at a given price. We set aside issues about whether the angler actually finds these fish and the specific details of how extra units of fish contribute to wellbeing. Another feature of our analysis is that the recreational angler is assumed to pay a one-time fee to gain access to the lake. This fee does not vary with the number of fish that are caught. The recreational fisherman must buy sufficient numbers of quota units to cover the number of fish he extracts. By definition, a model must include some abstractions and simplifications. We feel that our representation of access costs is both simple and reasonable. Finally, the reader will note that, in this discussion, we are assuming that units of quota are sold. While we will come back to this issue, it is useful to note that this is different from most recreational settings where the right to harvest the resource is not sold on a per unit basis.

of all anglers. Other things being unchanged, it is likely that the total recreational demand for quota units will vary inversely with price. If a lower price is set, more quota units will be demanded.

**Commercial Demand**

We will suppose that the goal of the commercial fishermen is to act individually so as to obtain their highest possible level of profits. These fishermen use a harvesting (production) technology that allows them to convert fish in the lake to landed (commercially marketable) fish. The only detail of the production process that is important for our present discussion is that 'factors of production' (sometimes called 'inputs') such as labour, boats, gas etc. are brought together and used to catch the fish and to transport them to market. Each productive factor must be hired and paid a 'wage' or 'rental rate' as appropriate for the period under consideration. The fishery manager's stated price for quota units is the per unit price that commercial fishermen must pay for the factor called 'fish in the lake'. In our setting the commercial fisherman is assumed to choose the best configuration of inputs for his harvesting activity. The best configuration consists of the quantities of all of the productive factors (including quota units for fish in the lake) such that profit from fishing is at a maximum. Profit is defined as the difference between the landed value of the catch less the costs of all of the factors including quota units. The commercial fisherman knows that a bundle of factors is best if, relative to that bundle, profit declines whenever the quantity of any one of the factors is increased or decreased.

The best bundle of factors for any commercial fisherman will include a fish quota component. This is just the commercial fisherman's demand for quota units at the stated price. As in the case of the recreational fisherman, it is reasonable to suppose that the commercial fisherman's demand for quota units varies inversely with price. More exactly, if the stated price of quota units increases while all other factor prices and the landed price of fish are held constant, the quota unit component of the new bundle of factors that yields a maximum of profit will be smaller. Finally, we can sum the quantity of quota units demanded by each commercial fisherman to arrive at the total commercial demand for quota units at a given price.

## Properties of the Competitive Market Equilibrium

### Initial Comments

We have now established that, for any price of quota units, there will correspond a total quantity demanded for quota units. This will be the sum of the separate demands of recreational and commercial fishermen. Recall that the manager, by assumption, makes no attempt to take (monopoly) advantage of the fact that he is the only supplier of quota units. Rather, he simply accepts a price for quota units such that total quantity demanded is equal to total available supply (the total quota).

In the sections that follow we will first describe how an equilibrium is established and then why we have had the manager behave in what may appear to be a curious and arbitrary fashion. We will explain that the restrictions on the behaviour of the manager, given the activities of the recreational and commercial fishermen, guarantee that the available quota is allocated in a socially efficient competitive fashion.

### A Quota Allocation Is Determined by the Market

In this section we assume that the market for quota units clears. By this we mean that an 'equilibrium' price for quota units has been found such that no monopoly power is exercised and such that total quantity demanded at that price by recreational anglers and commercial fishermen equals total quota (supply). The pricing mechanism further serves to allocate quota units amongst recreational and commercial users. All users have access to the market in that they are able to purchase their desired quantities of quota units at the price established by market clearing. The market mechanism does not discriminate against any individual or group of individuals: anyone who is prepared to pay the market price will receive a quota unit.

Depending on the preferences and budgets of recreational fishermen and further upon the production technology, factor and landed fish prices faced by commercial fishermen, a variety of quota allocations may arise. For example, it may be the case that, at the equilibrium market price for quota units, no commercial fishermen can afford to stay in business. That is, all of the commercial demands are zero. This may occur if demand on the part of recreational fishermen is particularly strong. Perhaps there is a large number of rich recreational fishermen who are prepared to pay a very high price per unit of quota. The resultant high prices may mean that poorer recreational anglers and commercial fishermen may find it optimal not to fish. Alternatively, commercial fishermen may buy the entire quota (if, for example, the landed price of fish is particularly high) or the quota may be purchased by a mixture of recreational and commercial fishermen.

**Efficiency of the Market Allocation**

Given that our pricing mechanism leads to an allocation of resources, is this allocation in some sense efficient or socially desirable? The answer is yes. In what follows we will explain how the behaviour we imposed on the manager leads to a competitive allocation of resources. This allocation exhibits a variety of individual and social efficiency properties.

By way of background, we note that markets tend to arise with the simultaneous presence of economic agents (firms and consumers) who are prepared to buy and sell units of a good or service. In competitive markets, individual agents act as if they have no market power and thus no influence over price. Individual consumers in the market take the market price as given and use it to determine their budget sets from which they choose the best bundle. At the same time, firms use the fixed market price to calculate revenues (fixed output price multiplied by quantity supplied), costs (fixed input prices times the number of factor units used) and ultimately, profits (equal to revenues less costs). The firm chooses the mix of factors that is best in the sense that it produces an output level that maximizes profits. If, at a given price, there is a shortfall or, alternatively, a surplus of a good, the price level adjusts in the market until total quantity supplied equals total quantity demanded at a new price. No agents are disappointed in that all of their desired purchases and sales are realized at the market price.

The constraints that were placed on the behaviour of the 'benevolent' fishery manager combined with the decisions of both types of fishermen guarantee that our representative quota market will clear as if it were competitive. As we noted, both recreational anglers and commercial fishermen took the quota price as given when determining their separate demands for quota units. The quota manager is also a price taker in that he willingly sells all of the quota units at the going market price. Finally, the quota market clears at a price where demand just equals supply.

The quota allocation that results from the clearing of the 'competitive' market in quotas has a number of desirable features. We consider three properties in the discussion that follows.

First, no agent (recreational or commercial fisherman or the manager) has any desire to change his behaviour given the price level. Each is acting in an individually optimal fashion given that he is a price taker. Alternatively stated, the allocation is privately or individually efficient.

Second, the allocation is nondiscriminatory. Any agent who wishes to buy units of quota at the market price will be able to do so. Similarly, the manager is allowed to sell all of his units of quota.

Third, the allocation is socially efficient. That is, there is no other way to allocate the quota so that one agent can be made better off without making at least one other agent worse off. This latter point is somewhat complex and lies at the heart of both theoretical economic analysis and the allocation issues at hand. Another way to state the result is that at any alternative allocation, those who gained could not compensate those who lost where the amount of compensation is such that the losers are ultimately no worse off. The gains from moving away from the equilibrium are not large enough to bribe the losers to accept the new allocation.

An example may serve to clarify some of the points about social efficiency. Suppose, as in the initial example, that the total quota is 5 units and that there are now just two agents: one recreational angler and one commercial fisherman. We will consider a situation where the demand behaviour of the agents is such that the 'simulated' quota market clears at a price of $.25 per unit. At that price, the recreational fisherman demands and buys 2 units while the commercial fisherman demands and buys 3 quota units. The fishery manager thus sells the entire quota of 5 units at a price of $.25 per unit and receives $1.25 in revenue. Finally, from the mathematical model that underlies this example, we have calculated that the profit made by the commercial fisherman is $.64 and, measured in terms of his non comparable utility scale, the recreational angler achieves a wellbeing level of 1.[4]

What makes this competitive equilibrium and corresponding quota allocation so exciting from an economic point of view? To see this we consider what happens when we change some of the conditions that led to this equilibrium.

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[4]The calculation of profit and wellbeing levels depend upon the explicit forms of the production and utility functions. Details are available in the Appendix to this paper.

Suppose that we offer the recreational fisherman the following opportunity. He is free to reallocate the total quota in any way he wishes subject only to the condition that, when all new decisions are made and implemented, the fishery manager must receive no less than his original revenue of $1.25 and the commercial fisherman must receive at least his original profit of $.64. Subject to these minimum compensation restrictions, the recreational angler can direct and control all of the operations of the commercial and recreational fisheries and the fishery manager. There is no requirement that the commercial fisherman or the fishery manager be consulted in any way. Anything is allowed as long as the other two agents receive their compensation.

Without presenting the detailed manipulations of the underlying mathematical model, we state that the very best that the recreational fisherman can do with all of this extra freedom and control is to reselect the quota allocation of the original competitive equilibrium. That is, the best outcome for the recreational angler is to allocate 2 units of quota to himself and 3 to the commercial fishery. The same result would have arisen if the commercial fisherman had been given complete freedom to maximize his profits subject to the 'wellbeing' of the recreational fisherman and the manager! The same holds for the fishery manager. If he was given complete freedom to sell quota units so as to maximize his revenue subject to the 'wellbeing' levels of the fishermen, the competitive allocation would again be chosen. The competitive allocation thus has the remarkable social efficiency property that it is not possible to reallocate resources so as to make one agent better off without having some other agent become worse off. The 'wellbeing' of any one agent is at a maximum subject to the given levels of 'wellbeing' of all other agents. As can be imagined, this is a very important property of a competitive equilibrium. It is also fairly technical to present. Nonetheless, some insight may be gained from the following discussion.

When the recreational fisherman takes over the quota allocation mechanism, he can make himself better off, other things being equal, by allocating a greater proportion of the quota to himself. However, along with this extra allocative freedom comes the added responsibility of looking after the needs of the commercial fisherman (a profit of $.64) and the fishery manager (revenue of $1.25). The necessary compensation payments can come out of the income of the recreational fisherman (this means that purchases of other goods and services must be cut back, thus reducing wellbeing) or he can raise revenue by running the commercial fishery (perhaps at a restricted level) and selling its output. If the commercial fishery is to operate, however, it must be allocated an amount of quota equal to the size of its catch and these quota units will no longer be available to the recreational fisherman.

Thus, every departure from the competitive equilibrium that the recreational fisherman contemplates involves some form of tradeoff. Every time there is a private benefit associated with a new quota allocation, there is a corresponding cost or commitment that must be met. The recreational angler soon learns that the costs associated with any move are at least as great as any ensuing benefits. It is therefore never optimal for him to change the quota allocation from the levels of the competitive allocation. The recreational fisherman cannot improve his own position and still meet the responsibility of compensating the other agents.

In fact, the freedom to choose a better allocation is illusory. Another way to think of the position of the recreational fisherman is as follows: the recreational fisherman is free to change the quota allocation as long as he remains at least as efficient in making profits as the commercial fisherman and the fishery manager so that their compensation payments can be covered. It turns out that the only way to be as efficient as the commercial fisherman and fishery manager is to adopt their original production and allocation strategies. Essentially, it is best to accept the allocation provided by the competitive market .

## Concluding Comments

This section has established some of the remarkable allocative properties of a competitive equilibrium. They are reviewed below in point form.

1. The competitive price, established such that quantity demanded just equals supply, provides an allocation of quota units amongst users.
2. The quota allocation is privately optimal in that, for fixed prices of all goods, services and factors entering the commercial production process, no agent wishes to revise his production (commercial), consumption (recreational) or supply (manager) decisions. Each agent finds his (privately) best allocation of resources.
3. The allocation is nondiscriminatory in that any agent who pays the market price will receive a unit of the quota.
4. The allocation is socially efficient in the sense that no agent would wish to change the competitive allocation given that, in doing so, he must be prepared to compensate all other agents for any change in their 'wellbeing'.

It is useful to compare the tradeoff of values that arises in our notion of social efficiency to the discussion of values that takes place in the companion valuation paper. Recall that in the valuation paper, value was determined as a form of payment that exactly compensates for an actual or planned equilibrium change that is imposed on an individual. In that paper we considered four types of compensation: compensating and equivalent surpluses and variations. In describing the social efficiency notion for this paper, we considered an individual who was free to reallocate resources to his own benefit given that compensation is be paid to the other agents. This compensation is very much like our earlier notion of compensating surplus. It is as if a quantity (quota units) has been removed from two agents (commercial fisherman and the government agent) and they are paid amounts of money (profit of \$.64 and revenue of \$1.25 respectively) so that, in a sense, they are no worse off. Starting from a competitive allocation, we found that no reallocation would be adopted by the recreational fisherman. We could just as easily have started from an allocation that was not socially efficient, and deduced that it is possible to reallocate resources so as to improve the wellbeing of one agent without making any other agent worse off.

In order to resolve the lake quota allocation problem in a practical setting, it is first necessary to find a mechanism to determine whether the proposed quota allocation is socially efficient. We know that most quotas are allocated between users following some historic pattern. This, of course, is not necessarily socially efficient but it possibly could be. Unfortunately, in practice there is no competitive market operating in quota units that solves the allocation problem for us. It is necessary to determine if generally available information (including what recreational fishermen pay for trips and the market price received by commercial fishermen for landed fish) can be used to resolve the problem of the best inter-user allocation of quota.

In closing this section we point to one feature of the analysis that we have not stressed but which could be very important in an applied setting. Throughout, we have simply assumed that the output of the commercial fishery is sold at a fixed price per unit of landed fish. As well, the wellbeing of the consumers of the commercial harvest has not been taken into account. This would be appropriate if, for example, the entire commercial catch is exported. Similarly, we could ignore this issue if changes in the commercial harvest on the lake had no effect on domestic consumers of the commercial product (perhaps because any harvest shortfall was replaced by identical imports brought in at the same price). However, if quota reallocations begin to affect the functioning of domestic markets for commercial products then the social efficiency of the reallocation cannot be determined until appropriate compensation is also given to these domestic consumers.

## *5. Properties of Socially Efficient Quota Allocations*

### Introduction

The previous section introduced and discussed theoretical aspects of the notion of socially efficient quota allocations. It was further suggested that this allocation can coincide with the allocation provided by a competitive market. In this section we consider how the socially efficient market allocation of quota units may change in response to changes in underlying conditions. For example, we examine what might happen if:

a. individuals decide that recreational fishing is a less desirable activity;

b. other things being unchanged, the incomes of recreational fishermen increase;

c. other things being equal, the landed price of fish received by the commercial fishery increases;

d. other things being unchanged, it becomes more expensive to gain access to the recreational fishery.

The simulation results that we present are all generated by the mathematical model that appears in the Appendix to this paper. The consumer part of this example is very close to what appears in the companion valuation paper. Our view is that it is not necessary to work through the complete mathematical simulation model to obtain a feel for the pattern of results that emerges. The payoff to the simulation exercises comes in two parts. First, the results illustrate how the socially efficient quota allocation depends upon consumer preferences as well as other prices and income. Second, we find what might be considered a surprise result. In particular, we find that the more that recreational fishermen spend to gain access to the lake (gas, accommodation, rental etc. but excluding changes per quota unit), the lower is their socially efficient quota. This, of course, is exactly opposite to the spirit of the initial example argument. It will be recalled that in the example it was argued that because recreational fishing expenditures were so high, the quota allocated to recreational anglers should be increased. The theoretical economic model is thus seen to partially contradict the argument attributed to the recreational lobby in the lake quota allocation problem. The remainder of the section is then devoted to explaining this result.

### Simulation Results

We now turn to a discussion of the quota allocation simulation results. It is important to keep in mind that we are dealing with example cases. The numerical magnitudes are not intended to describe any existing fishery. Nonetheless, the results are qualitatively correct in that they illustrate the direction of change in allocations that one can expect to observe. The results are summarized in Table 1. Case 1 forms the base relative to which all subsequent cases are compared.

### Case 1: The Base Case

This case was first encountered in the previous section where social efficiency and allocation issues were introduced. It was found that, other things being equal, no individual would choose to deviate from this allocation given that all remaining agents must be compensated so that they are no worse off than under competitive conditions. In the cases that we now turn to, prices, incomes, costs and preferences that were all originally held fixed are allowed to change one at a time. The effect of the changes is then measured relative to this initial equilibrium situation. The initial market clearing price for quota units is $.25. At the social optimum, the recreational fishery is allocated 2 quota units while the remaining 3 units go to the commercial fishery. Recall that in this simple example the recreational fishery is made up of only 1 angler and there is only 1 commercial fisherman. This restriction does not affect the qualitative characteristics of the simulation results.

**Case 2: Preference Change**

The underlying model of consumer preferences includes a parameter which, when increased, causes an individual to enjoy recreational fishing less. The more the parameter increases, the less enjoyable is fishing relative to other goods and services. Increasing this parameter therefore tends to decrease the demand for recreational fishing. Two effects ensue. First, overall demand for quota units decline[5] and the market clearing price for quota units must fall (from $.25 to $.17 in this case) in order for the market to again clear. Secondly, because the demand of the recreational user has fallen relative to that of the commercial user, it is socially efficient to allocate more quota units to the commercial fishery. In this case, the commercial quota now increases to 5 units and the recreational fishery gets 0. The change in preference of the recreational angler is such that recreational demand drops to 0 at the market clearing price.

**Case 3: Income Change**

In this case the recreational angler's income increases by $1 from its base level of $2. As such, the budget set of the angler expands reflecting the fact that he can now afford more bundles. The recreational demand for fishing increases with two resultant effects on market equilibrium.

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[5]Other things being unchanged, the demand by the commercial fishermen is unchanged while the recreational demand declines.

First, the equilibrium price of quota units rises from $.25 to $.33. This happens because higher income has increased (shifted out) recreational, and hence total, demand for quota units. As well, though, recreational demand has increased relative to commercial demand for quota units. This explains the fact that the equilibrium allocation of quota units to the recreational fishery rises from 2 to 3 and the commercial fishery allocation drops to 2. Another way of interpreting the result of this case is that, other things being equal, the richer are the recreational fishermen, the greater should be the recreational quota allocation because recreational demand is relatively greater.

**Case 4: Landed Price Increase**

Commercial fishermen benefit when, as we suppose, the market price at which they sell their catch rises from $1 to $2.50. Their profits will increase after they optimally increase output. However, in order to increase output it is necessary to have more quota units. The commercial demand for quota units accordingly increases causing a change in the quota market equilibrium. First, the price of quota units increases from $.25 to $.50 because the total demand for quota units has increased. As well, because the commercial demand rises relative to recreational demand, the equilibrium quota unit allocation to the commercial fishery increases to 4 while that of the recreational fishery drops to 1.

**Case 5: Increase in Access Cost**

The final case we consider arises as, other things unchanged, the amount that recreational fishermen must pay to gain access to the recreational fishery (that is, the costs of travel, accommodation, food, gas, guides, boat and equipment rental etc.) is increased from $1 to $1.60. This access charge must be paid whenever a fishing trip is taken. Alternatively, if the angler decides to forego fishing, these charges do not arise.

The effect of increasing access costs is to reduce the demand for quota units. Less income is available to the recreational angler for purchases of quota units as well as other goods and services once this one-time access charge is paid. As the total demand for quota units drops, the quota market is forced to clear at a lower price per unit. In this case, the price drops from $.25 to $.2. As well, though, the demand of the recreational fisherman falls relative to the demand of the commercial fisherman. At the new socially efficient equilibrium, the allocation of quota units to the commercial fishery has increased to 4 while the recreational fishery receives only 1 unit.

## Discussion

From a strictly economic perspective, the results arising in Case 5 seem reasonable and straightforward. Increasing the cost of access to the lake reduces the recreational demand for quota units as income left over to spend on quota units is effectively reduced. The market for quota units clears at a lower price and more quota units get allocated optimally to the commercial fishery. But, this is opposite in spirit to the case of our stylized example where the recreational lobby argued for an increased quota allocation. In part, the lobby's point was that the greater the payments made for access, the greater was the value of the fish in recreational use and, thus, the greater was the entitlement of the recreational fishery to quota units. If fact, the new optimal allocation moves quota units away from the recreational fishery and the market price of quota units actually drops. The market value of the total quota therefore drops in response to an increase in the lobby's measure of 'value'. As noted in the companion valuation paper, the market value for quota units is not a dollar measure of the total wellbeing associated with the resource.

### A Final Point

The preceding discussion has shown that there is an inverse relationship between changes in required access payments and optimal quota allocation for recreational fishermen. It does not establish that recreational fishermen are only entitled to a small quota when access charges are high. Income could be high as well or the landed price of fish could be low. Both of these factors (and many others) could compensate for high access costs and the tendency to lower recreational quotas in a quota market setting. The point to be noted is that, ultimately, we are faced with an empirical problem: Is the gain from reallocation large enough so that all those who lose can be compensated? This empirical problem cannot be solved by looking only at the size of access or tourist payments. In order to solve a quota allocation problem without the interplay of market forces, the researcher ultimately needs to know a considerable amount about the preferences of recreational anglers as well as the compensation required for all the other affected agents. This is as much information as would be required to simulate a market solution

## *6. Some Other Issues Related to the Stylized Example*

In the previous section we noted, amongst other things, that the fact that recreational fishermen paid higher access payments did not logically lead to larger optimal quotas. Notwithstanding this result, there appears to be another sense to the recreational lobby's argument relating total access payments and quota entitlement. There seems to be a notion that the access expenditures (sometimes bundled with tourist expenditures), by the very fact that they are made, increase the entitlement of recreational anglers to quota units. We now briefly consider this 'pure expenditure' argument.

In its simplest form, the pure expenditure argument can be made as follows. The existence of a relatively large recreational quota[6] attracts recreational fishermen. These fishermen make expenditures locally and thereby 'help' the local economy. In contrast, the commercial fishery does not bring in these tourist dollars. In fact, since the commercial fishery uses up quota units potentially available to recreational anglers, it tends to remove the opportunity for even more tourist dollars. Therefore, we should reallocate quota units to the recreational fishery.[7]

The problem with the argument lies in the feeling it leaves that local economies get something for nothing when they attract tourist dollars (or access payments). This is simply not true. Access payments are made to purchase goods and services in the marketplace. Scarce resources are used up to meet these demands. Thus, a decline in access payments also implies that resources can be saved or that they are available to meet alternate demands.

Consider the case of a store. Suppose that access payments fall and the store owner sells fewer cans of food and thus has lower revenue. At the same time, resources are saved in that the canned food does not have to be produced. The store owner's costs decline because he does not have to order and pay for the cans. What about the 'profit' the store owner would have made from selling the cans of food? The profit would have represented payment for the store owner's time and talents but, since the sale does not take place, these resources can now be allocated in a productive fashion to some other activity.

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[6]When the total quota is fixed, this implies that the commercial quota is relatively small.

[7]This argument assumes that there is no formal market for quota units.

It is sometimes argued that access payments (as tourist dollars) help to reduce unemployment in a region[8]. Peoples' jobs are therefore tied to the maintenance of a strong recreational fishery with large recreational quotas. The point to note with this argument is that contraction of the recreational fishery does not necessarily mean that individuals will become and forever remain unemployed. In practice, debate can become heated on this point because we are dealing with the livelihood of individuals. Nonetheless, the economic argument to be made is that the contraction of access payments tends to free up labour resources. These resources will seek and find alternative employment. There can be no doubt that hardships may arise during this search process, no matter how brief it is, but social policies and funds exist to cushion this transition and compensate the affected individuals. Temporary unemployment is not an uncommon phenomenon and it will never disappear. Employment profiles follow the short and longer run business cycles and they also reflect the pattern of development as industries grow, prosper and sometimes enter into decline. While it remains an empirical issue, it has never been established that the amount of money needed for temporary unemployment compensation would comprise either a large or a small fraction of total access payments.

Why not just avoid all of these problems and hardships by simply increasing the recreational quota? First, we are not avoiding problems with such a policy because they will now arise on the commercial side. Secondly, it is by no means obvious that the best resolution to problems associated with a possible decline in access payments is to introduce a potentially serious distortion in quota allocations. Again, the problem is an empirical one and all the relevant information needs to be gathered before it can be resolved.

[8]Alternatively, it is argued that reductions in access payments reduce employment thereby leading to underemployment or unemployment. This is relevant to the case of the store owner introduced above.

## 7. *Optimal Quota Allocation Without Markets*

### Introduction

To this point we have encountered a considerable amount of abstract economic reasoning and related detail. The analysis began with what appeared to be a straightforward issue in valuation. We considered a stylized recreational lobby argument which suggested that, because recreational anglers spent more money per fish gaining access to the resource, they were entitled to a greater share (perhaps all) of the total quota. We noted two grounds to dispute this argument. First, we showed that, other things being equal, the competitively determined socially efficient quota share of recreational anglers will decline as access payments increase. This result arose because increased access costs tend to reduce available income and ultimately recreational demand for quota units. Secondly, we argued that, in many important ways, total access payments for recreational fishing are not 'special' or essentially different from other types of consumer expenditures. A decline in access payments of a given amount will not lead to an equal net reduction in economic activity. Even though some frictions or waste may arise in the resultant economic adjustment process, a drop in access expenditures also means that resources have been freed and can be reallocated to meet the needs arising in any changed pattern of consumer demand. Thus, any forecast of a reduction in access expenditures should not be treated as a guarantee of a sustained decrease in economic activity.

The foregoing issues have arisen out of problems with the stylized argument for higher recreational quotas. The fact that these arguments may not be convincing from an economic perspective of course does not mean that recreational quotas should not be increased. It could easily be the case that society would benefit from such a reallocation. However, the stylized arguments outlined above cannot, by themselves, be used to justify any quota changes. Much more extensive analysis is required. In this section we will identify a practical decision rule that will provide a best way of dividing a given total quota amongst recreational and commercial fishermen. The decision rule will lead to an allocation that is individually and socially efficient and nondiscriminatory. Implementation of the rule, while formally straightforward, would require currently unavailable estimates of economic values.

**Some Initial Considerations**

Our search for an allocation rule is guided by the theoretical result that a competitive market allocation will be individually and socially efficient and nondiscriminatory. At the same time practical considerations must be faced. Often these practical considerations will entail problems that may have no unique resolution and which stand in the way of complete achievement of the desired allocation properties. It is useful to consider some of these issues.

First, determining an optimal quota allocation requires a considerable amount of information. For example, the quota demand curves are needed for all potential recreational and commercial fishermen. In principle, these curves, relating quantity demanded and price for each agent, are needed in order to compute the quota price at which the sum of all quantities demanded (total demand) equals total supply. Gathering all of this information would be extremely expensive and perhaps, because of financial disclosure laws, impossible. Some agents may not be represented and others may choose to misrepresent their preferences. Perhaps the best that can be done is to obtain information for representative commercial and recreational agents that is reasonably accurate in some statistical sense. Conditional upon these limitations, a market clearing price could be determined.

A second consideration concerns the distribution mechanism that must be put in place if quota units are sold. Not only must a market clearing price be determined but the purchased rights to the quota units must also be distributed in some tangible fashion to the demanders. The largest problem would involve delivery to recreational demanders. One mechanism that has been suggested in another setting is a tagging system. Recreational anglers would be required to purchase tags that would be affixed on a one time basis to their catch. Whatever method is chosen, the costs of distribution and enforcement will still need to be borne. It is also perhaps significant that the purchase of quota units would mark a major change in quota allocation procedures. A per unit charge has typically not been levied on recreational or commercial harvesting.

A final point to consider concerns entitlements or property rights to quota units that may have arisen from a maintained pattern of historical allocations or aboriginal claims. For example, suppose that the commercial fishery has had a quota of 3 units for the past 50 years. Should this be interpreted as a perpetual right to these units (or their equivalent). One reason why this is important is because it raises compensation issues which can ultimately affect the characteristics of the optimal quota allocation. Commercial fishermen, in this case, may become both buyers and sellers in the market for quota units. No theoretical, legal or empirical research seems to be available on this issue. Nonetheless, it does have important allocative and distributive implications.

It is unlikely that one allocation rule could incorporate all of the issues and problems noted above. In what follows we will work in a somewhat simplified but still very realistic setting. We will assume that recreational and commercial interests can be described by 'representative' recreational and commercial fishermen. We will further consider a payment mechanism that requires the minimum of social overhead to implement. We will assume that past activity has conferred no property rights or entitlements to quota units for either recreational or commercial fishermen. Finally, we will focus on just recreational and commercial fishermen. No attempt will be made to incorporate the values of other affected individuals including consumers of the commercial harvest.

**Market Allocation of Quotas with Nondistorting Transfers**

This section provides a necessary but brief theory detour. It deals with the issue of payment for quota units and the administrative complications of collecting revenues and distributing quota units. We ask the following question: Is it possible (in theory) to have an allocation mechanism for quota units where all the desirable properties of a competitive market allocation are maintained but where the net payment by individual demanders for quota units is zero? We stress that this is a theoretical exercise. We are simply interested in what such an allocation might look like and how it might compare to the allocations described earlier where the government ended up with revenue from the sale of quota units. It is not immediately important to us that such an allocation, should it exist, may not be implementable as such. With these caveats noted, we turn now to the conceptual exercise.

We recall the setting in which market forces served to allocate the total quota. For a range of prices for quota units the individual demands of recreational and commercial fishermen were added and compared to the total available quota. The equilibrium quota price equated total demand and supply. The total revenue received by the government for the quota was equal to the sum of payments by recreational and commercial fishermen for the quota units they bought in equilibrium.

Suppose that the government decides to 'give back' its revenue from the sale of quota units. This transfer of funds will be accomplished in a 'nondistorting' fashion. By this we mean that the transfer does not involve any form of per unit subsidy which may distort what recreational and commercial fishermen feel is the price of quota units. Rather, the agents receive a lump sum transfer of income just equal to the total amount they pay for quota units in equilibrium. In a theory setting we can introduce the following scenario: At the same time as any (recreational or commercial) individual declares his demand for quota units, he simultaneously receives an income transfer equal to what he must pay in market equilibrium for the units he buys. The individual is assumed not to associate the income gift with the purchase of quota units. Within the economics literature, this is the essence of a nondistorting transfer.

What happens to the market for quota units when this transfer scheme is introduced?

The important point to note is that we still get competitive market clearing. The fundamental clearing process of the market is not affected by the fact that the agents receive 'gifts' which, 'by accident', just equal what they end up paying for the quota units. The demand behaviour of the representative commercial fishermen is unchanged. In theory, it is as if he scooped up as packet of money in his nets. This does not change his optimal pattern of fishing. Alternatively, there is a change in the equilibrium demand behaviour of the representative recreational fisherman. The transfer from the government is considered as an increase in income and, other things being unchanged, this will tend to increase the demand for quota units on the part of the angler.

To summarize, nondistorting income redistribution will not affect the achievement of a competitive market allocation of quota units. The resulting optimal allocation will, in general, differ from the case where there is no redistribution of government revenues. Nonetheless, the new allocation is still a competitive market allocation. As such, it is both individually and socially efficient and nondiscriminatory.

In order to illustrate the differences that arise, we recalculated the market equilibrium for the case where quota revenues are returned in a nondistorting fashion. Except for this addition, the underlying mathematical model was identical to the one that gave rise to the base case (Case 1) in Table 1. When revenues are returned, the new equilibrium is such that recreational angler gets 3 quota units and the remaining 2 go to the commercial fishermen. The price of quota units rises from $.25 to $.33. The transfer to recreational anglers increases their demand and, other things being unchanged, the market price of quota units must rise if the quota market is to clear. At this higher price commercial fishermen demand one unit less. In equilibrium, the government returns \$.66 to commercial fishermen and \$.99 to recreational anglers in the form of nondistorting transfers.

What have we gained from the foregoing theory detour?

First, we have outlined some additional theoretical results about the achievement of a competitive equilibrium allocation of quota units (with all of its attendant desirable properties) when government revenues are given back.

Second, we have developed another useful way of looking at the current government practice of quota allocation. Typically, quotas are allocated to recreational and commercial fishermen with an eye to past allocations and with no charges levied per quota unit. Extending our example, suppose that the government decided to freely allocate 3 quota units to the recreational fishery and 2 to the commercial fishery. This would be a socially optimal allocation. As long as the agents realized and behaved as if the price of quota units was \$.33. Thus the best quota allocation can be implemented without the need for a fully functioning competitive market in quota units as long as, somewhere in the background, the parameters have been simulated.

Finally, it turns out that we have developed an equivalent description of the quota allocation that arises when the economic value allocation rule introduced in the next section is used to allocate the total quota to recreational and commercial fishermen.

## An Allocation Rule Based on Economic Valuation

### Background

Before presenting the rule we briefly recall a valuation notion from the companion economic valuation paper. In particular, we are interested in the notion of 'compensating surplus'.

Compensating surplus is the greatest amount of money that an individual would pay to obtain a specified change in his consumption of a good that is currently rationed to him at some fixed level. We will denote this amount (which will tend to change as conditions of his budget change) by *CS*. Now suppose that we are considering a small quota increase for a recreational angler who currently receives a fixed quota. *CS* is just the maximum total payment that the angler would pay for this quota increase. It is useful to think of *CS* as having a price and a quantity component. The quantity is just the small quota increase. The price, then, is just the maximum that the angler would pay per unit of the quota increase. We will refer to this price as the 'marginal compensating surplus' and denote it by *MCS*.

The counterpart notion to *MCS* for a commercial fisherman is 'marginal profit' (*MP*). Suppose that the quota of a commercial fisherman was increased by a small amount. The most that he would pay for this quota increase would be any resultant increase in his profits. Suppose that we decompose this profit change into a price and a quantity component. The quantity component is just the quota change. The price is just the maximum amount that the commercial fisherman would pay per unit of quota increase. We will call this maximum price the 'marginal profit'.

**Statement of the Rule**

Suppose that a total quota $x$ is to be allocated to recreational and commercial fishermen without a market mechanism. Consider a 'trial' allocation consisting of $\tilde{x}$ to recreational fishermen and $x$ - $\tilde{x}$ to commercial fishermen. Consider increasing the recreational quota by a small amount. Let $M\tilde{C}S$ be the marginal compensating surplus of the representative recreational fisherman at this allocation. Next, consider increasing the commercial quota by a small amount. Let $M\tilde{P}$ be the marginal profit of the representative commercial fisherman. If $M\tilde{C}S = M\tilde{P}$ then the existing allocation is optimal. Otherwise, if $M\tilde{CS} > M\tilde{P}$, increase the allocation going to the recreational fisherman and reapply the rule. Alternatively, if $M\tilde{CS} < M\tilde{P}$, increase the commercial allocation and reapply the rule. The recreational fishery is allocated the entire quota if $M\tilde{CS} > M\tilde{P}$ when the initial allocation has the entire quota going to the recreational fishery. Alteratively, the commercial fishery should receive the entire quota if $M\tilde{CS} < M\tilde{P}$ when the initial allocation has the entire quota going to the commercial fishery.

**Discussion**

The intuition behind the allocation rule can be explained as follows. Quota units are allocated to those demanders who will pay the most for them. The most that demanders will pay is given by the marginal compensating surplus (for recreational demanders) and marginal profit (for commercial demanders). The allocation mechanism is somewhat like an auction with quota units assigned to the highest bidders. In this theory exercise, however, we do not require the bidders to pay for the quota units. Indeed, we are looking for a division of quota units such that each group bids the same amount for a small quota change or where one group completely dominates the bidding. The allocation of quota units that results from the above rule has the following properties:

1. The allocation that results will be identical to the competitive market allocation that would arise if quota units were bought and sold in a competitive market and the government made nondistorting and unanticipated transfers of its sales revenue back to the purchasers.
2. Given 1, the resultant quota allocation is individually and socially efficient and nondiscriminatory.

3. If the optimal allocation occurs where $M\tilde{C}S = M\tilde{P}$ (i.e. the quota is not all allocated to one group), then the price per quota unit that would have prevailed in a competitive quota market with transfers is just equal to $M\tilde{C}S$ ($= M\tilde{P}$). That is, $M\tilde{C}S$ would have been the competitive market clearing price.

4. Given 4, consider a policy setting where an agency is considering implementing a policy that would increase the total quota by a small amount at a cost of \$z per unit. It would be optimal to undertake this policy only if its cost per unit (\$z) was less than or equal to the maximum of the two prices $M\tilde{C}S$ or $M\tilde{P}$ at the current optimal allocation. That is, don't undertake the policy unless at least one member of the affected groups is willing to pay (but does not necessarily have to pay) the cost per unit of supplying the extra resource units.

**Summary**

The results of this section are abstract and complicated. The decision rule, which appears to make good common sense, requires considerable care and computation in its implementation. It also supposes that the necessary compensating surplus and marginal profit information is available to the analyst. In the third paper of this series we examine how statistical techniques may deliver this information.

## *Mathematical Appendix*

### Recreational Fisherman

We suppose that the recreational fisherman has preferences over quota units (x) and an index of all other goods (y). The price of quota units is (temporarily) given by \$p and the each unit of the index good sells to \$1. The utility function of the recreational fisherman is taken to be:

$U(x, y) = ay + xy$ , $a \geq 0$ is a parameter.

The parameter 'a' measures the relative strength of preference for good y. The larger is a, other things equal, the greater is the preference for good y.

The budget of the recreational angler is the collection of nonnegative bundles (x, y) that satisfy:

$px + y \leq I - F$ if the individual chooses to fish

or $y \leq I$ if no fishing takes place

Above, I is the income of the angler and F is the access charge that must be paid only if x > 0 (that is, when fishing takes place).

From the above we can deduce that the demand curve for quota units is given by:

$$x* = \frac{I-F}{2p} - \frac{a}{z} \text{ if } x* \geq o \quad \text{and} \quad \frac{(I-F+ap)^2}{4P} \geq Ia$$

$$= 0 \qquad \text{otherwise}$$

### Commercial Fisherman

We suppose that the production process transforms quota units (x) into landed fish (q) according to:

$q = ln\,(1 + x)$

where ln $(\cdot)$ is the natural logarithm function. Each unit of landed fish sells (abroad) for \$$P_L$. The only cost incurred by the fisherman (we suppose) is that of quota units. Thus, the profit of the commercial fisherman is:

$$\Pi = P_L \ln (1 + x) - px$$

where the commercial fisherman spends \$p per unit of quota.

The demand for quota units is given by:

$$x^* = \frac{P_L}{p} - 1 \text{ if } P_L > p$$
$$= 0 \quad \text{otherwise}$$

If the landed price of fish falls short of the cost per quota units (\$$P_L$ < \$p) then the commercial fisherman will leave the industry.

## Competitive Market Clearing: No Reallocation

Markets clear at a price where total demand just equals total supply. Suppose that 5 quota units are available. The condition that demand equals supply is given by:

$$\frac{I - F}{2p} - \frac{a}{z} + \frac{P_L}{p} - 1 = 5$$

Given fixed values for I, F, a and $P_L$ we seek a value of p such that the above equation is satisfied. Formally, the solution is:

$$p^* = \frac{I - F + 2P_L}{12 + a}$$

In the base case simulations we have I = 2, F = 1, $P_L$ = 1 and a = 0 so that p* = \$.25. At this price the recreational demand is 2 and the commercial demand is 3. Since a = 0 and $P_L > p^*$, we know that this is the optimal solution.

**Competitive Market Clearing: With Reallocation**

If the government gives a gift of \$G in income to the angler then his demand for quota units becomes:

$$x^* = \frac{I+G-F}{2p} - \frac{a}{z} \; if \; x^* \geq 0 \quad \text{and} \quad \frac{(I+G-F+ap)^2}{4p} \geq Ia$$
$$=0 \quad \text{otherwise}$$

However, we know that G = px* at market equilibrium. Thus we can compute equilibrium demand as:

$$x^* = \frac{I-F}{p} - a \; if \; x^* \geq 0 \quad \text{and} \quad \frac{(I-F)^2}{p} \geq Ia$$

The new market clearing condition is:

$$\frac{I-F}{p} - a + \frac{P_L}{p} - 1 = 5$$

When the conditions of the base case hold (I = 2, F = 1, $P_L$ = 1 and a = 0), p* = ⅓. The total quota is distributed with 2 units going to the commercial fishery and 3 units to the recreational fishery.

**Compensating Surplus**

Suppose the angler is given $\tilde{x}$ units of the quota at zero cost except he must pay his access charges of F. This means that he can buy I - F units of good y. His total utility is $\tilde{U}$ and given by

$$\tilde{U} = (\tilde{x} + a)\,(I - F)$$

Suppose we give the angler $\Delta x$ more units of the quota and take away the most money that we can (CS) so that the new utility level is just equal to the old. That is:

$$(\tilde{x} + a)\,(I - F) = (\tilde{x} + \Delta x + a)\,(I - F - CS)$$

CS is just the compensating surplus associated with the $\Delta x$ increase in quota units. It is the most that the consumer would pay for these units. We can solve for $\tilde{CS}$ as:

$$\tilde{CS} = \frac{\Delta x\,(I-F)}{a+x+\Delta x}$$

We can solve for marginal compensating surplus ($M\tilde{CS}$) as the rate of change in $\tilde{CS}$ as $\Delta x$ increases from $\Delta x = o$. This is given by:

$$MCS = \frac{\partial CS}{\partial \Delta x}\bigg|_{\Delta x = 0} = \frac{I-F}{a+x}$$

Because $\tilde{CS} = 0$ when $\Delta x = 0$ we can interpret $M\tilde{CS}$ as the approximate increase in $\tilde{CS}$ per unit increase in $\Delta x$ when $\Delta x$ is small. It is what you would be at most willing to pay per unit of quota increase if you were only buying a small number ($\Delta x$) of additional quota units. Expressed in this way, $M\tilde{CS}$ has the interpretation of a maximum per unit price that you would pay for a small increase in the quota.

**Marginal Profit**

Suppose that the commercial fishermen receives $\tilde{x}_c$ quota units ($\tilde{x}_c$ = x - $\tilde{x}$, $\tilde{x}$ = the recreational quota) at zero charge. His profit is:

$$\Pi = P_L \, ln \, (1 + \tilde{x}_c)$$

Marginal profit is given by:

$$MP = \frac{\partial \Pi}{\partial x_c} = \frac{P_L}{1+x_c}$$

This is just the largest price per unit that the commercial fisherman would pay to have his quota increased by a small amount. The reasoning here is identical to the recreational angler case.

**Valuation Equilibrium**

We look for a situation where the maximum price that either agent would pay for an extra (small) amount of quota is the same. Thus we look for a situation where:

$$MCS = \frac{I-F}{a+x} = MP = \frac{P_L}{1+x_c} = \frac{P_L}{6-x} \; ; \; x_c = 5 - x$$

When I = 2, F = 1, a = 0 and $P_L$ = 1, the solution to this equation is $\tilde{x}$ = 3 and $\tilde{x}_c$ = 5 - $\tilde{x}$ = 2. This is the same allocation that arises at the competitive equilibrium with redistribution. Note that, at the equilibrium, $M\tilde{C}S = M\tilde{P}$ = ⅓ which was p* at the competitive equilibrium.

**TABLE 1: SIMULATED SOCIALLY EFFICIENT QUOTA ALLOCATIONS**

| Simulation Experiment | Preference Parameter | Consumer's Income | Access Cost | Landed Price | Quota Allocation | | Market Price |
|---|---|---|---|---|---|---|---|
| | | | | | Commercial | Recreational | |
| Case 1 | 0 | 2 | 1 | 1 | 3 | 2 | .25 |
| Case 2 | 3 | 2 | 1 | 1 | 5 | 0 | .17 |
| Case 3 | 0 | 3 | 1 | 1 | 2 | 3 | .33 |
| Case 4 | 0 | 2 | 1 | 2.5 | 4 | 1 | .50 |
| Case 5 | 0 | 2 | 1.6 | 1 | 4 | 1 | .20 |