GREAT LAKES FISHERY COMMISSION
Research Completion Report *

AN INTRODUCTION TO ECONOMIC VALUATION PRINCIPLES FOR FISHERIES MANAGEMENT

by

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Preface

The work was produced as part of the Economic Value Task Group of the Board of Technical Experts (BOTE). The basic idea and proposed format were discussed at BOTE meetings. As the work progressed, further discussions with BOTE members helped to focus the paper. I am grateful for this assistance and especially for the detailed comments of Dennis Cauvin and Paul Sutherland.

The use of allegory and the "folksy" way in which the text was written met with widely divergent reactions when this document was put out for preliminary review. Some loved it. "It's really great. It doesn't read like economics". Others were somewhat put off or felt patronized. "Are economics comic books next?"

It is hoped that readers will take this work for what it is. It is written in a different way to provide an alternative to the many other more technical volumes that already have been prepared. Some of them are listed in the references if any reader wants a different approach.

CHAPTER 1

Introduction

The purpose of this volume is to explain for the non-economist how economic values are derived, how and why they are frequently misinterpreted in the policy area, and, most importantly, how they can be correctly used in devising and implementing fishery management policies. This is not an easy task. The subject matter is fairly difficult and it requires that words be used in very special ways. In addition, many individuals have preconceived notions about what economics is about which are, to be blunt, incorrect. Certain ideas will have to be dispelled before, or concurrently with, the introduction of others.

This is not the first document which has been prepared with these objectives in mind. See for example an excellent work prepared under the auspices of the National Marine Fisheries Service by Steven Edwards (1991). It is not even the first one prepared by the Great Lakes Fisheries Commission. See Talhelm (1985). Other similar studies as well as more advanced references, are listed in the references. Why prepare another one?

The earlier reports are well prepared and useful. All get generally good grades from professional economists. The documents explain most of the topics and issues which economists think fisheries managers should understand. In addition, many readers have given them high marks. However, other readers think they contain too much jargon and too much theory to be easily assimilated for use in fisheries management decisions.

This document was written to try to make the material more accessible. The goal is to tell the same story as do the previous works, but to do so in a slightly different manner.

These other documents had preliminary chapters on definitions of values and on how they are related to demand and supply curves, followed by final chapters which show how these principles can be used to provide useful information to decision makers. However, in some instances, short lessons in economics do not provide enough of a framework for the principles to be usefully applied.

The approach here will be different. Although the stated purpose is to teach economic principles, there will be no formal discussions of economics per se. Rather the approach will be to look at the basic problems facing resource managers and show how economic principles and economic valuation can <u>help</u> solve the problems. In the course of the presentation, all of the concepts normally introduced in the "economics chapter" will be discussed.

The stress on the word "help" in the previous paragraph is intentional. There are many ways to look at decision making in resource management. Other frameworks have different ways of posing the questions to be asked and different ways of arranging information to provide answers. It will not be the purpose here to evaluate the biological, the anthropological, or the political science approaches or to compare them with an economics approach. Suffice it to say that these approaches can generate useful information. The motivation behind this document is that economics is also a constructive approach that is commonly used, as well as one that can provide a valuable means of comparing alternative courses of action if the results are interpreted correctly.

In order to introduce the economic concepts in as neutral a way as possible, the first main chapter will not be in terms of fisheries management. It is sometimes easier to discuss the necessities of, and the procedures for, evaluating allocations of scarce inputs when the competing outputs are alfalfa and wheat rather than commercial and recreational harvest. The discussion will focus on the role of a farmer as a resource manager and will cover the necessary economic concepts in terms of the short and long run decisions he or she must face. A separate chapter will discuss how the concepts can be applied to fisheries management decisions. This involves a degree of repetition, but this is often useful in explaining new and complex issues. While it is true that the problems of a private individual operating a farm for his or her own benefit will not be the same as those of an agency head managing a public resource for the public good, they are analogous in enough ways to make the comparison interesting. The differences will be illuminating as well.

Stated briefly, the justification for the comparison is as follows. Both have certain inputs or assets under their control and both have to make decisions about how they can or should be used. While there are many criteria to use in making these decisions, the economic approach is to maximize, over time, the net value of output produced. The purpose of this volume is to explain the rationale for the economic approach, and it is hoped that this comparison will be a useful aid in telling the story.

A farmer has control over a piece of land with unique features such as location, average amount and distribution of rainfall, other sources of water, natural fertility, access to transportation facilities, etc. The farmer also has control over other assets such as labor, machinery, and fertilizer either through ownership or through the ability to hire them on the market. The amounts of these other inputs that can be used are limited by the farmer's current cash reserves and his or her ability to borrow.

Faced with the given amount and quality of land, the amounts of other inputs that can be used to work the land, the prices that must be paid to obtain them, and the existing legal structure, the role of the farmer is to decide for the current year and for the foreseeable future, what combination of products should be produced, how they should be produced, and how much of each should be produced. The criterion that is most often used to determine if these decisions are made correctly is the net income that is earned over the years. Net income is the value of goods and services produced minus the full cost of all inputs used to produce them.

The time element is important because what is produced in one year, and how it is produced, can have a positive or negative effect on future production capabilities. Using scarce labor to build a flood control system in one year may mean reduced production in that period because there is not enough time left to cultivate all of the acreage; however, future production may be increased because of reductions in flood damage. As another example, intensive cultivation in the present may temporarily increase yields, but production may fall off in the future if the intensive culture damages soil productivity.

In a similar way, a fisheries manager has control over the use of living resources with unique features such as natural productivities, inter-species relationships, desirability as a source of food or recreational catch, accessibility to users, etc. The manager also has control over other assets such as research and enforcement staffs, facilities, and supplies. The amounts of these other assets are limited by the agency's budget. In most instances an agency cannot increase its current expenditures by borrowing as can the farmer.

Faced with the nature of the resources and limited amounts of other inputs that can be used to control the use of the fish stocks and with the existing legal structure, the role of the manager is to determine -- for the current year and for the foreseeable future -- what combination of fisheries based outputs and activities should be produced, how they should (or will) be produced, how much of each should be produced, and, in some instances, for whom they will be produced or who will produce them.

Except for the way in which the other inputs are obtained and the necessity for the manager to answer "for whom" questions, one could argue that the cases of the farmer and the fisheries manager are almost analogous. Another difference is that the farmer has built in incentives to consider the net value of production because his or her income over time will depend on it. The net gain of the farmer, and one measure of successful farm operation, is the value of the output minus the value of the inputs used in production. Although fisheries management agencies are not commercial enterprises, the net value of the production from the resources and inputs under their control is also one measure of successful operation. While there may be other issues, it is important for a fisheries agency to look at the value of the goods and services produced and the value of the inputs used.

Yet another difference is that the net income of a farmer comes only from goods and services which are sold on a formal market. A flow of dollars corresponds to the value of the output produced. This is not the case for fisheries agencies, however. Some of the goods they produce and some of the services they perform are not matched by a flow of dollars from the consumer. For example, individuals do not always purchase recreational fishing on the market. They simply proceed to the water and begin to fish. This activity is valuable, nonetheless, in exactly the same way that fishing from a charter boat is valuable. As a result of this lack of dollar transactions, some of the output produced by the resources and inputs under the control of the management agency will have to be counted and valued in a more general way. However, as the discussion below will show, the basic procedures used to count amounts and values for the farmer can also be applied in a very straightforward manner to the operations of a management agency.

Before beginning the discussions, I ask the reader to bear in mind the natural limitations in undertaking this endeavor. First, the examples used will have to be very simple and must ignore many of the niceties of the situation. The numbers will be "rigged" to make computations more simple. Second, there will be some fairly complex issues, and full comprehension may require several readings and some calculations in the margin. I ask for the reader's patience. At the same time, in some instances the methodology used will produce answers that were fairly obvious from the start. However, with more complex examples it is much more difficult to explain the methodology. I ask for the reader's indulgence.

Finally, the ease with which accuracy can be obtained and analyzed is treated rather cavalierly. In many instances fisheries managers will not have all the requisite data and what they do have will be of uncertain quality. Such problems are ignored in the interests of getting along with the story. The purpose is to describe the correct concepts as clearly as possible in the hopes that it will generate interest in the collection of the proper types of data.

For readers who feel they have a fairly good grasp of basic economic concepts such as opportunity cost, trade-offs, and comparison of marginal benefits and marginal costs, or for who wish to save some reading time, it is possible to start with the fisheries management analysis in Chapter 3. Each of the sections has a reference to a section in Chapter 2 where the economic concept is introduced in detail. The reader can go back and read those sections of Chapter 2 he or she feels is necessary.

CHAPTER 2

Economic Valuation and Farming

2.1 Introduction

The purpose of this chapter is to introduce economic valuation concepts and to show their applicability to resource allocation decisions. The discussion will be in terms of a hypothetical case study of an individual who inherits a farm but who knows nothing about farming. The fundamental questions of what, how, how much, and how long are answered through interchanges between the farmer and an advisor. The analysis is static at first, but as certain concepts are introduced, dynamic considerations are also introduced. The discussion is divided into discrete segments, each of which, hopefully, will introduce concepts with direct relevance to the economics of fisheries management and utilization. At the risk of being too obvious, two or three paragraphs describing this relevance will be appended to each section.

The next chapter will provide an analogous discussion of allocation decisions in the context of fisheries management. It will contain a hypothetical case study of an individual who is charged with developing a fisheries agency. It will be shown that, the fundamental differences in the two types of organizations notwithstanding, the farmer and the fishery manager face the same sorts of problems and can use similar approaches to solving them.

2.2 What to Produce: A Preliminary Look

> The concepts derived in this section are opportunity cost, the necessity of choice, and potential for using net value as a criterion for making choices.

One day Jean got a letter that would significantly change his life. A lawyer informed him that a long lost uncle had passed away and had made him the sole beneficiary of his will. The principal asset was a farm. The news put Jean in a bit of a turmoil. He had been considering a change in career, and he was not adverse to leaving his present employment; however, he knew nothing about farming. Should he work on the farm just because it was given to him?

After considering the matter for several weeks, Jean decided to give the farm a try for a year or so to see if the work and the income were suitable. This option was possible because a contractor had approached him, and offered to provide the necessary labor, seed, fertilizer and other inputs, as well as the capital equipment to prepare the land, plant the seeds, and harvest the product for whatever sort of an operation Jean wanted. Exactly what was to be produced and how it would be decided between them, and an annual operation fee would be established.

From the start, however, Jean set up certain criteria to be used when ultimately deciding whether to keep the farm or to sell it. Money was obviously very important. Jean was making $65,000 a year in his present employment, and somebody had offered him $400,000 a year in perpetuity for the right to develop the land into a vacation and year round country living complex. Therefore, Jean felt the farm should return at least $465,000 a year to match the opportunities for himself and his land to earn income elsewhere. He wasn't prepared to be dogmatic about income, but he felt that if it was less than this he would require that something else make up for the difference.

The farm had not been active for several years, and records of what had been planted were very sketchy. Jean knew that the main crops had been wheat and alfalfa, but he did not know where on the land each had been planted. To get the ball rolling, he asked the consultant to provide information on expected yields from different parcels of land. The contractor was hesitant to start such a study. He said that what you get out of the land depends to a large degree on what you put into it. Yields were not only a function of the natural fertility of the land and the expected amount of rainfall, but also of the types of seeds used, the cultivation procedures and so forth. They agreed that the study should be undertaken under the assumption that the contractor would have $350,000 to spend on crop production. This figure was based on average costs per acre at other near-by farms.

The contractor's initial report is summarized in the first three columns of Table 2.1. The contractor found that, except for two parcels of land, the rest of the farm was capable of producing either wheat or alfalfa. All of the land was not the same in topography, soil moisture, etc., however, and some was better suited to wheat and the rest to alfalfa. In addition, there was no clear distinction between wheat land and alfalfa land. Starting in the north, the land had ideal conditions for wheat, but as one moved south the conditions changed in favor of growing alfalfa. For purposes of analysis, the contractor divided the usable land into 8 strips. If all strips were used to produce alfalfa, given the allowable contracting costs, the expected production would be 4800 tons, whereas if all were used to produce wheat, the expected output would be 5200 tons. These two land use patterns are described in rows 1 and 9 in the table. Row 2 shows what would happen to expected production if the northern most strip was used to produce wheat rather than alfalfa. Remember, this is the strip that is best suited to wheat. With a change in land use patterns from 1 to 2, alfalfa production doesn't fall very much (this land isn't well suited for growing alfalfa) but 1000 tons of wheat will be produced.

Rows 3 through 8 describe other land use patterns and show what happens to production as strips of land (moving from north to south) are taken out of the production of alfalfa and used to produce wheat. The production of wheat goes up but by decreasing amounts because the land is less and less suited to producing wheat. On the other hand, the fall in the production of alfalfa becomes larger and larger as the land better suited for that crop is switched to the production of wheat.

To summarize, reading down the table shows how production of the two crops will vary as the production of wheat is increased in a southerly direction. Reading up the table shows how production will change as the production of alfalfa is increased in a northerly direction. This information gave Jean a fairly good idea of what his farm could produce given a certain crop production budget. Two things were clear to Jean. First, increasing the production of one crop could only come with a reduction in the production of the other. The opportunity cost of getting more wheat is a loss in production of alfalfa. Second, as more of one crop was obtained, the opportunity cost in terms of foregone production of the other was increasing. However, this technical information was not enough to decide what to produce.

The goal of running a business is not to maximize the tons of products produced or to try for some specific combination of output. The most common way of measuring business success is to see how much income is earned. While Jean did not consider himself to be a worshiper of the almighty dollar, he felt that the amount of income earned by the farm was something in which he was interested.

The contractor told Jean that the normal price per ton for wheat and alfalfa was $200 and $175, respectively. The total revenue that would be earned at these prices for each of the possible production combinations is listed in the fourth column.

Put simply, Jean has a choice of which land use pattern to use. Economic value measures can provide a criterion for making the choice. What is the trade-off? What is gained and what is lost as different choices are made relative to the status quo?

It can be seen that the production from land use pattern number 5 yields the highest revenue. To determine which production combination is the best, one needs relative prices. Physical output measures are not enough. Further, if the relative prices accurately measure the value that society places on the two crops, the combination that produces the most money for the producer will also be the one that has the highest value for society.

Note that changing the allocation of the land use pattern from 1 to 5 results in an increase in total revenue. This means that the value of the increase in the production of wheat is more than the value of the decrease in the production of alfalfa. For the change from use pattern 5 to 6, this is not true, however. Expanding wheat production into the range where the land is better suited to alfalfa means that the gain in production of wheat will fall and that the opportunity cost of lost alfalfa will go up.

The contractor was quick to point out that the choice of land use pattern 5 as the best production level was not necessarily a permanent thing. It would be incorrect to conclude that the northern four strips should always be used for wheat and the southern four for alfalfa. A change in the relative prices could mean that a different use pattern would yield higher revenues. As an extreme case, if the price of wheat went to a $1000 a ton, total revenue would be maximized by growing wheat exclusively.

Now that Jean knew which combination would produce the highest return given existing prices, he needed to find out if this return was worth all of the effort. The fifth column shows the net return to the farm for each of the possible use patterns. The net return is total revenue minus the cost of production. The costs of production include the $350,000 given to the contractor to grow the crops, the $400,000 that could have been earned by leasing the land to the developer, and the $65,000 that Jean could have been earned at his other job. The last two items are the opportunity cost of Jean's labor and of the land. The net return for operating at use pattern 5 is $390,000.

Jean was pleased with this preliminary analysis. He was able to determine what combination of output would earn him the most money. Further when that combination was produced, he did very well indeed. All of the costs were covered and he came out with $390,000 more than he would have had if he kept his old job and just leased out the land. As far as net income was concerned, it looked like making the switch to a farmer was a good idea. He realized, however, if the price of wheat and alfalfa were to fall, it is possible that even using the land use pattern which maximized revenue may not produce enough dollars to cover all opportunity costs. If he expected that to happen, on money income terms, he would be wise to keep his old job and sell the farm.

On reflection, Jean concluded not only that was he coming out $390,000 ahead of the game, but also that he could make a case that the value of goods and services in the economy would go up by the same amount if he decided to run the farm according to this plan. Using land use pattern 5, the farm would produce wheat and alfalfa which had a value to consumers of $1,205,000. However, because he was supervising the operation of the farm, he could not work at his old job. Therefore, production at his old place of employment would go down. He knew his boss was a nice person, but not one to give money away. Thus, if his boss was willing to pay him $65,000 a year, the value of his output must be pretty close to that amount. Similarly, if the developer was willing to pay $400,000 a year for the land, the value of the annual output of the project after paying all other costs must be at least $400,000. Also, the contractor was going to have to hire workers and rent combines and so forth to plant and harvest the crops. He would have to pay the workers what they could earn elsewhere, and that amount could serve as a good proxy for the value of the output they were producing in their other jobs. Likewise, to rent a combine he would have to match what the owner could get for it elsewhere. Following the same logic, the existing rental rate of the machinery seems as a good measure of the value of output it produces.

So, while the value of production on the farm would go up by $1,205,000, the value of production elsewhere in the economy would fall by a total of $815,000. This still left an increase in the value of overall production in the economy as a whole of $390,000. The use of the farm, his labor, and inputs used by the contractor could thus be considered as socially justified. However, if the maximum revenue earned by the farm was less than $815,000, it could be argued that these resources should be used elsewhere. The value of production would be higher if the farm were sold to the developer, the contractors used his inputs elsewhere, and Jean went back to his old job.

Several important concepts have been introduced. First, what can be produced on a specific piece of land depends upon its natural characteristics and how the land is used. Therefore, within certain ranges, what to produce is a matter of choice. Second, when these choices are made, a decision to produce more of a particular item results in the loss of another item. This is the concept of opportunity cost. Third, as the production of a particular good is increased, the opportunity cost in terms of production reductions elsewhere will go up. This is the concept of increasing marginal cost. Fourth, one criterion for determining which land use pattern should be used is the maximization of the value the output which results. Fifth, while using the land in a manner that maximize gross revenue is a good start on the problem, it is also important to consider opportunity costs. Is gross revenue greater than the opportunity cost of the land and other related inputs.

These principles and concepts are useful for fisheries management agencies as will be shown below. But to anticipate the argument, the natural resource base can produce different combinations of outputs and, all else equal, more of one can be produced only with the loss of another. Also, one criterion for determining which combination should be produced is the maximization of the value of output, be it commercial or recreational harvest. Finally, one way of measuring the worth of a management agency is to see how it affects the value of output from the fishery resources and how it affects the costs of the users of the resource. If there is a net increase in the value of goods and services produced and this increase is greater than the cost of running the agency, then on economic efficiency grounds, the agency is a success.

2.3 What to Produce: A More Detailed Look

> The main concept discussed in this section is the usefulness of marginal analysis when making choices about resource allocation. When total net value is the criterion for making choices, comparisons of marginal gains and marginal costs can provide useful information.

While Jean was pleased with the possibility of earning an annual net return of $390,000 over and above all costs, he wondered if he had considered all possible ways to improve net return. He remembered that the contractor had said that what you get out of the land depends on what you put into it. He asked himself if he was really putting the right amount of resources into farming. He knew that how he allocated the land between the production of wheat and alfalfa affected net returns, and so he guessed that how he allocated the inputs among the two crops would affect his gains as well. When he questioned the contractor about the $350,000 in growing costs, he learned that in deriving the material in rows 2 through 8 of Figure 1, the contractor had based his estimates on the assumption that exactly half of the allotted money would be spent on each crop.

He asked the contractor to estimate how production would change, using the land use pattern described in row 5, if the money spent on inputs were allocated in different ways among the two crops. The results are pictured in Table 2.2. The left half shows how alfalfa production varies with the dollar amount of inputs used in its production. The right side shows the same thing for wheat production. The asterisks indicates the allocation of input funds used in Table 2.1. There are 3000 tons of alfalfa and 3400 tons of wheat grown when each crop has $175,000 spent on its production. The return over contracting costs for each of the two crops at this point, is $350,000 and $505,000 respectively. The sum of the returns over contracting costs ($855,000) minus the opportunity rent and wages of $465,000, equals the net return of $390,000, which is the figure derived above.

From studying the information, Jean realized he could increase net returns from the farm if he spent the contracting costs differently. He realized he should try to maximize the return over growing costs for both crops. For example, if contracting costs for alfalfa were reduced to $125,000, returns over costs would actually increase to $360,625. The reduction of $50,000 will reduce production from 3000 tons to 2775; however, the market value of the lost 225 tons is only $39,375, which means the return over growing cost goes up by $10,625.

On the other hand, with wheat the return over contracting costs would go up if growing costs were increased by $75,000 to $250,000. This would increase production of wheat by 900 tons which, at a market price of $200 a ton, would increase revenues by $180,000. The return over contracting costs would therefore increase by $105,000 to $610,000.

Using the preceding logic, Jean realized that he should cut expenditures on alfalfa by $50,000 but increase them on wheat by $75,000. As a result total contracting costs for growing the crops would increase by $25,000 but net profits would increase from $390,000 to $505,626. This increase of $115,625 is the sum of the increase in returns over contracting costs to alfalfa ($10,625) and to wheat ($105,000). The opportunity rent and wage costs do not change.

From all of this, Jean learned that determining the size of the operating budget is an important step in farm operation. It may not be possible to determine how much should be spent on growing crops by using averages of other farmers. That may be a good guide with which to start, but what really matters is how much extra dollars spent on growing crops will affect production and hence net returns. In the case of wheat he saw that "it takes money to make money". Increased expenditures increased net returns. In the case of alfalfa, however, he saw that increases in physical production weren't always worth what they cost.

Since the total amount of contracting costs and the way in which they are allocated among the crops can affect net returns, Jean no longer had confidence in the land allocation decision he had made using the information in Table 2.1. Therefore he asked the contractor to take a second look at the problem. This time however, he was to consider how different growing costs for each of the crops would affect the net results. The contractor was asked to do an analysis similar to that in Table 2.2 for each of the rows in Table 2.1. A summary showing the optimal findings for each row is presented in Table 2.3. A comparison of Table 2.1 and Table 2.3 will demonstrate that by carefully planning how much to spend on each crop, the return over contracting costs in each row can be increased. At any given allocation of land between the two crops, revenues can be increased by looking at the effect an extra dollar spent on either of the crops will have on revenue.

Row 1 is where all of the land is allocated to alfalfa. Notice that the optimal contracting cost is only $200,000. As before, net returns can be increased by cutting back on growing costs. The northern land is not that well suited to alfalfa and it just doesn't make much sense to spend extra money on growing costs because the extra production is not worth it. Although alfalfa production falls compared to row 1 in Table 2.1, net return to the farm goes up.

Row 9 is where all of the land is allocated to wheat. It makes sense to spend more money on growing costs. Up to a point, the extra production adds more revenue than it cost to produce. Compared to Table 2.1, contacting costs are up $25,000, but the extra 750 tons of wheat increases revenues such that net returns increase by $125,000.

Rows 2 through 8 show the optimal results for the other land use patterns. In general, as more of the land is allocated to alfalfa, the optimal amount of contracting costs go down. As more land is allocated to wheat (i.e., shifts from row 2 downward) it initially makes sense to increase contracting costs. However, as more and more land that is better suited to alfalfa is shifted to the production of wheat, it eventually makes sense to reduce contracting costs.

When these changes are considered, the land use pattern represented by row 5 no longer generates the highest net returns. While the change in land use from pattern 5 to 6 will increase input costs by $25,000, revenues go up by a greater amount and so net revenue increases. Row 6, where the northern 5 strips are allocated to wheat and the southern 3 to alfalfa, has the highest net returns.

Jean was very glad he asked for the extra analysis. By expanding the analysis to consider the allocation of both land and the resources used to grow the crops and by not determining "a priori" how much should be spent on crop production costs, he was able to come up with a plan that increased his net returns. He made the decision that this is how he wanted to operate, and he made the formal agreement with the contractor and started life on the farm.

The main point raised in this section is that decisions about how to use resources can be very complex. The optimal allocation of the land is affected by the allocation of other inputs. Because of the complexity of the interactions between inputs, it is sometimes useful to use a marginal analysis and compare what is gained and what is lost by making changes in one aspect of production. In terms of the above example, the operational rule for the marginal analysis is that it makes sense to spend an extra dollar on the tillage, fertilization, etc., of a particular crop, if the increase in production generates more than a dollar of extra revenue.

The lessons from this section apply to a fishery agency as well. Fisheries managers must make decisions on how to use the resource base and on how to allocate their budget among various activities. One difference is that although farmers can increase their operating expenditures, through borrowing for instance, if they think revenues will go up appropriately, fisheries agencies cannot so easily increase their budgets. This is described in more detail in Chapter 3.

2.4 An Insect Invasion

> This section describes an example of using marginal analysis to make resource allocation choices. It emphasizes the fact that care should be given to consider all of the gains and all of the losses for any action.

After several years of successful operation, the farm suffered from an infestation of crickets which ate alfalfa. The county agent indicated that the pests would likely remain in the area for the foreseeable future. The effects of this catastrophe are shown in Table 2.4. Before the insects came, annual wheat production was 5200 tons, and alfalfa production was 1975 tons. This produced a net return of $520,625. The insects ate or ruined 395 tons of alfalfa, causing production to fall to 1,580 tons. This caused a decrease in net returns to $451,500. The contractor did a quick study and found that changing the amount of money spent on crop production would not increase net returns. While the farm was still making a net return over all costs, Jean and the contractor decided they should consider fighting the insects to see if their effect on net returns could be reduced.

The contractor suggested spending $25,000 on insecticide, but Jean had learned the lesson of comparing marginal gains and marginal losses when making allocation decisions. He asked the contractor to show what would happen to production and to net returns as the amount of money spent on insecticide increased in $5,000 increments. The results are shown in the bottom half of Table 2.4. Initially the effect on alfalfa production is quite large for each $5,000 expenditure. Eventually however, the increase in production falls off. The first $5,000 expenditure on insecticide would increase production from 1580 tons to 1650 tons. However, increasing insecticide expenditures from $20,000 to $25,000 would only increase alfalfa production by 10 tons.

The contractor was a very careful individual and knew that insecticides sometimes had other effects that are unintended. He found out that the insecticide, while beneficial to alfalfa, would decrease wheat production. These effects are also shown in the table. The more insecticide used, the greater would be the loss in wheat production. Thus, one of the costs of using the insecticide would be the loss in the value of wheat that could be produced.

After studying the figures, Jean saw that it made sense to spend $15,000 on insecticides. At that level of expenditure, the net return to the farm would be maximized. The first $5000 spent on insecticide would increase revenue by a larger amount, and so net returns would increase. The same would be true of the next two doses. However, increasing the insecticide expenditures from $15,000 to $20,000 would actually decrease the net return.

Jean and the contractor decided that expenditures on insecticides would be useful. Although it did not increase production up to where it was before the insect invasion, up to a point the money spent on insecticides was more than matched by increases in the value of output -- even taking into account the decrease in production of wheat. Just to be certain that the insects did not affect the land use decision, Jean asked the contractor to do the analysis for Table 2.3 again, taking the effect of the insects into account. While alfalfa production was affected no matter how the land was used, and this sometimes changed the amount of crop production money was allocated to it, net returns were still maximized when the northern five strips were used on wheat and the southern 3 were used on alfalfa.

Jean was interested to learn that many other farmers in the area also decided to use insecticides. However, one farmer found that given the circumstances of his farm and the way the insecticide affected alfalfa and wheat production, it made sense to do nothing. Even at small doses, the cost of the insecticide was more than the increased value of production. While he was definitely not happy with the situation, anything he tried to do would just make matters worse.

The lesson here is fairly straightforward and so is the application to the fisheries management world. Infestations of new species in the ecosystem can affect the output of other products. A useful criterion for deciding what is to be done is to compare the cost of control with the change in the value of desired outputs. In doing so, it is important to consider the possibility that killing the interloper can sometimes produce negative effects on other parts of the ecosystem which can translate into a decrease in the value of output. The full cost of the control system may be more than the cost of the poison. Using this approach will ensure that control programs are not wasteful. It may not necessarily make sense to try to kill the last insect (lamprey) or to try to return the productivity of the ecosystem to what it was before the infestation.

2.5 The Construction of a Dam

> This section describes another example of how to use marginal analysis. It emphasizes that gains and losses can occur in different years, and that is necessary to properly compare values from different time periods.

In an annual report to Jean, the contractor complained that constraints on water availability was limiting potential production. He indicated that a small dam which could save water in between growing seasons could increase production and hence profits. Jean asked the contractor to look into this more carefully so that they could determine if it was, in fact, a good idea. After studying the topography of the land and making plans for an appropriate irrigation system, the contractor found that a dam could be built at a cost of $1 million. He predicted that as a result of the extra water, production of wheat would increase by 10% and that production of alfalfa would increase by 15%. Additionally, contracting costs would fall by $50,000, because with the extra water, cultivation and fertilizer use could be reduced. The effects on net returns are shown in Table 2.5. The first line shows the production of the farm with no dam and the second line shows the net projected production, costs and net returns given the dam is built.

The construction of the dam would increase the net return for the farm over and above all costs by about $200,000 a year. The real question is: Dies this extra $200,000 a year justify the current expenditure of $1 million on a dam? To answer this question, it is necessary to compare units of value at different points in time. The $1 million expenditure would be in the present, but the $200,000 per annum gains would be spread over the future.

Because most people would agree that a dollar today is not the same as a dollar tomorrow, direct comparisons of value at different points in time are not appropriate.

It is possible to make comparsions of value across time by using present value analysis. One way to understand present value is to think in terms of savings accounts in banks. At 5% interest, a deposit on $100 this year will result in $105 next year. Therefore, at a discount rate of 5%, $105 next year has a present value of $100.

To continue the example, a $100 deposit at 5% this year will result in $110.25 in two years. Thus, $110.25 two years from now also has a present value of $100. It is also possible to add present values. The present value at 5% of $105 next year plus the present value of $110.25 in two years time is equal to $200.

The formula for calculating present value is quite simple to express.

$$PV = \frac{X_i}{(1+r)^i}$$

In the expression, X_i is an amount of money i years in the future and r is the discount rate. For example, if the interest rate is 10%, the present value of $350 fifteen years from now can be expressed as:

$$PV = \frac{350}{(1.1)^{15}}$$

These expressions can be somewhat tedious to calculate by hand, but fortunately the work is made quite simple by specialized calculators and computer software.

Whether the construction of a dam is a wise decision or not can be determined by comparing the sum of the present values of the two series of net revenues. The contractor calculated the flow of net revenues for 15 years with and without a dam and this information is shown in the bottom of Table 2.5. With a dam the net revenue in year 1 would be minus $536,100. This is the total revenue earned that year minus the cost of the dam. The second year -- when the dam is up and running -- net revenues would increase to $636,515. The net revenue without the dam would be $463,900 in every year.

With an interest rate of 10%, the net present value of net returns with the dam is $3,956,189 whereas the net present value of net returns without the dam is only $3,528,460. This means the extra value of output in years 2 to 15 with the dam, expressed in present value terms, is more than the cost of the dam in year 1. Otherwise, the net present value of output could not be higher with the dam. Another way to say this is that the sum of the present value of $200,000 for fifteen years is more than $1 million. Therefore, the net present value of the production of the farm could be increased by building the dam.

Jean wanted to be sure that the size of the dam was correct. He learned that it is wise to check alternative cost options when the contractor specified a fixed crop production cost in the initial analysis. Given the topography of the land, there were only 3 different ways to build the dam. A smaller dam was possible at a cost of $250,000, but it would barely increase production; a comparison of the net value with and without a dam of this size showed the increase in the value of production would not be sufficient to justify the cost of the dam. Similarly, a large dam could be built for $10 million, and - while it would increase production more than the $1 million dam - a comparison of the net present values showed that the extra value produced by the large dam was not enough to compensate for its $10 million construction cost. Jean was confident that the $1 million would be a good investment. Further, he was confident that it was the best possible way to invest in a dam. Neither the larger nor the smaller dam would produce higher net present value of output.

When Jean considered the dam with respect to the value of production in the entire economy, he concluded that what was useful to him was also a good idea for the economy. While building the dam would cause the value of other goods and services produced elsewhere in the economy to fall in year 1 by $1 million, over time the increase value of production from his farm would more than make up for that loss in value in net present value terms computed at a 10% discount rate.

The main concept discussed in this section is the allocation of resources over time. The returns from allocating inputs to cultivation activities will, for the most part, come in the current year. Therefore, it is fairly straightforward to determine if such an allocation will be wise. If returns go up more than do costs, the extra cultivation is economically efficient. However, allocating resources to the construction of a dam will produce returns for many years. Such a move will make economic sense if the overall gains are greater than the costs, but if one is to make such a comparison, it is necessary to first convert future years' gains into present value terms so that they can be compared to current costs.

Fisheries management agencies can sometimes make or encourage allocations of resources for projects that will produce gains for many years. Therefore, using these principles can be useful in making decisions that have long time frames.

2.6 The Green Revolution Comes to the Farm

> The example in this section uses net present valuation techniques to compare the gains and losses of project that can have long term effects on the productivity of the environment.

After the dam was built, the contractor and Jean continued to look for other ways to increase production and hence net returns from the farm. One day, an expert on technological farming tried to get them to consider his methods. He guaranteed them that with a small increase in crop production costs, his methods would increase production significantly. The expert did an analysis of Jean's farm for a production period of 4 years. This information is shown in the first four rows of Table 2.6. Now that there is a dam, current wheat and alfalfa production is 5716 and 2001 tons, respectively, and net returns are $663,515. The technology expert predicted that by using his methods, the production of wheat and alfalfa could be increased in the first year to 6500 tons and 2250 tons, respectively. While this would necessitate an increase in production costs to $500,000, net returns would increase to $728,750 in the first year. The technology expert acknowledged that production would not stay this high forever, but over the 4 year period the net returns would be higher than without his program.

Jean did not like the downward trend in production that started in the third year, so he asked the contractor to duplicate the study and to extend it to a 15 year analysis. The contractor agreed that the technology expert correctly estimated outputs for the first 4 years but that the predictions for years 5 to 15 were very discouraging. Production of wheat and alfalfa would fall dramatically even if production costs went up significantly. The effect on net returns was drastic.

Apparently, this so called scientific farming procedure took a harsh toll on the land which caused a large reduction in productivity in later years. Still, there was a high increase in the value of production in the early years and Jean wondered if it was worthwhile to take these returns and retire before the production fell drastically. However, by comparing the net present value of returns with and without the new technology, he found that the net present value of his production would fall if he used the proposed method. With a 10% discount rate, the net present value without enhancement - which is the net present value of $663,515 for 15 years - is $3,956,189. The net present value with enhancement - which is the net present value of the flow of 15 values in the bottom part of the last column in Table 2.6 - is $3,832,415. The increase in the value of production in the early years was just not enough to compensate for the decrease in value in later years.

He also realized that if he were to take this action there were other significant effects. Even ignoring the fact that the present value of the farm decreased by using technology, he could see that if he were to use it and then retire in 10 years and give the land to his children, all of the gains from the technology would accrue to him, but that his offspring would have net returns that were significantly lower as a result of his bounty. So, based on the analysis of net present value and on the intergenerational transfer implications, Jean determined that this new farming technique was not a good idea. The increased production in the early years was not worth the stress placed on his land which would lower production in later years.

This section shows another use for present value analysis. Certain current activities can negatively affect productivity in future years, and dynamic efficiency requires that gains and losses in different periods be compared. Fisheries managers face similar problems when considering current densities for fish stocking programs or approvals of aquaculture projects.

2.7 The Spill of the Exxon Dezval

> This section describes how the economic damages from environmental accidents can be measured and how marginal gain and loss comparisons can shed light on the desirability of rehabilitation programs.

A major highway runs along the eastern side of the farm. Among other things, it was used to transport oil from a refinery to gas stations. One day a driver by the name of Mr. Overwood, who had christened his truck the Dezval, had too many gin and tonics before making his run. The inevitable happened, and he overturned the truck into an irrigation channel in the northeastern part of the farm. The petroleum products were subsequently distributed fairly evenly over the 8 strips of land. Jean was very angry that his land was affected by the spill, and he was more outraged when the contractor said it would take about 4 years for the productive capacity of the farm to return to normal.

The oil company admitted that it was all their fault and agreed to pay full compensation for any losses. They asked Jean to estimate what the spill would cost him. To determine this, Jean requested the contractor to estimate the effect the oil spill would have on production. In response, the contractor presented the information contained in

Table 2.7. The first section shows the normal production of the farm over a four year period during which annual net returns are $663,515.

The second section shows what would happen if the farm land was left to recover on its own. In the first 3 years production of wheat would be 4000 tons, 4200 tons, and 4800 tons, and production of alfalfa would be 1000 tons, 1200 tons, and 1600 tons, respectively. Both crops would return to full production in the fourth year. While the reduction in output would allow for some reduction in crop production costs - because with less production, harvesting costs would fall - there would still be a decrease in net returns. For example, net returns would fall to $210,000 in the first year. This meant that Jean would suffer a loss in net revenue of $453,515 in the first year. It also meant that the net value of production in the economy as a whole would fall by the same amount. This would be a reduction in the value of farm production, and a small increase in production elsewhere as the inputs which used to be used for harvesting were freed up for other uses. To obtain an estimate of the total losses, the contractor showed that with a discount rate of 10%, the present value of normal production for four years, which produced $663,515 per year, was $2,103,253. The present value of production for four years under a natural recovery program would be $1,189,929. Therefore, Jean felt safe in asking for compensation equal to the difference between these two amounts or $913,324. That is, as a result of the spill, the net present value of the production of the farm would fall $913,324. If the oil company was to compensate Jean for the full effects of the spill, this would be the amount that must be paid.

Jean, however, did not like the idea of just waiting for the effects of the oil to go away and he asked the contractor if some sort of a rehabilitation project could get the farm back to normal production more quickly. After exploring several different possibilities, the contractor came up with the plan the effects of which are described in the third section in Table 2.7. By spending $75,000 on rehabilitation in the first year and $50,000 in the second year, the farm could be back to full production by the third year. In addition, production of both crops in the first and second year would be greater than under a natural recovery scenario. The effects of this policy on the net returns to the farm looked promising. While the net return the first year would be lower under the rehabilitation plan, the net returns would be higher in the other three years. The net present value of the flow of output under the rehabilitation plan would be $1,483,103 or $293,174 higher than the net present value of production under normal recovery.

Jean showed these figures to the oil company and said that if they would pay the rehabilitation costs, he would accept a lower compensation payment. The present value of the rehabilitation costs was $109,504, so Jean agreed to accept compensation of $729,654. That would give him enough money to pay for the rehabilitation and have enough left over to make up for his loss in net returns. The oil company was pleased with this arrangement because its compensation payment would be $183,670 lower than the first estimate.

Jean realized that the analysis of rehabilitation was similar to that on the insecticide problem. In certain instances, it may make sense to spend money on rehabilitation. The key is whether the net value of production goes up by more than the net present value of the rehabilitation costs. If it doesn't, rehabilitation does not make sense, and the best thing that can be done is allow for natural recovery. In either case, however, the party responsible for the damage should be required to pay all of the potential losses. If rehabilitation makes sense, the responsible party should be required to pay those costs as well.

The major lesson from this section is that from an economic perspective, it is fairly straightforward to conceptually calculate the damages that result from environmental accidents. The damages are simply the present value of the reduction in the net value of output caused by the accident. Furthermore, there are many ways to react to the accident. In instances where rehabilitation programs cause a net increase in the value of production, they should be used. On the other hand, even though it sounds good, rehabilitation is not always a sensible proposition. When it is, however, the economic damage is the cost of the rehabilitation program plus the net present value of any remaining reductions in the net value of production.

2.8 The Effects of Increased Employment

> The example in this section demonstrates how changes in the level of employment should be evaluated from an economic perspective and shows how it is related to the principle of maximizing the net value of production.

After the ravages of the oil spill were over, things returned to normal. Jean was convinced that his production combination was appropriate from both a short run and a long run prospective; net returns could not be increased in the present without unduly affecting net returns in future years. All in all he felt that if he could just keep things going as they were, while keeping his eyes open for things that would increase the value of production, he would be doing a good job.

One day he was talking to another farmer in the region and they began to compare the operation of their farms. Since their lands were not identical, Jean was not surprised that both farms did not operate in the same way nor did they produce the same outputs or earn the same net returns. But as the comparisons went on, Jean was a little upset to learn that while his farm provided full time work for 15 persons, the other farm employed 27 people. In fact, the other farmer began to disparage Jean for not doing his social duty in providing employment. While Jean had considered the net returns he was earning for himself and the value of extra production his farm was adding to general economy to be a measure of his success, he hadn't considered the number of workers he hired as being important in and of itself. It was true that the larger farms generally had more workers, but this wasn't even always the case. Farms with more machinery sometimes had less workers than farms of equal size with less machinery.

His conscious was pricked, and he met with his contractor and asked him to consider hiring more individuals. The contractor said that this was considered very carefully in the design of the optimal combination of production. Although the analysis of Table 2.2 was in terms of extra dollars spent for production costs, part of those costs were spent for labor. The contractor said that given the way they were operating, an extra dollar spent on labor (or any other input for that matter) would produce output that would add less than a dollar to revenue. It did not make sense to hire more workers. Jean remained unconvinced and asked the contractor to report on the specific effects of adding an extra 12 workers. The results are shown in the top two lines of Table 2.8. Using the extra 12 workers as efficiently as possible with respect to the two crops would increase production of wheat to 5750 tons and alfalfa to 2020 tons. This extra output would have a market value of $9,985. This certainly was good for the farm and good for the economy as a whole; however, to get the extra value of farm output he would have to hire the extra workers. Individuals with appropriate skills were available in the city, where they were paid $5,000 per year. Therefore, Jean would have to match that salary to get them to work for him. This would increase total wages by $60,000. At first glance, the decision to hire extra workers could be interpreted as a wise move. The value of farm output would go up, total wages earned in the area would go up, and he could now match his neighbor as far as his employment level was concerned.

Jean was impressed. In fact, he thought he might be able to get a Chamber of Commerce Good Citizenship Award if he hired the extra workers. He thought his chances were especially good if he could get the selection committee to realize that the workers would spend their incomes in the area, and so not only would farm income go up, but also the value of output of local merchants would increase as well.

While Jean was preparing a place on the mantel for his award, the contractor urged him to look at the rest of his report. His wage bill would go up by $60,000, but revenues only would go up by $9,985. Therefore, the net return of the farm would fall by $50,015. While Jean still thought the extra employment and extra gross value of output on his farm (and indirectly in the rest of the region) would be good, he was not too pleased by the thought of the loss in net revenue to the farm.

This started him to think about the total ramifications of such a plan on the whole economy. By moving the workers to the farm, the value of output in the city would fall. Because employers in the city would not hire the workers unless they were adding enough to output to pay for their wages, the value of output in the city would have to fall by a minimum of $60,000 if the workers changed jobs and worked on the farm. Since the value of output on the farm would only go up by $9,985, the value of output in the whole economy would fall by $50,015. This is exactly the amount by which the net return of the farm would go down. He also realized that while the economy in the farming region would go up as a result of the new workers spending their salaries there, there would be an opposite and equal negative effect in the city because those same workers would not be spending their salaries there.

It was clear to Jean now that any purported gains from the employment switch were illusionary. The value of output in the economy as a whole would fall because any gains in the farming area would be offset by losses in the city. Using the level of employment in any area did not seem to be a very good signal as to what was the appropriate way to run a particular farm and, by extension, to run the economy as a whole.

He realized that in certain circumstances it might make sense to hire more workers. For example, if the 12 extra workers would add more than $60,000 in extra output, then one could argue that they should be hired. From the farm's point of view, it made sense because net returns would go up. And, from the point of view of the whole economy, it also made sense because the total value of output would go up; the increase in the value of farm output would be more than the decrease in the value of output in the city. Even in this case, however, the number of people working in any area was not the criterion to use in making the switch. The appropriate criterion was the effect on the net value of production.

From an economic point of view, there is one more scenario to consider. If the potential workers were unemployed in the city, then putting them to work on the farm would increase the total value of production in the economy. There would be no opportunity loss of output in the city because these workers were not producing anything. However, even in this case, the critical issue is not the number of people employed per se. The important thing is the value of goods and services produced and how it changes when the people start to work on the farm.

The main economic concept introduced in this section is that from a national prospective, changes in employment in one area can come only as a result of opposite changes in other areas. The positive impact in one region will be matched by an equal but opposite negative impact in the other. Therefore, using the level of employment per se as a measure of success in a particular region or industry is not correct. The important issue is how the value of production changes as workers move from one area or industry to another.

While the futility of comparing the success of different farms on the basis of their employment levels is fairly clear, the fact that this notion has direct applications to fisheries policies is often overlooked. In fact, employment levels in the commercial or recreational sector in this or that region are often discussed in fisheries management debates. And, points made are just as valid as the one Jean's friend made when he said his farm was better because it employed more workers.

2.9 Using the Raspberry Patch

> The example in this section demonstrates why open-access utilization of a natural resource can lead to biological and economic waste and how a comparison of marginal gains and losses from different operation levels can provide useful information on appropriate exploitation rates.

On one portion of the Jean's farm which was not suitable from crops was a raspberry patch which no one had tended since the previous owner died. Jean was so busy that he did not think about it until he saw people park their trucks outside the area. He counted eight trucks and noticed that they all came back every day for the week that the berries were suitable for harvest. He was not necessarily a selfish individual, but he decided that it might be wise to look into this situation.

He asked the contractor to investigate and was told these people had been harvesting the berries for several years. While the number of people who participated had varied initially, over the past few years only the eight individuals had shown up. They only came during the harvesting period, and they were, quite frankly, not very careful workers. While they would not intentionally damage anything, they would frequently step on plants to get at others which had more ripe berries, and when they picked, they were not careful to leave the bud where the fruit could grow again. This type of behavior was especially apparent when several people were working in the same area and there was a race to get the best and most berries. It was also noted that no one made any effort to cultivate the plants or to add fertilizer to the patch.

When asked why they behaved this way, they gave two types of answers. In the first place, they were never sure when the owner (Jean) would decide to use the land for something else or to claim all the berries. They didn't see any sense in being extra careful when they weren't sure they could use the land in future years. In the second place, if any one of them were more careful, they were never sure how much of the resulting return they would get and how much would go to the other seven pickers or even to others who might decide to join if productivity went up.

Jean then asked to see an economic analysis of raspberry growing on the plot. The contractor produced the information contained in Table 2.9a. The number of cases of berries that can be produced from the land varies with the number of workers. Each additional worker would add more to output, but the increase in total production would decrease as the number of workers increased. This change in output, which can be called marginal product, is shown in the third column. For example, the third worker would increase production by 21 cases, from 48 to 69, whereas the fourth worker would only increase production by 19 cases.

Using the berry price of $20 a case, the total revenue that can be earned for each level of employment is shown in column 4. The change in revenue contributed by each worker, which can be called marginal revenue, is shown in column 5. Column 6 shows the average revenue per worker. Since eight workers normally work the patch, the amount that each earns, assuming that they are all equally good pickers, is $360. The contractor guessed that this was the lowest amount for which any of them would work. Although there had been more than eight workers in some of the earlier years, they didn't stay around. When there were more than 8 workers and the average return fell below $360 for the one week period, some of them must have concluded that it was not worth their time, and they stopped participating. When he studied employment opportunities elsewhere in the region, the contractor found this was exactly the case. During the time that berries were available, there was always unskilled work available at construction sites for $360 a week.

Using the $360 as an estimate of the opportunity wage of the pickers, the net return to the patch is shown in column 7. The net return at 8 workers is zero. If Jean were to take over the patch, keep the same number of workers and pay them their opportunity wage, the revenue from selling the berries would cover the wage bill but no more. Jean decided it would not make sense to take over the patch under these conditions.

Also, he realized that from a social point of view, at the current level of output, the patch wasn't adding anything to the net value of production. Although $2,880 worth of berries are produced, an equivalent value of output was lost in the construction industry because the workers were at the raspberry patch.

While Jean was ready to forget about the raspberry patch, the contractor pointed out that while 8 people were willing to come to the open patch, Jean wouldn't have to use that many if he decided to make the patch part of the farm.

Assuming an opportunity wage of $360, the net returns would be maximized with 4 workers. Compared to uncontrolled use of the land, the production of berries would fall from 144 to 88 cases. The value of production would therefore fall by $1120; however, the opportunity cost of the four extra workers would only be $1440, so that by cutting back on the number of workers, costs would fall more than revenues and net returns would then increase. The net return from the patch would increase from zero to $320. Jean would have that much extra money per year, and the workers would still have the same income for the week. Those that were not working in the patch could find work in the construction industry.

The change in the profit to the patch under this plan is matched by the change in the value output in the economy as a whole. While the value of raspberry production would fall by $1220, the value of output in the construction industry would go up by $1440, and the value of the output in the whole economy would go up by $320. If Jean decided to take over the patch, not only would his profits go up, but so would the value of output in the economy.

While these numbers sounded right, the principle didn't make sense to Jean. Why did he have to control the use of the patch to make sure net returns were maximized? Why couldn't the individuals who worked it make the right decision? After studying the material in Table 2.9a, he came up with the answer.

Although net returns are maximized when there were four workers, under an uncontrolled system the average return to workers at this level of employment is $440. This is much higher than a worker can make in the construction industry, and as a result other workers are motivated to come and pick. Because Jean wasn't enforcing his rights to the patch, there was nothing to prevent others from working there. As more and more workers came to the patch, the average return to the workers fell. When it got as low as the wage in construction, no more workers wanted to switch to the patch.

By looking closer, Jean could also see how the workers making independent production decisions concerning the output level of the patch could ignore the total profits. Notice that the fifth worker increased production by $340. If this worker got paid what he added to production, he would not work at the patch because he could earn $360 in construction. He would lose $20 by working the patch.

What happens, however, is that the fifth worker gives up $360 intending to earn $420 -- the average revenue when there are five workers. This one worker will thus increase his income by $60. On the other hand, with only four workers, each original participant was making $440 and when the fifth entered their individual return fell to $420. The four of them lost a total of $80. For the industry as a whole, there would be a net loss of $20; the original four would lose $80, but the new entrant would gain $60 over his opportunity wage. The new entrant only considered his own returns when making the decision to switch from construction. When all of the costs do not fall on the one who is making the decision, private decision making does not lead to the proper level of employment.

Jean then tentatively planned to operate the patch and hire four workers. Because he felt that those who had been working there for the past few years should share some of the gain, he thought he would hire four people to work the patch, and pay them $380 for the week. Since they worked for $360 per week under the uncontrolled system, they would be better off. Jean also was determined to give the people who could not continue to work in the patch $20 a week. They then could work in construction and make a total of $380 a week as well. All of the workers would therefore have a higher weekly return than under the uncontrolled situation. The return to Jean from running the patch under this system would be $160. Since some of the net gain would be distributed to the workers, Jean and all of the workers would increase their income because of the change.

Even with this plan, Jean was still not certain that this was exactly how the patch should be operated. He realized that his decisions were based on the facts that the workers would only spend their time picking and that there would be no effort on bush maintenance or on improvement of the patch. He realized that with bush maintenance (i.e., transplanting bushes when they were too close together and tying them to poles) and with cultivation, output per plant would go up, and it would likely be easier to pick the berries. The contractor studied the issue and found that if one worker spent one week per year on these sorts of activities, the production possibilities of the patch would be as described in Table 2.9b. Note that total output would increase at every level of employment, and that the extra output (the marginal product) produced by each worker would go up as well.

Looking at the figures Jean could see that with cultivation, the patch would be more profitable if more workers were used. Net returns would be maximized with six workers. At this level of employment, returns are $840 and after paying for the worker who did the cultivation, the annual net returns would be $480 - $160 more than could be earned with no cultivation. In essence the results showed that annual investment activities which would increase the productivity of the patch, but which would not be done with the uncontrolled system, made sense.

Looking at the table it is easy to see why cultivation would not be done under uncontrolled picking. If cultivation work was done, but there were no controls on using the patch, twelve workers would show up. Essentially this would eliminate all of the gains made possible by the cultivator. However, there would be no money left over to pay the cultivator, and there would be no incentive to do that sort of work in the following year.

The contractor did the same sort of analysis under the assumption that two workers would be used for cultivation. The results showed that the increase in revenues, even after adjusting the optimal number of pickers, would not be enough to pay the cost of hiring that second worker.

Jean then decided that it was definitely a good idea to operate the patch and that he would do so and hire one worker for one week to do the cultivation. He also decided that all of the workers would be paid $380, so that some of the gains from closing of the uncontrolled harvest would be passed on to the workers.

Quite frankly, this section is a transition to the discussion in the next chapter. The concepts introduced are fundamental to an economic analysis of fisheries utilization even though they may be of only a sideline in the operation of a farm. The idea is to present these principles in a non-fisheries context in the hope that they can be more easily understood. The story will be repeated, but with less detail, in terms of fisheries in the next chapter.

The basic principles introduced can be summarized as follows. An open access fishery where participants can enter as long as it is in their best interest to do so, is exactly analogous to Jean's raspberry patch. Individual operators do not consider the effects their actions have on other participants. As a result, although they will make private gains, the fishery as a whole will suffer losses. The value of extra fish production will be less than the opportunity cost of producing it. Additionally, there will be no incentives to invest in - or even care for - the fish stock, because any potential gains will be open to harvest by all current and potential operators. Just as open access raspberry pickers may step on bushes, participants in an open access fishery can likewise push stock to very low levels.

2.10 Camping vs. Maple Syrup

> This section introduces the concept of non-market values and demonstrates that using the net value of output produced as an allocation criterion can lead to improper chooses if both market and non-market values are not considered.

Just when Jean thought that all of the decisions on farm operation were made (at least until prices of outputs, costs of inputs, or interest rates changed), he was forced to face another decision about use. There was another remote section of the farm which was comprised mainly of a stand of maple trees. The area was quite beautiful with hills and vales and several lovely streams which supported natural fish stocks. Jean periodically walked through the area, and he had looked into producing maple syrup but he found that there was not enough production to pay the necessary workers.

One day he received a letter from the leader of a local Girl Scout troop who asked for permission to use the land to produce maple syrup. The girls needed a fund raising activity, and this would be a good one because it would teach them about how to use natural resources. The expected sales would be $10,000 a year, which was much more than they could make at other fund raising schemes. Since the scouts and their leaders would volunteer their time, they could look at labor costs differently than Jean. They didn't have to meet a payroll, and since the girls would not be taking time off from other jobs during the project's duration and the project would not unduly interfere with their school work, there was no real opportunity cost for their labor. No production would be given up elsewhere in the economy. Therefore, the only variable to consider was the value of the syrup which would be produced.

Jean thought this was a good idea. He couldn't use the land, the scout troop would earn money for their activities, and consumers would get $10,000 worth of syrup. He was just about the give his permission, when he opened another letter in the same mail from another Girl Scout leader who asked permission to use the land for a summer camp. When he telephoned the writer of the first letter, he was told that the syrup project could not be carried out if the land were used for a camp. There was no way that the collecting devices could withstand the curious hands of many little campers. Jean knew that he couldn't say yes to both leaders, and so he had to make a decision on who could use the land. Since both letters arrived the same day and both activities sounded useful, there was no obvious way to choose between them. He was in a quandary.

He knew the use of the land for syrup would produce output valued at $10,000, but he did not know the value that would be generated if the land was used for camping. He called up the leader of the second troop and found that they had been going to another camp which was located in an area that was becoming increasingly urbanized. That camp was still available, and they could get it for $9,000 for the summer. The troop normally ran

12 one week sessions with 40 campers per week. This meant that the 480 campers had to pay $18.75 each.

The leader said the reason they wanted to switch was that Jean's land was more beautiful and more conducive to the their camping activities. The leader said that during the discussion to make the switch, all of the campers and all of their parents felt that Jean's land would be far superior. In fact, one mother said she would be willing to pay $35 for the week rather than the $18.75. All of the other parents agreed.

All of this information was interesting, but it was also confusing. Jean had already decided that he was not going to use the land himself and that he was willing to let one of the troops use it at no cost. He just wanted to know which one would make the best use of it. His first inclination was to give it to the maple syrup troop. If he let them use the land, they would make $10,000 whereas if he gave to the second troop, they would save $9000. Looking at pure market values only, which he was accustomed to do in his role as a farmer, the first troop would obtain more value from the land.

He then considered the fact that maybe his decision to let the land be used for free was making him consider the wrong things. If the parents from the second troop really would be willing to pay $35 per camper, the total amount they would be willing to pay to use the land would be $16,800. Therefore by allowing the second troop to use the land, even if he was not charging for it, he was allowing them to enjoy camping activities which - according to their own evaluations - were worth $16,800. There was no market activity involved, but services worth that amount were being generated all the same. He therefore gave permission to the second troop to use the land as a campground. It was not easy to say no to the first troop because their project had many merits, but then again, if allocation decisions were between good things and bad things, they would not be so hard. In reality it is often necessary to choose between two or more good things. If only one can be done, it is necessary to select one that is judged to be better. Jean could have used many different criteria, but he felt that comparing the value of the activities produced from the use of the land was a good as any other of which he could think.

The main concept in this section is that using the value of goods and services produced as a measure of success does not have to be abandoned if some goods are not bought and sold in a formal market place. This concept is important where considering management decisions dealing with recreational fisheries.

For market goods, price measures what people are willing to pay. Even when there is no market for a particular item, consumers still have a willingness to pay; it is just more difficult to ascertain what that amount is. In this hypothetical example, the measure of willingness to pay was derived from the parents. In the real world, it is much more difficult to obtain estimates, but there are many techniques for doing so. Because of their complexities, these techniques cannot be explained in any detail in this document. See, however, a companion GLFC document by J. Barry Smith. For the purposes of this handbook it is only necessary to understand the concept of willingness to pay as a measure of value.

CHAPTER 3

Economic Valuation and Fishing

3.1 The Value of Commercial Fishery Production and the Role of a Management Agency: A Preliminary Look

Background material for this section is introduced in 2.9.

The purpose of this chapter is to show how the concepts developed in Chapter 2 can be useful in analyzing fisheries management decisions. Again the discussion will be in terms of a hypothetical case study. This time it will center around Judy who is a staff person for a general natural resource agency. To make the analysis analogous to the farm case, it will be assumed that the agency has previously not focused specifically on fisheries issues, and the legislature wants to determine if it is time to do so. Judy, who happens to be a cousin of Jean, is given the task of preparing a report on the advisability of starting a specialized fisheries agency. Because the current agency has a very wide focus, Judy has spent all of her time working on non-fisheries issues. She is told to determine the types of things the agency should do and to estimate what benefits will accrue to citizens as a result of its actions. She is told to base her analysis on a planned general budget of $50,000 and an enforcement budget of $20,000. While there is general support for starting a fisheries agency, it is a time of tight budgets and the finance committee will want to be sure that the scarce government funds will be well spent.

Judy was eager to start work and was pleased that an analyst had been assigned to assist her. His job was to brief her on the state of the fisheries and to ascertain what kinds of benefits could be expected from different policies. After doing some preliminary work, he told Judy that there were two main fish species: the Eschalot fish and the Rhodolite fish. At present they were exploited only by commercial fishermen. Each participant fished alone, and each used a small boat and similar gear.

The analyst was trained in biology and economics and had derived a effort-catch relationship for each of the two species and also had estimated the cost of producing effort. This information is displayed in Table 3.1.[1]

Effort was measured in terms of participants, and the cost per participant was $35,000 regardless of which fishery they worked. This covered the income of the worker, current expenses such as fuel and bait, and wear and tear on the equipment.

The catch in tons in each fishery increased as the number of participants increased, however, as effort increased, the amount of production added by the last worker declined. Note that the third participant in the Eschalot fishery increased catch by 90 tons but that the tenth participant only increased it by 20 tons. The analyst alerted Judy to the fact that if large amounts of effort were applied to the stock for long periods of time, catch would fall at each level of output because the stock of fish would be adversely affected. When Judy asked how high effort could get before this would happen, the adviser told her that total effort would have to be seven units or higher before there would be any problem.

[1]The reader is asked to remember the warning about the availability and accuracy of data in real world fisheries. While it may be difficult to produce neat little tables like this, the idea is to understand the economic issues involved. In the real world what data there is should be used to produce as much of this type of information as possible.

The final two columns of the table show the net returns to Eschalot and the Rhodolite fisheries given price per ton for the two fish of $430 and $470, respectively. According to the data, the net returns to the Eschalot fishery turn negative at seven units of effort, and the net returns to the Rhodolite fishery turn negative at eight units of effort.

While Judy was reviewing this material, she came across a report generated by the Department of Business Planning which analyzed the fishing industry in the state. The report verified that the analyst had done a good job. The report estimated revenue and costs for the two fisheries under conditions that corresponded to six units of effort in the Eschalot fishery and seven units of effort in the Rhodolite fishery. The report showed that the net value of output from fisheries was $23,200; $5,000 came from the Eschalot fishery, and $18,200 came from the Rhodolite fishery.

Judy concluded that the fisheries were in fairly good shape. Both were making profits, and neither currently produced enough effort to cause any long run problems with the stock. When she shared these conclusions with the analyst, he agreed with her on the second point, especially given the present levels of effort. As long as prices and costs stayed the same, the fishery could not support enough effort to cause long term stock reductions.

He did not agree with her conclusions on the economics of the fishery, however. Things were not as good as they seemed, both from the industry point of view and from an economy wide perspective. In the first place, any increase in effort on either stock would cause net returns to become negative.

Because the analyst thought it important for the legislature to see an economy wide perspective, he tried to provide a detailed analysis of the fisheries. The output of the two fisheries entered a national market for prepared fish. The flesh from the Rhodolite fish was somewhat firmer, so its price was higher than that of the softer Eschalot fish, but the amount sold of either was small relative to the entire white fish market and did not affect the price of that particular class of fish. As a result, the total revenue from the two fisheries was a good indication of the value placed on fishery output by consumers; revenue to the participants measured the value of output to society. At the same time, for reasons discussed in the previous chapter, the costs of the two fleets represented the value of goods and services that could have been produced had the inputs which were used to produce effort been used in other parts of the economy. If effort were to be reduced by one unit, labor, fuel, and other inputs could be used to produce other products which would have a value of $35,000. Therefore, net revenue of the fishing industry also measured the net value of output contributed to the economy by the two fisheries.

From the information in Table 3.1, Judy realized that while there were positive gains from the two fisheries, the net returns weren't as high as they could be. If effort in the Eschalot fishery were reduced by three units, net revenue would increase to $19,700. Similarly, if effort in the Rhodolite fishery were reduced by four units, net revenue would increase to $54,800. When she asked why the fishing industry did not operate so as to maximize its returns, the analyst explained the problems of open-access utilization of a shared resource: everybody's property becomes nobody's property, and there are no incentives to conserve it.

This concept was explained using Jean's raspberry patch in the previous chapter, but it will be useful to review it in the context of these two fisheries. Assume that three units of effort were used in each of the fisheries such that profits were at their maximum levels. Then, other individuals would be tempted to begin fishing to take advantage of these profits. If effort were to increase by one unit in each fishery, net returns would fall but still remain positive; in other words, each operator would still be making money. Six and seven units of effort are the respective open-access equilibria for the two fisheries because with any more effort, industry net revenues would become negative.

It was now clear to Judy that a fisheries agency could potentially help the economy. If effort could be reduced, the net value of goods and services produced in the whole economy would go up. Although the gross value of fisheries output would fall, but the value of goods and services produced elsewhere in the economy would increase by a larger amount when those inputs which used to produce effort were transferred to other uses.

While she realized that all this information was very preliminary, Judy felt very good about the prospects of a successful and viable fisheries agency. The current fishing industry was earning $23,200, but there was the potential to earn $74,500 - a gain of $51,300. While she was encouraged by this data, she knew she did not have enough information to complete her report. She still had to decide how to use the natural productivity of the lakes and the fish stocks and how to allocate her basic annual budget. Then she would have to see if the net gains were positive.

3.2 The Value of Fisheries: Allocation of Natural Resources

Background material for this section is introduced in 2.2.

The next day the analyst presented Judy with another report. He had been working on different proposals for research, stocking, and habitat protection activities. He told Judy that while the two species of fish could grow in all parts of the state, the Rhodolite stock normally did better the further south it lived, while the Eschalot stock did better in the northern part of the state. A relevant question, therefore, was whether the use of one particular fish stock should be favored in certain parts of the state, and a related question was how the budget should be allocated to activities related to each of the species. Because the analyst wanted to focus on the question of the use of state waters, he initially designed a budget where basic research and administration support was spent equally on each species.

To help consider the specialization issue, the analyst divided the state into five strips running east and west. If the rules for commercial fishing were set up such that the fishers for the Rhodolite fish were given preference in all five strips, the analyst predicted that their waters could produce 405 tons of the Eschalot fish and 695 tons of the Rhodolite fish. (See allocation 1 in Table 3.2.) At the other extreme, if the rules favored the Eschalot fishers in all areas, 780 tons of Eschalot fish could be produced, but only 70 tons of the Rhodolite fish would be caught. (See allocation 6.) Allocations 2 through 5 represent the predicted tonnages if the rules were changed to favor the Eschalot fishery in the various areas, starting in the northern-most one. For example in allocation 2, the rules favored the Eschalot fishery in the northern-most area, but they favored the Rhodolite in the four southern areas.

Notice that as the more areas are allocated to the Eschalot fishery (i.e., with movements down the table) the production of Eschalot fish increases but at a decreasing rate. This is because the Eschalot stocks don't do as well the further south they live. At the same time the amount that the Rhodolite catch decreases goes up. A movement from allocation 1 to allocation 2 would increase the Eschalot catch by 125 tons but would decrease the Rhodolite catch by 75. This means that each ton (2000 pounds) of Eschalot catch "costs" or comes at the loss of 0.6 tons (1200) pounds of Rhodolite catch. On the other hand, a movement from allocation 5 to allocation 6 would increase Eschalot catch by 25 tons but would decrease the Rhodolite catch by 175 tons. Over this range, each ton of Eschalot catch would come at the loss of 7 tons of Rhodolite fish. The same thing works in reverse for movements up the table; the cost for each ton of Rhodolite catch in terms of lost Eschalot catch goes up. These trade off ratios are of critical importance in determining how to allocate the productive capacity of the environment between the two stocks.

The total gross value of the catch for each of the 6 allocations in the third column. It can be seen that allocation 2 produces the highest gross revenue. In making the change from allocation 1 to allocation 2, the value of the increase in the Eschalot catch more than makes up for the decrease in the value of the Rhodolite catch; however, this is not the case for a change from allocation 2 to allocation 3.

While some may have been tempted to say that allocation 2 was the one to choose, Judy knew that as in the operation of Jean's farm, it is the net value of production that is important. Gross values do not tell the whole story. The analyst had not given any good information about the costs of harvesting the various levels of catch, so there was not enough information to make a proper decision.

Judy then asked the analyst to describe the operation of the fishing industry under allocation 2 in the same way that he described it in Table 3.1. The result is pictured in Table 3.3. The cost of producing effort in either fishery remains the same, but the amount that each unit of effort will catch goes up. This increase is due to the stocking, habitat, and research activities performed by the agency as well as to the way in which the natural production of the environment is allocated between the two stocks. Looking at the table, Judy could see that in order for the Eschalot and Rhodolite fisheries to produce 530 and 620 tons respectively, the former would have to produce 6 units of effort and the latter would have to produce 8 units. Net returns in the Eschalot fishery would be $17,900 while the profits in the Rhodolite fishery would be $11,400.

Judy quickly saw another problem that might come from using strictly biological analyses of projected catch levels. It is obvious that the estimated catches would not actually occur given the realities of the fishing industry. The Eschalot fishery would operate at 7, not 6, units of effort. As explained above, under open-access, the equilibrium of effort will be the highest one where net returns are positive. At the equilibrium levels of effort, the net returns to the whole fishing industry in this situation would be $15,800. The Eschalot fishery would earn $4,400 while the Rhodolite fishery would earn $11,400.

Again, the open access operation of the fishery would not produce the highest net revenues. The maximum net return for the Eschalot fishery ($32,600) would be produced with 3 units of effort and the maximum net return level in the Rhodolite fishery ($69,900) would be produced by 3 units of effort in that fishery.

Therefore, if one would specify an allocation of the natural environment as in allocation 2, the total net revenue for the whole fishery could be as high as $101,500. Judy realized that if she was going to make a decision on the different allocations of the various areas of the state, this total net value figure would be the most important economic parameter to consider.

Judy then asked the analyst to recalculate Table 3.2 showing the maximum net value that could be produced from each of the allocations of the natural resource base. The analyst did this by creating a table similar to Table 3.3 for each of the allocations in Table 3.2. A summary of this information is presented in the top half of Table 3.4. The maximum net returns from both of the species from Table 3.3 are entered in row 2, and the values in the other rows have a similar interpretation for the different allocations of the state waters for producing the two different species. Note that the maximum net value can be earned at allocation number 3. That is, if rules are such that the Rhodolite fishery is favored in the northern two sections and the Eschalot fishery is favored in the southern three sections, <u>and</u> if the fisheries are managed to maximize the net value of output, then the two fisheries can generate a net value of output of $112,000.

Judy started to feel like she was finally getting a grasp on the potential net economic benefits to be obtained from a fishery management agency. This is summarized in the bottom half of Table 3.4. Since the fishing industry produced output having a net value of output of $23,200 with no agency (see Table 3.1) and there was the potential of earning a maximum of $112,000, there are potential gross gains from fisheries management of $88,800. This is an increase of $37,500 over the first estimate of potential gains of $51,300 given in Table 3.1.

Judy knew the problem wasn't solved yet, even though she had taken a careful look at the effects of allocating the natural resource base between the two fisheries, she had not yet considered the full ramifications of allocating parts of her budget to the two uses. She knew from conversations with Jean, however, that in planning for his farm, he found that the net value of output not only depended on how much land was used for wheat and how much for alfalfa, but also on how much money was spent on fertilizers, seeds, and labor for each of the two crops.

3.3 The Value of Fisheries: Allocation of the Budget

Background material for this section is introduced in 2.3.

Judy asked the analyst to study the effects of changing the amounts of money spent on each of the particular species. In the previous analysis, it was assumed that the $50,000 budget was divided evenly between the two. The results of his work are presented in Table 3.5. The top half shows what would happen to maximum potential returns if the Eschalot fishery budget for stocking, habitat protection, research, etc. was increased in $5,000 increments. The row marked with an asterisk is the situation pictured in allocation 3 in Table 3.4. The corresponding net returns to the fisheries agency from the Eschalot fishery are listed in column 3. Net returns are the increase in the value of production which results from the activities of the agency. It is the difference between the net value of production from managed fishery and what the fishery would produce with no management minus all agency expenditures. As demonstrated in Table 3.1 the Eschalot fishery produced a net value of $5,000 under open-access conditions. In each case the amount in column 3 is the difference between the figures in columns 1 and 2 minus $5,000.

Judy noticed that the returns from spending agency funds directly on the Eschalot fishery reached a maximum of $30,250 when the amount spent was $20,000, leading her to believe that the even split of $25,000 spent on each fishery was not the best way to spend the proposed budget.

The bottom half of Table 3.5 provides a similar analysis for expenditures on the Rhodolite fishery. The agency returns in column 3 is the difference between columns 1 and 2 minus the open access value of output of $18,200. See Table 3.1. The row marked with an asterisk is the situation pictured in allocation three in Table 3.4. The net agency benefits from managing this fishery reach a maximum of $13,300 with an expenditure of $40,000.

Based on the analysis of both fisheries, Judy was convinced that the equal split of the budget was not a good idea. And, just as Jean realized that while you have to spend money to make money, sometimes you can spend too much, Judy realized that when the budget was evenly split, there was too much being spent on the Eschalot fishery and too little on the Rhodolite fishery.

If Judy wanted to maximize net gains, the agency should spend $20,000 on the Eschalot fishery and $40,000 on the Rhodolite fishery. Unfortunately, the proposed budget was only $50,000. In this regard the role of an agency director is different than the role of a private businessman. Recall what Jean was able to do when he faced the budget decision. From a planning point of view, he could vary the size of the budget because he knew he that if all went according to plan he would make enough revenue to cover his expenses. An agency director cannot do that. The action of the agency may increase the value of goods and services in the economy, but those gains will not show up as revenue to the agency. An agency manager must live with the budget allocated by the legislature.

The problem facing Jean in the previous chapter was finding the operating budget that would maximize the net returns to the farm. (See the analysis in Table 2.2.) The immediate problem facing Judy was to maximize the net returns given its limited budget.

Given the $50,000 budget, and assuming for convenience sake that the budget had to be spent in $5,000 increments, the best way to spend it would be to use $15,000 on the Eschalot fishery and $35,000 on the Rhodolite fishery. (See the rows marked with double asterisks.) The total potential net returns would be $115,000 -- $3,000 more than that possible with an evenly split budget.

Note that with the best possible allocation of the $50,000 budget, the marginal gain in net value for the last budget dollar spent in either fishery is the same. When the Eschalot fishery budget is increased from $10,000 to $15,000, the marginal agency net returns are $1,500. The $5,000 increase in expenditures will increase potential returns to the fishery by $6,500 from a net gain of $1,500. Similarly, when the budget for the Rhodolite fishery is increased from $30,000 to $35,000, the marginal net gains are $1,500.

If a dollar spent on one fishery earns more net benefits than it would if it were spent on another fishery, total net benefits could be increased by taking the dollar away from the fishery where it earns the lower amount and instead spending on the fishery where it earns the higher amount. For example, if $10,000 were spent on the Eschalot fishery and $40,000 were spent on the Rhodolite fishery, the last $5,000 spent on the former would produce a marginal gain of $2,500 while the last $5,000 spent on the latter would produce a gain of $500. It would make sense to take $5,000 away from the Rhodolite fishery and spend it on the Eschalot fishery. By following the rule of equalizing the marginal net gain from expenditures on different agency activities, the agency will always get the largest possible total gains from its budget.

While the $15,000-$35,000 split is the best that could be done given the fixed budget, Judy knew she could legitimately argue for a higher budget. She took this information to the legislative staff and argued that the fishery agency budget should be increased to $60,000. She showed that doing so would increase the net value of output in the economy because another $5,000 spent on each of the fisheries would increase the net value in the economy by a total of $1,250. There would be a decrease in the production of other goods and services elsewhere in the economy by $10,000 due to the extra inputs used in the fishery management agency; however, the net value of output would go up by $5,750 in the Eschalot fishery and by $5,500 in the Rhodolite fishery. The net value of output overall would increase by $1,250. Her arguments fell on deaf ears. The staff could not argue with the logic, but given the current government budget, they simply could not come up with the extra money.

3.4 The Value of Commercial Fishery Production and the Role of a Management Agency: A Final Look

> The material in this section follows and builds upon the analysis in 3.1, 3.2., and 3.3.

Now that Judy was confident that she had a handle on the allocation questions that the fishery agency would have to face, she wanted to prepare a "bottom line" analysis to show what the agency could accomplish. She asked the analyst to prepare an estimate of what industry revenues and costs would be under a fully managed scenario. The results are presented in the top half of Table 3.6. While similar to Tables 3.1 and 3.3, the catch at each level of effort is different because of the way the agency would allocate the environment to the two fisheries and the way it would spend its budget on each of them.

The maximum net returns to the Eschalot fishery of $49,370 can be achieved when effort is equal to 3. The $66,080 of maximum net returns to the Rhodolite fishery can also be produced with 3 units of effort. (These are more precise estimates of net returns than those provided in the rows with the double asterisks in Table 3.5.) The maximum potential net returns from both fisheries would be $115,450. On the other hand, if left to their own devices, the two fisheries would each have an open-access equilibrium of 8 units of effort, and the net revenue for each would be $3,370 and $8,580 for a total of $11,950.

Judy could see that there was a significant difference between the maximum potential net revenue and the net revenue likely to be produced by an unregulated industry. She asked the analyst to demonstrate the net gains to the agency under two alternatives. In the first case there would be no controls on entry to the fishery, and in the second effort would be restricted to that which maximized the value of fishery output. His results are shown in the bottom half of Table 3.6. With a complete open-access system, net returns to the fisheries actually fall. Although the agency activities will increase the productivity of the fish stocks and hence the potential for gains, under open-access, these gains are dissipated. Recall that the net returns to the fishery with no agency and no regulation are $23,200 (see Table 3.1); with the agency the open-access net returns are $11,950. This represents a loss of $11,250.[2] Additionally, when the $50,000 agency budget is subtracted out, the total net economic benefit of the fisheries agency is a loss of $61,250.

In fact, the picture under open access may likely be worse than pictured in this snapshot look at the fishery. These catches are possible this year, but biologists doubt that the stock could take the pressure exerted under open-access, and so catch per unit of effort might fall in the future.

Judy obviously did not like a scenario of net losses this year with the likelihood of worse to come. She realized that some sort of fisheries management would be necessary. The analyst had determined that the $20,000 enforcement budget would be sufficient to initiate and operate a management program which could cause the fisheries to efficiently move to the maximum net revenue positions.[3] The full net benefit of the agency with

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[2]It should be noted that if the revenues and costs were different it is possible that the open-access returns with the agency could be equal to or even greater than those with no agency. Regardless, the open-access gain will always be less than the maximum possible.

[3]The exact details of the management plan will not be discussed here. The story would get much too complicated. However, there are many ways to regulate a fishery and each has its biological and economic strengths and weakness. There has been volumes written on this subject and many citations can be found in the references.

appropriate regulation can thus be calculated: the increase in net returns to the industry is $92,250; subtracting out the basic agency budget ($50,000) and the enforcement budget ($20,000) yields an overall net economic benefit to the agency of $22,250. Furthermore, at the reduced levels of effort the stocks would not be adversely affected, and the projected levels of catch could be maintained indefinitely.

During the discussion of this material, a colleague suggested that a better way to manage the fishery would be to let effort increase as long as future stocks were not affected. As long as fishers were making money and the stock was not damaged, why should the agency care how many people fished? In fact, wouldn't the legislature be pleased with more employment than less?

Judy had a ready answer for this because she had talked to her cousin Jean about his thoughts about increasing employment on his farm. (These were discussed in the previous chapter.) Unless there are no alternative employment opportunities elsewhere in the economy, allowing employment to increase in the fishery will mean there will be less workers for other industries and the value of output in the non-fishery sector of the economy will fall. Also, these extra fishermen will affect the returns to existing fishermen. Any expansion of effort beyond three units of effort in either fishery will decrease the overall value of output because the increased value of output in the fishery will be less than the decrease in the value of output elsewhere.

Judy was now prepared to make an initial report to the legislature on the desirability of starting a fishery agency. As she looked over the information in Table 3.6, she realized that Jean was right when he said that although there were some significant differences, there were also many similarities between determining how to run a farm and how to run a fisheries agency.

In both instances decisions have to be made on the best way to allocate the natural resource base as well as the operating budget. A difference here is that the farmer has more flexibility in determining the size of the operating budget. Also, in both instances the allocation decisions will have an effect on the net value of output produced by the economy.

A difference is that the farmer directly reaps benefits when the value of output goes up (as do the consumers of farm products) and suffers losses when they go down. This is not so for the fishery agency. The gains, if any, will be earned by the fishing industry and consumers of fish. The costs will be paid by the general tax payer.

Another difference is that the farmer's allocation decision covers the procedures for harvesting the product. Therefore, with the exception of the raspberry patch where originally Jean did not make the harvesting decisions, there was always a built in incentive to operate where net revenues were maximized. The fishery agency, on the other hand, only sets up the potential for harvest. Without specific regulations, the decision of how much to harvest is made simultaneously by many independent agents. And, as is described above, when each operates in their own best interest, the fishery will not operate so as to maximize net returns. This is why the agency must have a regulatory budget to help determine how much will actually be harvested.

3.5 The Value of Recreational and Commercial Fishery Production

Background material for this section is introduced in 2.2, 2.3, 2.4, 2.8, and 2.10.

When Judy presented her report, the legislature was convinced that a fishery agency was a good idea. They authorized such an agency and appointed Judy as the first Director. The first thing she did was appoint the analyst as her assistant. She allocated the natural resource base and her budget as described above, and she instituted a management plan which kept the fishing industry at the net revenue maximizing levels of effort.

Things were going well, which for a fishery agency director meant that there were no hassles with government or industry people. However, one day it was discovered that the Eschalot fish could also be taken with recreational gear. The Eschalot fish, besides tasting good, put up a good fight, and hence the recreational fishery started to expand very rapidly. Soon Judy started to feel the heat. The commercial industry for the Eschalot fish began complaining that their livelihoods were being affected. The recreational participants formed a club and started writing letters to their legislators asking that something be done to give them a legitimate stake in the fishery.

Judy realized that some sort of allocation between the commercial and recreational sectors would be necessary. She knew that there were many different criteria for making such allocations, but since she had done very well so far by paying attention to the economic value of goods and services produced, she decided to continue to use that criterion - at least for the present.

She knew that there were benefits from commercial use of the Eschalot fish. If the recreational sector reduced the stock available to the commercial sector, some of these benefits would be lost. On the other hand, she also knew that there were benefits derived from recreational fishing. She was going to have to compare the losses in value to the commercial fishery with the increases in value to the recreational fishery and try to find an optimal balance.

As a first step in understanding the problem she asked the analyst to determine how the Eschalot commercial fishery would be affected by different levels of recreational quotas. The results are presented in Table 3.7. The first four columns show the operation of the fishery with no recreational fishing. The fifth column shows how catch at each level of effort will be affected if recreational participants are allowed to take 100 tons. Note that allocating 100 tons of fish to the recreational sector does necessarily decrease commercial harvest by that amount. It merely reduces commercial catch per unit of effort. The sixth column shows the net returns. The rest of the table shows what would happen to landings and net revenues when the recreational catch is 200 and 300 tons, respectively.

Notice that with a 100 ton recreational quota, the maximum net revenue still occur at 3 units of effort. The returns are lower than they would be without the quota, but the maximum still occurs at the same level of effort. The same is true with a 200 ton recreational quota. However, with a 300 ton recreational quota, net returns are maximized at two units of effort. Given the effects of recreational fishing, it doesn't make sense to use as much commercial effort.

The maximum net revenues in the commercial fishery for the three quota levels are $45,500, $41,200, and $28,900. Using these figures, it is easy to calculate the cost to the commercial sector of the various quotas. See the bottom half of Table 3.7. The 100 ton quota reduces the net value of output by $3,870 ($49,370 minus $45,500) so this is the cost of the quota. It would not be proper to use the gross value of the 100 tons of recreational harvest as a measure of its cost. While the quota will reduce catch to the commercial fishery, there is not necessarily a one for one trade off. Catch in the commercial sectors would only fall by 9 tons in this instance. The value of the lost 9 tons at a price of $430 a ton is $3,870. Following similar reasoning, the costs of a 200 and a 300 ton quota would be $8,170 and $20,470, respectively.

However, with the 300 ton quota, the reduction in the cost of operating the fishery must also be taken into account. Consider the effects of the 300 ton quota in detail. At the 3 units of effort where the fishery would normally operate, this quota will cause commercial harvest to fall by 49 tons; but - because optimal utilization in the presence of the quota will require a reduction of one unit of effort, the actual reduction in harvest will be 129 tons. Revenue to the fishery will fall by $55,470. Yet, the reduction in effort would lower costs by $35,000, making the net effect on the commercial fishery equal to $20,470.

Finally, note the marginal cost of increasing the quota in 100 ton increments. The first 100 tons reduce the net value of output in the commercial fishery by $3,870. If the quota was increased to 200 tons (which is to say that another 100 tons is allocated to the recreational fishery), the extra reduction in net value is $4,300. A third increase of 100 tons will reduce net value by $12,300. This increasing marginal cost of the quota is important.

It may make sense to allocate a 100 ton recreational quota, but this does not mean that all fish should be given to the recreational sector. As more and more is taken from the commercial sector, the cost - in terms of decreased value of commercial output - goes up.

Now that Judy knew what would be given up if there was an allocation to the recreational sector, she wanted to know what would be gained. She had heard of economic research procedures for measuring the value of recreational fishing which could measure the value despite the fact that no product is sold on the market. The value of a commercial fisheries product is its price, which is what people are willing to pay for it. Since recreational fishing is a service, people value it in the same way they value other goods and services in the economy. Research on the valuation of recreational fishing attempts to measure what people are willing to pay to participate in this activity; the result is a measure that is commensurate with the measures of net value used in commercial fisheries.[4]

The analyst happened to be well trained in doing such valuation work, and after considerable effort he derived the information contained in Table 3.8. He explained that while recreational fishers participate for the relaxation it provides and while they do not go out strictly for the fish they obtain, the amount of fish caught is important. That is, it plays a role in determining how much they are willing to pay for a recreational fishing day, because one important measure of success in recreational fishing is the number of fish caught per day. The analyst determined this was, in fact, a very critical variable for the recreational value obtained and, subsequently, a very critical component of the willingness

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[4]This is not the place to go into the details of measuring the value of recreational fishing. See the study prepared for the Great Lakes Fisheries Commission prepared by Barry Smith and the references cited therein.

to pay by participants in the recreational fishery for Eschalot fish. His work determined that there was a direct relationship between the catch per day and the number of days a participant would fish.[5] Since the analyst knew that bag limits (the legal maximum number of fish that participants would be allowed to take) would likely be an important part of the regulation program for the recreational fishery, he knew this relationship would be very important. The estimated number of days a participant will want to fish given various bag limits is displayed in columns 1 and 2 of the table.[6] Notice that days fished per individual goes down as the bag limit is lowered. While every participant doesn't always catch the bag limit, a reduced bag limit lowers the potential for a "great day" and hence lowers the relative potential gains from fishing. Therefore, people may switch to other recreation activities and participation rates will fall.

The analyst found that the total annual willingness to pay for recreational fishing for each individual depends on the number of fish caught per day, the number of days fished per year, and the feeling of being crowded if forced to fish in a congested area. Obviously, the annual value (i.e., willingness to pay) will go up with the number of days fished and the catch per day, but it will go down as congestion on the grounds increases. Column 3

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[5]Please note that while the discussion of the valuation of recreational fisheries is based on the general premises of current research methodology, it is very much simplified. Please remember the warning given in the first chapter. The examples are constructed to make them easy to explain. Also in all cases, the recreational values are set at a level where they will be comparable with the commercial values. The values themselves are completely hypothetical.

[6]In this hypothetical example it is assumed the number of days fished per year is the square root of the bag limit. The exact form of the relationship will vary according to the fishery.

represents the individual annual benefits from recreational fishing for the various catch levels and participation levels if there is no congestion.[7]

The fourth column shows the total maximum catch per participant given the bag limit and the days fished per years. The numbers in this column are the product of the corresponding numbers in columns 1 and 2. Knowing the catch per participant is important because it can be used to calculate the number of people that can be allowed to fish when there is a particular bag limit and a total quota. Column 5 gives the number of people that can participate at various bag limits given a 100 ton quota. It can be calculated as follows. For any particular bag limit, it is possible to determine the number of days fished per individual, and hence it is possible to calculate the number of fish each participant will take each year. If one assumes that the average fish weighs a pound, there will be a quota of 200,000 fish. (Remember that Judy is considering a 100-ton recreational quota.) Dividing this 200,000 fish quota by the number of fish caught per person yields the number of participants that can be accommodated.[8] As one might expect, the number of possible participants goes up as the bag limit goes down. These calculations are repeated to get an idea of how different quotas would affect the number of participants; columns 7 and 9 show

[7]In this case annual benefits are assumed to be related to the bag limits in the following way. Since days fished are a function of bag limits, benefits can be expressed solely in terms of catch per day.

$$B = .03125\ (\text{bag limit})^2 - .001375\ (\text{bag limit})^3$$

[8]This analysis is simplified by assuming that each person can always take the bag limit. When this is not the case, the estimate of the number of people which can be accommodated will have to be revised upward.

the possible number of participants at various bag limits with quotas of 200 and 300 tons, respectively.

Using this information and the knowledge of how congestion affects individual benefits, the analyst was able to calculate the total recreational benefits that would be generated by the various regulation programs. A regulation program is defined in terms of the size of the recreational quota and the allowable bag limit. Assuming all participants take the bag limit, it is possible to calculate how many participants could be allowed. This number could be maintained by issuing that many fishing licenses. For the 100 ton quota, these gross benefits are displayed in column 6.[9] With a 100 ton quota, the total recreational benefits are maximized when the bag limit is 8 and the number of permissible participants is 8,839. Although a bag limit of 7 will allow around 2000 more people to participate, the congestion effects they impose on each other are such that total annual benefits fall.

The total recreation benefits that can be achieved with the 200 and 300 ton quotas are displayed in columns 8 and 10, respectively. When the quota is increased to 200 tons, 8 fish is still the bag limit that will produce the maximum total value, so the number of possible participants at the maximum benefit point will double; however, because of congestion effects, the total benefits will not double. If the quota is increased to 300 tons,

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[9]To correct for the congestion, total benefits are not just the product of participants (P) and individual annual benefits (B). There is a correction factor to take into account of how congestion will increase as the number of participants increase. The equation used in this hypothetical case is:

$$\text{Total benefits} = P^{*}B - .0004P^{2}B$$

the maximum potential recreational value will be achieved when there is a bag limit of 9. If the bag limit were to stay at 8 while the allowable number of participants went up by another 8,839 people, the congestion or crowding factor would be very large. Thus, the total recreational benefits can actually be increased by raising the bag limit, because this raises the individual annual benefit when there is no congestion (see column 3) and reduces the number of possible participants which reduces the congestion effects. Although the individuals who can no longer participate lose the value they associate with recreational fishing, those that still participate gain even more.

Since an open access recreational fishery will not spontaneously choose the appropriate number of participants and bag limit combination, regulation will be necessary. The analyst determined that an adequate enforcement program could be implemented for a annual cost of $7,000. In response to lobbying from the recreational fishing club, the legislature has promised to provide this additional money to the agency.

It is now possible to state the benefits that can be achieved for various recreational quotas. If the quotas are allocated and the appropriate combination of total participation levels and bag limits are enforced (the former could be achieved by limiting the number of licenses that could be given each year), the total net values listed at the bottom of columns 6, 8, and 10 are possible. When these benefits are compared with the losses those quotas would impose on the commercial fishery, a policy which maximizes the sum of the net values from joint utilization can be determined.

With an appropriate regulation program, a 100 ton quota can provide net benefits to recreational fishers of $11,151. Similarly, a 200 ton quota can provide $21,695 in total net benefits, and a 300 ton quota can provide $31,710. Using these figures it is possible to show how value to the recreational sector changes as their allocation is increased by 100 ton increments. A 100 ton quota will provide $11,151. The marginal gain from increasing the recreational quota to 200 is $10,544; the gain from increasing further to 300 tons is $10,015.

Looking back to Table 3.7, it can be easily seen that a 300 ton quota does not make sense if one is concerned with the total value of production. Going from a 200 ton quota to a 300 ton quota will increase value in the recreational sector by $10,015 but will reduce value in the commercial sector by $12,300. On the other hand, going from no quota to a 100 ton quota ($11,151) will increase value in the recreational fishery more than it would decrease it in the commercial fishery ($3,870). Similarly, going from a 100 to a 200 ton quota will increase recreational benefits by $10,544 and only reduce commercial benefits by $4,300.

To get a complete picture of the analysis, consider Table 3.9. The top half shows the maximum total potential net benefits to both sectors associated with various quota levels. Following from the discussion above, the sum of the net values is maximized with a 200 ton recreational quota. The maximum possible net returns for the entire fishery are $62,895. By comparing this to the $49,370 which was the maximum possible when the fishery was used exclusively by the commercial industry, it can be seen that allocating part of the Eschalot fishery to recreational participants can increase the returns. When this is added to the net value generated by the Rhodolite fishery (which - according to our implicit assumptions - is not suitable for recreational fishing) and the value of the open access utilization of the commercial fishery from both stocks is subtracted out, it can be seen that the increase in value of the two fisheries due to the agency's management will be $105,775. After the general agency budget and the enforcement budgets for both sectors are subtracted out, the net economic benefit of the agency is $28,775. Referring back to Table 3.6, it can be seen that this is an increase from when there were only commercial fisheries and the agency's net economic benefit could potentially be $22,250. It does cost something to regulate the recreational fishery, but in this case the net values gained are more than enough to make up for it.

The recreational fishing club was pleased with the change in policy because it gave them a legitimate role in the fishery; however, some of their members wanted more. They knew that increasing the quota to 300 tons would allow more recreational participants, so these individuals met with Judy and tried to persuade her to increase the recreational quota. They were not convinced that the criterion she used of maximizing the total net value of production was the proper criterion on which to base allocations.

Everyone agreed that the additional participants which would be possible with a 300 ton quota would spend money on fishing gear, bait, gas, hotel rooms and other items that go along with recreational fishing. Surely, all of these expenditures represented an important component of the value of the recreational fishery. Judy was not swayed by this argument. She knew that to treat expenditures as a measure of value was a logical fallacy because expenditures represent costs of fishing. For example, she asked, what would happen if the price of gasoline fell? Fishermen would spend less on each fishing trip, yet would this fall in expenditures mean that the value of recreational fishing would fall as well? Actually, the reverse would be true. The fishermen would be getting the same recreational fishing experience and would be spending less.

Judy rejected the arguments of the club members and kept the recreational quota at 200 tons in order to maximize the sum of the net values generated in each fishery.[10]

3.6 The Attack of the Lamprey

Background material for this section is introduced in 2.4.

Using the information collected, discussed and displayed in the previous sections, the agency established regulations to cause the Eschalot fishery to be allocated among the commercial and recreational fisheries in a way that maximized the sum of the net benefits and the Rhodolite fishery to be operated at 3 units of commercial effort. Regulating this way, the net gains to the two fisheries were $62,895 and $66,080, respectively. After taking into account what the fishery would produce with no management and after subtracting the general and the two enforcement budgets, the net benefits generated by the agency were $28,775. (See column 1 in Table 3.10a which summarizes the bottom half of Table 3.9.)

All went well for the agency and the fisheries for several years. The stocks remained healthy, and prices and costs did not change; there was no reason to consider any changes in fisheries policy. Trouble began, however, when there was an invasion of sea lamprey. These fish loved to eat both stocks of fish, and the extra source of mortality affected the net

[10]For more detail on methods of analyzing impacts of expenditures on commercial and recreational fisheries, see the companion GLFC publication "A Guide to Understand Economic Impacts of Fisheries Management."

productivity of both stocks. The maximum net benefits that could be achieved were therefore reduced.

The lamprey's effects on the net benefits produced from the two stocks of fish are summarized in column 2 of Table 3.10a. Under the best management possible, the net benefits of the Eschalot and the Rhodolite fishery fell to $31,448 and $52,864, respectively. Apparently, the Eschalot fishery was more susceptible to damage from lamprey than was the Rhodolite fishery. Given the lamprey attack, the two fisheries would produce a net value of $11,600 with no agency activity rather than the $23,200 it had previously earned. The gross return due to agency activity (which is the difference between maximum gains with the agency and the gains that would be produced without it) fell from $105,775 to $72,712. Because this is less than the $77,000 total budget of the agency,a the net benefits of the agency were completely wiped out. With the lamprey causing so much damage, the maximum net increase in value in the fishery that could be produced was just not enough to cover agency expenditures.

Judy talked to the directors of other nearby fisheries agencies, and found that they were similarly affected. Not all were as badly off as Judy's agency; some could still show positive net benefits. Regardless, all agency heads were looking into control programs, and Judy decided to do likewise.

She asked the analyst to see what would happen if a lamprey control program was instituted. She wanted to know if such a program could be justified and, if so, how much should be spent on it. Columns 3, 4, 5, and 6 of Table 3.10a show how the net benefits of both fisheries will change depending on the amounts spent on control. Increases in control expenditures (shown as $5,000 increments) would cause the net returns to the two fisheries to go up, but at a decreasing rate. For example, under a $5,000 program the net returns in the Eschalot fishery would go up by $12,000 (Row 1, Table 3.10a). Shifting to a $10,000 control program would only lead to additional increase of $9,000. A shift to a $15,000 program would cause an even smaller increase in net benefits. As can be seen from the second row of the table, the effect on the net benefits of the Rhodolite fishery would be similar.

Judy studied the results of a $5,000 program. Since the net benefits of the Eschalot fishery would go up $12,000 and those of the Rhodolite fishery would go up by $6,000 (for a total increase in net benefits of $18,000), she knew the $5,000 program could be justified. The increase in the values produced from both stocks would be more than the cost of the program. The bottom row in Table 3.10a shows that the net benefit of the agency would increase by $13,000 if they were to use a $5,000 control program. However, because of the decreasing returns to control program, Judy knew it wouldn't make sense to indefinitely continue to increase the amount she spend on the control program. By looking at the "bottom line" of Table 3.10a, she could see that the economically optimal lamprey control program would be to spend $15,000. With such a program the net benefit of the agency would be $19,212 higher than it would be with no program, but not as high as it was before the lamprey invasion. Increasing the money spent on control to $20,000 would increase the returns to both fisheries, but the gains would not be enough to cover the $5,000 increase in the budget.

When Judy first went to the legislature with these results, she was very disappointed with the response. She was told that although the gains from a control program would be positive, the state did not have the funds in the overall state budget to start one. She was told that if she thought a program was necessary, she would have to fund it out of her current budget.

Judy asked the analyst to determine what would happen if money was reallocated to a control program; she needed to know what the cost of funding the program would be. The cost to her agency would not be the money spent on control because she already had the money; rather, the cost would be the loss in net benefits that would result of cutting down other agency activities. She knew that if she were to be rational in cutting back on programs, she should cut the least effective ones first.

The predicted effects on the two fisheries of the various programs are displayed in Table 3.10b. There would be two effects on each fishery. First, the net value would fall because less money would be spent on stocking, habitat protection, etc. Second, however, the control program would cause an increase in the fisheries net value. Reducing the general budget by $5,000 would cause a loss in the Eschalot fishery of $4,500 and in the Rhodolite fishery of $1,000. (This meant that even the least effective programs which were cut were cost efficient, because they were producing net benefits of $5,500 for a cost of $5,000.) The estimated gains to the two fisheries from control would be $11,000 and $5,500, respectively. This $16,500 gain is less than the $18,000 gains attributed to a $5,000 program described earlier because the fisheries would not be as productive given the loss in the $5,000 in the general budget. Nevertheless, the net benefits of the $5,000 internally funded control program would still be worthwhile. After taking into account all agency costs, the net benefits of the agency would increase from negative $4,288 to $6,712. The table also demonstrates that a $10,000 internally funded program could be justified, too, but the increase in net benefits to the two fisheries would be smaller than for the $5,000 program. Additionally, the cost of removing other programs would increase because programs which produce higher net benefits would have to be cut. In spite of this there would still be an increase in the net benefits produced by the agency. Total control gains would equal $27,500, while the loss from eliminating other programs would be $12,000. Net agency returns go up to $11,212. The same could not be said for the $15,000 program, however. The loss in net benefits from cutting the general budget by an additional $5,000 would be greater than the returns of the increased lamprey control. Moving from a $10,000 to a $15,000 internally funded program would cause the agency's net returns to decrease from $11,212 to $10,712.

These results show that if the lamprey control program has to be funded out of the current general budget, it still would make sense to have a program but the amount spent should be less than the $15,000 she initially wanted to spend. Judy made the decision to make the reallocation of the budget, but when the proposed changes were announced, the users of the fisheries complained so vigorously that the legislature relented and decided to fund the $15,000 program by increasing the agency budget.

3.7 The Construction of a Dam

Background material for this section is introduced in 2.5.

After the control program was implemented with the new funding, the net benefits of the agency were $19,212. The calculations behind this amount are summarized in column 5 of Table 3.10a and are repeated in column 1 of Table 3.11. Then, just as things were settling down, Judy had to face a new issue: the legislature was considering the construction of a new $75,000 dam. The sole purpose of the dam was to enhance fisheries habitat.

Judy was asked if she could support the proposal to build the dam. Before responding, she asked the analyst to determine the efficiency effects of the dam on the fishing industry. He found that during the construction of the dam there would be significant mortality on the stocks and that the reproduction rate would be affected for several years. Eventually however, the dam would indeed increase habitat, and the standing stocks could increase. The net returns to the two stocks for the first four years after construction are listed in columns 2, 3, 4, and 5 of Table 3.11. After those four years, the returns would continue as described in column 5. These figures were calculated taking into account the optimal allocation of the resource base and the agency budget as well as the optimal utilization of both fisheries. For convenience, all of those calculations are not presented.

As can be seen, in the first two years, the net benefits of the fisheries agency would be negative. In the third year, while the agency would show positive net gains, they would still be lower than the gains from before the dam was built. In the fourth and all future years, the net gains to the agency (which are the net gains to society for the properly managed fisheries) would be higher than without the dam. The net effect on the value of fishery production for the first twenty years of the life of the dam are shown at the bottom of the table. In the first three years the dam would generate negative benefits. In the fourth and all future years there would be an increase in benefits equal to $25,741. Judy needed to know if these increases in the latter years justified the construction cost of the dam plus the losses in the first three years.

The present value of the flow of returns over a twenty year period calculated using an interest rate of 10% is $91,838. Therefore, the construction of the dam makes sense in terms of the value of goods and services produced. The present value of fisheries production would go up by $91,838 - even taking into account the reduction in the first three years- while the value of goods and services elsewhere in the economy would fall by $75,000 as a result of the construction. There would be net increase in the present value of goods and services produced of $16,838, and so Judy gave her approval to construct the dam.

As a sidelight, it is interesting to note how the economic analysis of another common problem facing fisheries agencies is very similar to the discussion in this section. It is often necessary to cut back on fishery production in order to let the stocks recover from overfishing. In this case, the economic question becomes: Is the reduction in the value of output in the present worth the increase in value in the future?

One can view the flow of net values in the bottom half of Table 3.11 as representing the effect of a management program which cut back effort and then let it increase in a controlled manner as the stock increased. If society does have a 10% discount rate for comparing values at different periods of time, the loss of output early in the program is more than made up for by the increase in the latter part. In order words, since the net present value of the flow is positive, the program could be judged to be an economic success.

3.8 Economic Valuation of a Fish Kill

Background material for this section is introduced in 2.6 and 2.7.

After the construction of the dam, everything went smoothly for the fishery agency for four years. The stocks recovered as predicted and the net benefits of the agency were $44,953. Then disaster hit. A chemical company on the shore of the lake where much of the fishing took place inadvertently spilled a large amount of waste into the water, producing a significant fish kill. According to the law, the company was responsible for the damages caused by the spill, and the legislature asked Judy to determine how much money should be collected. Judy asked the analyst to predict how the value of the fisheries output would be affected by the spill. His results are displayed in Table 3.12.

The analyst predicted it would take five years for everything to return to normal, thus his analysis involved comparing the 5 years of recovery to what would have been had the spill not occurred. The first row of Table 3.12 shows the net benefits that would have been generated during those five years if there had been no spill. These are equal to the value produced by the two fisheries with management minus the agency's total budget minus the amount the fisheries would have produced with no management. The net present value of the no-spill scenario's five years at $44,953 using an interest rate of 10% is $170,407.

The middle portion of the table shows the agency's net benefits over the five year period given a natural recovery of the stocks. The analyst determined that given the damage to the stocks, the way in which the fisheries should be managed over the recovery period should be changed. Because there were chemicals in the water, he found that stocking programs should be cut back because some of the fish would die. Therefore the agency budget could be reduced in the first four years. As time went on, however, the stocking program could gradually be increased back to its old level.

Taking this into account, the net value of the two fisheries during the recovery period is shown in columns 1 and 2. Their sum is shown in column 3, and the budget of the agency is shown in column 4. With the stock damage, the value that could be produced by an uncontrolled fishery would also be reduced over the recovery period. The value of the open-access fishery over the five year period is shown in column 6. The net economic benefit to the fishery agency over the five year period under a natural recovery scenario is shown in column 7. With no spill the agency would have a net value of $44,953 per year; with the spill the value in the first year would be a negative $9,668, and the net value would not get back to normal until the fifth year. The net present value of this flow of benefits at 10% would equal $57,050. Knowing that the net present value of damages equals the difference between the present value of the net benefits without the spill and the present value of net benefits with the spill, Judy told the legislature that the company should be forced to pay damages of $113,357.

The company wanted to reduce their damage payments by setting up a rehabilitation program. (Recall that with the oil spill on Jean's farm, such an option proved to be advantageous to all concerned.) The proposed rehabilitation program would cost $12,000, $20,000, and $8,000 in the second, third, and fourth years.

The effects of the rehabilitation program are shown in the bottom portion of Table 3.12. The program would indeed speed the recovery of the two fisheries; the net values generated by the fishing industry in the second, third, and fourth years would be higher than those occurring under a natural recovery scenario. As a result the net present value of the fishery over the five year period would increase to $60,534.

However, these increases are not enough to compensate for the costs of the program. Because the net present value of the fishery over the recovery period would go up with rehabilitation, the damage assessment against the firm would fall to $109,837. However, the net present value of the cost of rehabilitation program would be $30,408, making the total cost to the firm of $140,281. The company would be better off allowing for a natural recovery and paying a higher damage assessment.

The real point of this story, is not just that the company would be better off without providing the rehabilitation program; the point is that the entire economy is better off without the rehabilitation program. The increased present value of fisheries output resulting from the rehabilitation plan would not be large enough to compensate for the decreased present value of goods and services elsewhere resulting from undertaking the rehabilitation program.

3.9 Summary

It is not possible to summarize all of the concepts that have been introduced and the issues that have been addressed. However, the underlying theme has been that the basic principles of economics can be useful in designing and implementing fisheries management programs. Management involves making many different types of choices and economic principles and economic valuation offer one criterion for determining which choice is best.

While the analogy with the farmer is not perfect, a farmer and a fisheries manager do have much in common. They make decisions concerning the use of natural resources and other inputs so as to produce goods and services. One way to determine if wise choices are being made is to study the effects of the choices on the net value of all outputs produced. This can be done by comparing the values gained and values lost because of the choice.

Some of the choices described include dam construction, lamprey control, allocation of stocks between users, environmental rehabilitation, and natural resource and budget allocations within an agency. However, the economic principles developed apply to a host of other issues as well.

The examples also demonstrated that the choices of private individuals concerning common use of a open access natural resource will likely lead to wasted resources. The natural resources will be overused and too many inputs will be used to exploit it. The total net value of goods and services in the economy can potentially be increased by regulating private decisions.

References

Anderson, Lee G. 1986. The Economics of Fisheries Management, Revised and Enlarged Edition. Baltimore: Johns Hopkins University Press.

Beddington, John R. and R. Bruce Rettig. 1984. Approaches to the Regulation of Fishing Effort. FAO Fisheries Technical Paper #243, Rome: FAO.

Bell, Frederick W. 1978. Food From the Sea: The Economics and Politics of Ocean Fisheries. Boulder, Colorado: Westview Press.

Butlin, John A. 1981. The Economics of Environmental and Natural Resources Policy. Boulder, Colorado: Westview Press. (Chap. 7,8)

Clark, Colin W. 1985. Bioeconomic Modelling and Fisheries Management. New York: Wiley.

Clark, Colin W. 1990. Mathematical Bioeconomics: The Optimal Management of Renewable Resources, 2nd edition. New York: Wiley.

Conrad, Jon M., and Colin W. Clark. 1987. Natural Resource Economics. Cambridge University Press. (Chap. 2)

Cunningham, Stephen, Michael R. Dunn, and David Whitmarsh. 1985. Fisheries Economics: An Introduction. New York: St. Martin's Press.

Dasgupta, P. S., and G. M. Heal. 1979. Economic Theory and Exhaustible Resources. London: Cambridge University Press. (Chap. 5)

Fisher, Anthony C. 1981. Resource and Environmental Economics. Cambridge Surveys of Economic Literature. Cambridge University Press. (Chap. 3)

Hannesson, Rögnvaldur. 1974. Economics of Fisheries: Some Problems of Efficiency, Lund, Sweden: Student litteratur.

Hannesson, Rögnvaldur. 1978. Economics of Fisheries. Bergen, Norway: Universitets-forlaget.

Hartwick, John M., and Nancy D. Olewiler. 1986. The Economics of Natural Resource Use. New York: Harper & Row Publishers. (Chap. 8,9,10)

Howe, Charles W. 1979. Natural Resource Economics: Issues, Analysis, and Policy. New York: Wiley. (Chap. 12,13)

Howe, Charles W. 1982. Managing Renewable Natural Resources in Developing Countries. Westview Special Studies in Social, Political, and Economic Development. Boulder, Colorado: Westview Press. (Chap. 2)

Lawson, Rowena M. 1984. Economics of Fisheries Development. New York: Praeger Publishers.

MacKenzie, W. C. 1983. An Introduction to the Economics of Fisheries Management. FAO Fisheries Technical Paper #266, Rome: FAO.

McConnell, Kenneth E. 1985. The Economics of Outdoor Recreation. In Handbook of Natural Resource and Energy Economics, Vol. II, edited by A. V. Kneese and J. L. Sweeney. New York: Elsevier.

Milon, J. Walter. 1991. A Guide to Understand the Economic Impacts of Fisheries Management. GLFC Document.

Morey, Edward R. 1980. Fishery Economics: An Introduction and Review. Natural Resources Journal 20:827-851.

Munro, Gordon R., and Anthony D. Scott. 1985. The Economics of Fisheries Management. In Handbook of Natural Resource and Energy Economics, Vol. II, edited by A. V. Kneese and J. L. Sweeney. New York: Elsevier.

Neher, Philip A. 1990. Natural Resource Economics: Conservation and Exploitation. Cambridge University Press. (Chap. 10,11,12)

Panayotous, Theodore. 1982. Management Concepts for Small-Scale Fisheries: Economic and Social Aspects. FAO Fisheries Technical Paper #228, Rome: FAO.

Pearce, David W., and R. Kerry Turner. 1990. Economics of Natural Resources and the Environment. Baltimore: Johns Hopkins University Press. (Chap. 16,17)

Stevenson, David, Richard Pollnac, and Philip Logan. 1982. A Guide for the Small-Scale Fishery Administrator: Information from the Harvest Sector. ICMRD 81/82-005, University of Rhode Island.

Talhelm, Daniel R. 1988. Economics of Great Lakes Fisheries: A 1985 Assessment. Great Lakes Fishery Commission, Technical Report No. 54.

Talhelm, Daniel R. 1988. The International Great Lakes Sport Fishery of 1980. Great Lakes Fishery Commission, Special Publication 88-4.

Talhelm, Daniel R., R. C. Bishop, K. W. Cox, N. W. Smith, D. N. Steinnes, and A. L. W. Tuomi. 1979. Current Estimates of Great Lakes Fisheries Values: 1979 Status Report. Great Lakes Fishery Commission.

Tietenberg, Tom. 1988. Environmental and Natural Resource Economics. Second edition. Glenview, Illinois: Scott, Foresman and Co. (Chap. 12)

Waugh, Geoffrey. 1984. Fisheries Management: Theoretical Developments and Contemporary Applications. Boulder, Colorado: Westview Press.

Wilen, James E. Bioeconomics of Renewable Resource Use. 1985. In Handbook of Natural Resource and Energy Economics, Vol. I, edited by A. V. Kneese and J. L. Sweeney. New York: Elsevier.

Table 2.1

ALLOCATION OF LAND

USE PATTERN	WHEAT(tons)	ALFALFA(tons)	TOTAL REVENUE	PROFIT
1	0	4800	$ 840,000	$ 25,000
2	1000	4500	$ 987,500	$172,500
3	1900	4100	$1,097,500	$282,500
4	2700	3600	$1,170,000	$355,000
5	3400	3000	$1,205,000	$390,000
6	4000	2300	$1,202,500	$387,500
7	4500	1500	$1,162,500	$347,500
8	4900	650	$1,093,750	$278,750
9	5200	0	$1,040,000	$225,000

PRICE WHEAT $200
PRICE ALFALFA $175

OPPORTUNITY COSTS

Value of Land if Leased to Developer	$400,000
Jean's Current Salary	$ 65,000
Fee	$350,000
Total	$815,000

Table 2.2

ALLOCATION OF FUNDS FOR INPUTS

ALFALFA(tons)	CONTRACT COST	RETURN	WHEAT(tons)	CONTRACT COST	RETURN
2025	$ 25,000	$329,375	100	$ 25,000	($ 5,000)
2250	$ 50,000	$343,750	400	$ 50,000	$ 30,000
2450	$ 75,000	$353,750	800	$ 75,000	$ 85,000
2625	$100,000	$359,375	1600	$100,000	$220,000
2775	$125,000	$360,625	2300	$125,000	$335,000
2900	$150,000	$357,500	2900	$150,000	$430,000
* 3000	$175,000	$350,000	* 3400	$175,000	$505,000
3075	$200,000	$338,125	3800	$200,000	$560,000
3125	$225,000	$321,875	4100	$225,000	$595,000
3150	$250,000	$301,250	4300	$250,000	$610,000
3165	$275,000	$278,875	4400	$275,000	$605,000

MAXIMUM RETURN OVER CONTRACT COSTS

ALFALFA $360,625
WHEAT $610,000

OTHER COSTS

RENT $400,000
WAGES $ 65,000

PROFIT $505,625

CONTRACTING COSTS

ALFALFA $125,000
WHEAT $250,000

TOTAL CONTRACTING COSTS $375,000

Table 2.3

ALLOCATION OF LAND AND FUNDS FOR INPUTS

USE PATTERN	WHEAT(tons)	ALFALFA(tons)	TOTAL REVENUE	CONTRACT	OTHER COST	RETURN
1	0	4525	$ 791,875	$200,000	$465,000	$126,875
2	1000	4325	$ 956,875	$225,000	$465,000	$266,875
3	2200	3975	$1,135,625	$325,000	$465,000	$345,625
4	3300	3475	$1,268,125	$350,000	$465,000	$453,125
5	4300	2775	$1,345,625	$375,000	$465,000	$505,625
6	5200	1975	$1,385,625	$400,000	$465,000	$520,625
7	5650	1075	$1,318,125	$425,000	$465,000	$428,125
8	5850	400	$1,240,000	$400,000	$465,000	$375,000
9	5950	0	$1,190,000	$375,000	$465,000	$350,000

Table 2.4

INSECTICIDE PROBLEM

	WHEAT(tons)	ALFALFA(tons)	TOTAL REVENUE	CONTRACT	OTHER COST	RETURN
BEFORE	5200	1975	$1,385,625	$400,000	$465,000	$520,625
W/REDUCTION	5200	1580	$1,316,500	$400,000	$465,000	$451,500
OPTIONS	5199	1650	$1,328,550	$405,000	$465,000	$458,550
AT $5,000	5198	1700	$1,337,100	$410,000	$465,000	$462,100
PER DOSE	5197	1740	$1,343,900	$415,000	$465,000	$463,900
	5196	1720	$1,340,200	$420,000	$465,000	$455,200
	5195	1730	$1,341,750	$425,000	$465,000	$451,750

Table 2.5

INVESTMENT ANALYSIS ON DAM

	WHEAT(tons)	ALFALFA(tons)	TOTAL REVENUE	CONTRACT	OTHER COST	RETURN
NO DAM	5197	1740	$1,343,900	$415,000	$465,000	$463,900
WITH DAM	5716.7	2001	$1,493,515	$365,000	$465,000	$663,515

YEAR	NPV $3,956,189 WITH DAM	NPV $3,528,460 WITHOUT DAM
1	($536,100)	$463,900
2	$663,515	$463,900
3	$663,515	$463,900
4	$663,515	$463,900
5	$663,515	$463,900
6	$663,515	$463,900
7	$663,515	$463,900
8	$663,515	$463,900
9	$663,515	$463,900
10	$663,515	$463,900
11	$663,515	$463,900
12	$663,515	$463,900
13	$663,515	$463,900
14	$663,515	$463,900
15	$663,515	$463,900

Table 2.6

INVESTMENT ANALYSIS ON OUTPUT ENHANCEMENT

	WHEAT(tons)	ALFALFA(tons	TOTAL REVENUE	CONTRACT	OTHER COST	RETURN
CURRENT	5716.7	2001	$1,493,515	$365,000	$465,000	$663,515
Year 1 with enhancement	6500	2250	$1,693,750	$500,000	$465,000	$728,750
Year 2 with enhancement	6500	2250	$1,693,750	$500,000	$465,000	$728,750
Year 3 with enhancement	6400	2200	$1,665,000	$500,000	$465,000	$700,000
Year 4 with enhancement	6300	2150	$1,636,250	$500,000	$465,000	$671,250
Year 5 with enhancement	6200	2100	$1,607,500	$500,000	$465,000	$642,500
Year 6 with enhancement	6200	2100	$1,607,500	$500,000	$465,000	$642,500
Year 7 with enhancement	6200	2100	$1,607,500	$500,000	$465,000	$642,500
Year 8 with enhancement	6200	2100	$1,607,500	$500,000	$465,000	$642,500
Year 9 with enhancement	5500	1650	$1,388,750	$525,000	$465,000	$398,750
Year 10 with enhancement	4200	1500	$1,102,500	$625,000	$465,000	$ 12,500
Year 11 with enhancement	4200	1500	$1,102,500	$625,000	$465,000	$ 12,500
Year 12 with enhancement	4200	1500	$1,102,500	$625,000	$465,000	$ 12,500
Year 13 with enhancement	4200	1500	$1,102,500	$625,000	$465,000	$ 12,500
Year 14 with enhancement	4200	1500	$1,102,500	$625,000	$465,000	$ 12,500
Year 15 with enhancement	4200	1500	$1,102,500	$625,000	$465,000	$ 12,500

NET PRESENT VALUE
WITHOUT ENHANCEMENT
$3,956,189

NET PRESENT VALUE
WITH ENHANCEMENT
$3,832,415

Table 2.7

COMPENSATION FOR OIL SPILL

	Year	WHEAT (tons)	ALFALFA (tons)	TOTAL REVENUE	CONTRACT	OTHER COST	REHABILITATION COST	NET RETURN
WITH NO DAMAGE	1	5716.7	2001	$1,493,515	$365,000	$465,000		$663,515
	2	5716.7	2001	$1,493,515	$365,000	$465,000		$663,515
	3	5716.7	2001	$1,493,515	$365,000	$465,000		$663,515
	4	5716.7	2001	$1,493,515	$365,000	$465,000		$663,515
NATURAL RECOVERY	1	4000	1000	$ 975,000	$300,000	$465,000		$210,000
	2	4200	1200	$1,050,000	$320,000	$465,000		$265,000
	3	4800	1600	$1,240,000	$340,000	$465,000		$435,000
	4	5716.7	2001	$1,493,515	$365,000	$465,000		$663,515
REHABILITATION RECOVERY	1	4300	1200	$1,070,000	$325,000	$465,000	$75,000	$205,000
	2	4900	1700	$1,277,500	$345,000	$465,000	$50,000	$417,500
	3	5716.7	2001	$1,493,515	$365,000	$465,000		$663,515
	4	5716.7	2001	$1,493,515	$365,000	$465,000		$663,515

NPV NO DAMAGE	$2,103,253
NPV NATURAL RECOVER	$1,189,929
NPV DAMAGE	$ 913,324
COMPENSATION: DAMAGES	$ 913,324
NPV REHABILITATION	$1,483,103
NPV DAMAGE	$ 620,150
NPV REHABILITATION COSTS	$ 109,504
COMPENSATION: DAMAGES AND REHABILITATION COSTS	$ 729,654

Table 2.8

EFFECTS OF EMPLOYMENT

FARM PRODUCTION

	EMPLOY-MENT	WHEAT	ALFALFA	TOTAL REVENUE	CONTRACT	OTHER COSTS	EXTRA EMPLOY-MENT COSTS	RETURN
A	15	5716.7	2001	$1,493,515	$365,000	$465,000		$663,515
B	27	5750	2020	$1,503,500	$365,000	$465,000	$60,000	$613,500

CHANGE IN RETURN TO FARM ($50,015)

CITY PRODUCTION

	EMPLOY-MENT	LABOR COSTS	RETURNS
A	50	$250,000	$4,000,000
B	38	$190,000	$3,940,000

CHANGE IN GROSS REVENUE TO FARM	$ 9,985
CHANGE IN VALUE OF OUTPUT IN CITY	($60,000)
NET CHANGE OF VALUE OF OUTPUT IN CITY AND FARM	($50,015)

Table 2.9a

OPEN-ACCESS RASPBERRY PATCH

PRICE = $ 20

WEEKLY WAGE = $360

WORKERS	CASES	MARGINAL PRODUCT	TOTAL REVENUE	MARGINAL REVENUE	AVERAGE REVENUE	NET RETURN
1	25	25	$ 500	$500	$500	$140
2	48	23	$ 960	$460	$480	$240
3	69	21	$1,380	$420	$460	$300
4	88	19	$1,760	$380	$440	$320
5	105	17	$2,100	$340	$420	$300
6	120	15	$2,400	$300	$400	$240
7	133	13	$2,660	$260	$380	$140
8	144	11	$2,880	$220	$360	$ 0
9	153	9	$3,060	$180	$340	($180)
10	160	7	$3,200	$140	$320	($400)

Table 2.9b

OPEN-ACESSS RASPBERRY PATCH

PRICE = $ 20

WEEKLY WAGE = $360

WORKERS	CASES	MARGINAL PRODUCT	TOTAL REVENUE	MARGINAL REVENUE	AVERAGE REVENUE	NET RETURN
1	30	30	$ 600	$600	$600	$240
2	58	28	$1,160	$560	$580	$440
3	84	26	$1,680	$520	$560	$600
4	108	24	$2,160	$480	$540	$720
5	130	22	$2,600	$440	$520	$800
6	150	20	$3,000	$400	$500	$840
7	167	17	$3,340	$340	$477	$820
8	182	15	$3,640	$300	$455	$760
9	195	13	$3,900	$260	$433	$660
10	206	11	$4,120	$220	$412	$520
11	215	9	$4,300	$180	$391	$340
12	222	7	$4,440	$140	$370	$120
13	227	5	$4,540	$100	$349	($140)

RETURN AT 6 WORKERS	$840
COST OF ONE CULTIVATOR	$360
NET RETURN	$480

Table 3.1

ECONOMIC ANALYSIS OF FISHERIES

EFFORT	COST	OUTPUT IN ESCHALOT FISHERY (tons)	OUTPUT IN RHODOLITE FISHERY (tons)	NET RETURNS ESCHALOT FISHERY	NET RETURNS RHODOLITE FISHERY
1	$ 35,000	100	170	$ 8,000	$44,900
2	$ 70,000	200	260	$16,000	$52,200
3	$105,000	290	340	$19,700	$54,800
4	$140,000	370	410	$19,100	$52,700
5	$175,000	440	470	$14,200	$45,900
6	$210,000	500	520	$ 5,000	$34,400
7	$245,000	550	560	($ 8,500)	$18,200
8	$280,000	590	590	($26,300)	($ 2,700)
9	$315,000	620	610	($48,400)	($28,300)
10	$350,000	640	620	($74,800)	($58,600)

	SUM OF MAXIMUM VALUES	$74,500	MAXIMUM VALUE	$19,700	$54,800
-	SUM OF OPEN ACCESS VALUES	$23,200	OPEN ACCESS VALUE	$ 5,000	$18,200
	POTENTIAL GAINS	$51,300			

Table 3.2

ALLOCATION OF RESOURCE BASE

ALLOCATION	OUTPUT OF ESCHALOT FISHERY (tons)	OUTPUT OF RHODOLITE FISHERY (tons)	GROSS RETURNS
1	405	695	$500,800
2	530	620	$519,300
3	630	520	$515,300
4	705	395	$488,800
5	755	245	$439,800
6	780	70	$368,300

PRICE ESCHALOT FISH $430/ton
PRICE RHODOLITE FISH $470/ton

Table 3.3

ECONOMIC ANALYSIS OF FISHERIES: A SECOND LOOK

EFFORT	COST	OUTPUT OF ESCHALOT FISHERY (tons)	OUTPUT OF RHODOLITE FISHERY (tons)	NET RETURNS ESCHALOT FISHERY	NET RETURNS RHODOLITE FISHERY
1	$ 35,000	130	200	$20,900	$59,000
2	$ 70,000	230	290	$28,900	$66,300
3	$105,000	320	370	$32,600 *	* $68,900
4	$140,000	400	440	$32,000	$66,800
5	$175,000	470	500	$27,100	$60,000
6	$210,000	530	550	$17,900	$48,500
7	$245,000	580	590	$ 4,400	$32,300
8	$280,000	620	620	($13,400)	$11,400
9	$315,000	650	640	($35,500)	($14,200)
10	$350,000	670	650	($61,900)	($44,500)
				Maximum Potential Value for Eschalot Fishery $32,600	**Maximum Potential Value for Rhodolite Fishery $68,900**

Table 3.4

ALLOCATION OF RESOURCE BASE WITH FISHERIES MANAGEMENT

	ESCHALOT NET RETURNS	**RHODOLITE NET RETURNS**	**TOTAL NET RETURNS**
1	$ 8,200	$75,000	$ 83,200
2	$32,600	$68,900	$101,500
3	$60,000	$52,000	$112,000
4	$70,000	$35,000	$105,000
5	$75,000	$27,000	$102,000
6	$78,000	$14,000	$ 92,000

MAXIMUM NET POTENTIAL RETURNS	$112,000
RETURNS WITH NO AGENCY	$ 23,200
POTENTIAL GAINS	$ 88,800

Table 3.5

ALLOCATION OF BUDGET

NET RETURNS ESCHALOT FISH	BUDGET	AGENCY RETURNS	MARGINAL AGENCY NET RETURNS
$35,500	$ 5,000	$25,500	$25,500
$43,000	$10,000	$28,000	$ 2,500
** $49,500	$15,000	$29,500	$ 1,500
$55,250	$20,000	$30,250	$ 750
* $60,000	$25,000	$30,000	($ 250)
$64,500	$30,000	$29,500	($ 500)
$68,500	$35,000	$28,500	($ 1,000)
$72,000	$40,000	$27,000	($ 1,500)
$75,000	$45,000	$25,000	($ 2,000)
$77,000	$50,000	$22,000	($ 3,000)

NET RETURNS RHODOLITE FISH	BUDGET	AGENCY RETURNS	MARGINAL AGENCY NET RETURNS
$12,000	$ 5,000	($11,200)	($11,200)
$23,500	$10,000	($ 4,700)	$ 6,500
$34,000	$15,000	$ 800	$ 5,500
$43,500	$20,000	$ 5,300	$ 4,500
* $52,000	$25,000	$ 8,800	$ 3,500
$59,500	$30,000	$11,300	$ 2,500
** $66,000	$35,000	$12,800	$ 1,500
$71,500	$40,000	$13,300	$ 500
$76,000	$45,000	$12,800	($ 500)
$79,500	$50,000	$11,300	($ 1,500)

Table 3.6

NET BENEFITS OF AGENCY

EFFORT	COST	ESCHALOT	RHODOLITE	NET RETURNS ESCHALOT	NET RETURNS RHODOLITE
1	$ 35,000	169	194	$37,670	$56,180
2	$ 70,000	269	284	$45,670	$63,480
3	$105,000	359	364	* $49,370	* $66,080
4	$140,000	439	434	$48,770	$63,980
5	$175,000	509	494	$43,870	$57,180
6	$210,000	569	544	$34,670	$45,680
7	$245,000	619	584	$21,170	$29,480
8	$280,000	659	614	$ 3,370	$ 8,580
9	$315,000	689	634	($18,730)	($17,020)
10	$350,000	709	644	($45,130)	($47,320)

MAXIMUM VALUE OF ESCHALOT FISHERY $49,370	MAXIMUM VALUE OF RHODOLITE FISHERY $66,080

NET AGENCY RETURNS WITH OPEN ACCESS		NET AGENCY RETURNS WITH EFFORT CONTROL	
OPEN ACCESS RETURNS	$11,950	CONTROLLED ACCESS RETURNS	$115,450
- RETURNS WITH NO AGENCY	$23,200	- RETURNS WITH NO AGENCY	$ 23,200
INCREASE DUE TO AGENCY	($11,250)	INCREASE DUE TO AGENCY	$ 92,250
- AGENCY BUDGET	$50,000	- AGENCY BUDGET	$ 50,000
- ENFORCEMENT BUDGET		- ENFORCEMENT BUDGET	$ 20,000
NET ECONOMIC BENEFIT OF AGENCY	($61,250)	NET ECONOMIC BENEFIT OF AGENCY	$ 22,250

Table 3.7

NET VALUE OF ESCHALOT FISHERY WITH RECREATIONAL QUOTAS

	COST OF EFFORT	OUTPUT OF ESCHALOT FISHERY (tons)	NET RETURNS ESCHALOT FISHERY	OUTPUT AND RETURNS WHEN RECREATIONAL QUOTA is 100 tons		OUTPUT AND RETURNS WHEN RECREATIONAL QUOTA is 200 tons		OUTPUT AND RETURNS WHEN RECREATIONAL QUOTA is 300 tons	
1	$ 35,000	169	$37,670	160	$33,800	150	$29,500	140	$25,200
2	$ 70,000	269	$45,670	260	$41,800	250	$37,500	230	* $28,900
3	$105,000	359	* $49,370	350	* $45,000	340	* $41,200	310	$28,300
4	$140,000	439	$48,770	430	$44,900	420	$40,600	380	$23,400
5	$175,000	509	$43,870	500	$40,000	490	$35,700	440	$14,200
6	$210,000	569	$34,670	560	$30,800	550	$26,500	490	$ 700
7	$245,000	619	$21,170	610	$17,300	600	$13,000	530	($17,100)
8	$280,000	659	$ 3,370	650	($ 500)	640	($ 4,800)	560	($39,200)
9	$315,000	689	($18,730)	680	($22,600)	670	($26,900)	580	($65,600)
10	$350,000	709	($45,130)	700	($49,000)	690	($53,300)	590	($96,300)

MAXIMUM NET VALUE	$49,370	$45,500	$41,200	$28,900
TOTAL COST OF RECREATIONAL QUOTA		$ 3,870	$ 8,170	$20,470
MARGINAL COST OF RECREATIONAL QUOTA		$ 3,870	$ 4,300	$12,300

Table 3.8

VALUATION OF RECREATIONAL FISHING

1	2	3	4	5	6	7	8	9	10
BAG LIMIT	DAYS FISHED PER YEAR	ANNUAL BENEFIT	CATCH PER PARTICIPANT	# OF PARTICIPANTS WHEN QUOTA is 100 tons	GROSS BENEFIT	# OF PARTICIPANTS WHEN QUOTA is 200 tons	GROSS BENEFIT	# OF PARTICIPANTS WHEN QUOTA is 300 tons	GROSS BENEFIT
15	3.87	$2.39	58.09	3443	$ 8,145	6885	$16,120	10328	$23,925
14	3.74	$2.35	52.38	3818	$ 8,877	7636	$17,549	11454	$26,014
13	3.61	$2.26	46.87	4267	$ 9,521	8534	$18,796	12801	$27,823
12	3.46	$2.12	41.57	4811	$10,072	9623	$19,848	14434	$29,330
11	3.32	$1.95	36.48	5482	$10,520	10964	$20,689	16446	$30,505
10	3.16	$1.75	31.62	6325	$10,858	12649	$21,296	18974	$31,314
9	3.00	$1.53	27.00	7407	$11,073	14815	$21,643	22222*	$31,710*
8	2.83	$1.30	22.63	8839*	$11,151*	17678*	$21,695*	26517	$31,632
7	2.65	$1.06	18.52	10799	$11,072	21598	$21,403	32397	$30,992
6	2.45	$0.83	14.70	13608	$10,808	27217	$20,695	40825	$29,663
5	2.24	$0.61	11.18	17889	$10,316	35777	$19,462	53666	$27,437
4	2.00	$0.41	8.00	25000	$ 9,528	50000	$17,510	75000	$23,948
3	1.73	$0.24	5.20	38490	$ 8,311	76980	$14,453	115470	$18,424
2	1.41	$0.11	2.83	70711	$ 6,351	141421	$ 9,282	212132	$ 8,793
1	1.00	$0.03	1.00	200000	$ 2,390	400000	($2,390)	600000	($14,340

MAXIMUM TOTAL BENEFITS	$11,151	$21,695	$31,710
MARGINAL BENEFIT	$11,151	$10,544	$10,015

Table 3.9

MULTIPLE USE MANAGEMENT

RECREATIONAL QUOTA	NET BENEFIT TO RECREATIONAL	NET BENEFIT TO COMMERCIAL	TOTAL
0	$0	$49,370	$ 49,370
100	$11,151	$45,500	$ 56,651
200	$21,695	$41,200	* $ 62,895
300	$31,710	$28,900	$ 60,610

NET RETURNS TO ESCHALOT FISHERY	$ 62,895
NET RETURNS TO RHODOLITE FISHERY (from Table 3.6)	$ 66,080
OPEN-ACCESS RETURNS WITH NO AGENCY	-$ 23,200
INCREASE DUE TO AGENCY	$105,775
AGENCY BUDGET	-$ 50,000
COMMERCIAL ENFORCEMENT	-$ 20,000
RECREATIONAL ENFORCEMENT	-$ 7,000
NET ECONOMIC BENEFIT OF AGENCY	$ 28,775

Table 3.10a

ANALYSIS OF CONTROL PROGRAMS

	BEFORE	WITH LAMPREY	$5,000 SPENT ON CONTROL	$10,000 SPENT ON CONTROL	$15,000 SPENT ON CONTROL	$20,000 SPENT ON CONTROL
NET RETURNS TO ESCHALOT FISHERY	$ 62,895	$31,448	$43,448	$ 52,448	$ 58,448	$ 60,448
NET RETURNS TO RHODOLITE FISHERY	$ 66,080	$52,864	$58,864	$ 61,864	$ 64,364	$ 65,364
RETURNS WITH NO AGENCY	$ 23,200	$11,600	$11,600	$ 11,600	$ 11,600	$ 11,600
INCREASE DUE TO AGENCY	$105,775	$72,712	$90,712	$102,712	$111,212	$114,212
AGENCY BUDGET	$ 50,000	$50,000	$55,000	$ 60,000	$ 65,000	$ 70,000
COMMERCIAL ENFORCEMENT	$ 20,000	$20,000	$20,000	$ 20,000	$ 20,000	$ 20,000
RECREATIONAL ENFORCEMENT	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000
NET ECONOMIC BENEFIT/AGENCY	$ 28,775	($ 4,288)	$ 8,712	$ 15,712	$ 19,212	$ 17,212

REDUCTION IN OTHER ACTIVITIES TO PAY FOR CONTROL

Table 3.10b

ESCHALOT -BUDGET LOSS +CONTROL	$ 31,448 ($ 4,500) $ 11,000	$ 31,448 ($ 9,500) $ 19,500	$ 31,448 ($ 15,500) $ 25,000	$ 31,448 ($ 21,000) $ 26,500
RHODOLITE -BUDGET LOSS +CONTROL	$ 52,864 ($ 1,000) $ 5,500	$ 52,864 ($ 2,500) $ 8,000	$ 52,864 ($ 4,500) $ 10,000	$ 52,864 ($ 7,500) $ 10,500
NET ECONOMIC BENEFIT OF AGENCY	$ 6,712	$ 11,212	$ 10,712	$ 4,212

Table 3.11

BENEFITS OF DAM CONSTRUCTION

	1	2	3	4	5
	WITHOUT DAM	**YEAR 1 WITH DAM**	**YEAR 2 WITH DAM**	**YEAR 3 WITH DAM**	**YEAR 4 WITH DAM**
NET RETURNS TO ESCHALOT	$ 58,448	$46,758	$42,082	$50,499	$ 70,698
NET RETURNS TO RHODOLITE	$ 64,364	$51,491	$46,342	$55,610	$ 77,855
RETURNS WITH NO AGENCY	$ 11,600	$11,600	$11,600	$11,600	$ 11,600
INCREASE DUE TO AGENCY	$111,212	$86,649	$76,824	$94,509	$136,953
AGENCY BUDGET	$ 65,000	$65,000	$65,000	$65,000	$ 65,000
COMMERCIAL ENFORCEMENT	$ 20,000	$20,000	$20,000	$20,000	$ 20,000
RECREATIONAL ENFORCEMENT	$ 7,000	$ 7,000	$ 7,000	$ 7,000	$ 7,000
NET ECONOMIC BENEFIT/AGENCY	$ 19,212	($ 5,351)	($15,176)	$ 2,509	$ 44,953

CHANGE IN BENEFITS

	Without Dam	With Dam	Net Change
Year 1	$19,212	-$ 5,351	($24,562)
Year 2	$19,212	-$15,176	($34,387)
Year 3	$19,212	$ 2,509	($16,702)
Years 4-20	$19,212	$44,953	$25,741

PRESENT VALUE OF CHANGE IN BENEFITS $91,838

Table 3.12

ECONOMIC VALUATION OF FISH KILL

YEAR	NET RETURN OF ESCHALOT FISHERY	NET RETURN OF RHODOLITE FISHERY	TOTAL NET RETURN	TOTAL AGENCY COSTS	REHABILITATION COSTS	VALUE AT OPEN ACCESS	NET ECONOMIC BENEFIT OF AGENCY
WITHOUT FISH KILL							
1 to 5	$70,698	$77,855	$148,553	$92,000		$11,600	$44,953
NATURAL RECOVERY							
1	$28,279	$46,713	$ 74,992	$78,200		$ 6,460	($ 9,668)
2	$38,884	$54,498	$ 93,382	$81,650		$ 7,745	$ 3,987
3	$49,489	$62,284	$111,773	$85,100		$ 9,030	$17,643
4	$60,094	$70,069	$130,163	$88,550		$10,315	$31,298
5	$70,698	$77,855	$148,553	$92,000		$11,600	$44,953
REHABILITATION RECOVERY							
1	$28,279	$46,713	$ 74,992	$78,200	$0	$ 6,460	($ 9,668)
2	$40,519	$54,808	$ 95,328	$82,800	$12,000	$ 7,745	$ 4,783
3	$52,760	$62,904	$115,664	$87,400	$20,000	$ 9,030	$19,234
4	$65,000	$71,000	$136,000	$92,000	$ 8,000	$10,315	$33,685
5	$70,855	$77,855	$148,553	$92,000	$0	$11,600	$44,953

<u>EVALUATION OF NATURAL RECOVERY</u>

NPV WITHOUT KILL	$170,407
NPV NATURAL RECOVERY	$ 57,050
NPV OF DAMAGES	$113,357

<u>EVALUATION OF REHABILITATION RECOVERY</u>

NPV WITHOUT KILL	$170,407
NPV REHABILITATION RECOVERY	$ 60,534
NPV OF DAMAGES	$109,873
NPV OF REHABILITATION COSTS	$ 30,408
TOTAL COST	$140,281