AN INTRODUCTION TO ECONOMIC VALUATION PRINCIPLES FOR FISHERIES MANAGEMENT

Great Lakes Fishery Commission

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TABLE OF CONTENTS

PREFACE

The work presented in this publication was produced as part of the Economic Value Task Group of the Board of Technical Experts (BOTE) of the Great Lakes Fishery Commission. 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 readers 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.

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ABSTRACT. Fisheries-management agencies can use traditional economic principles and economic valuation to devise and implement fishery-management policies. A private individual managing agricultural resources and output within the context of fanning is analogous to the resource manager managing the commercial- and recreational-fishery harvest. Through application of basic economic concepts, the fisheries manager has control over the living resources in his jurisdiction. The fisheries manager will, therefore, possess the necessary understanding of current economic concepts and principles to determine for the current year and 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.

INTRODUCTION

The purpose of this volume is to explain for the noneconomist:

- how economic values are derived,

- how economic values are frequently misinterpreted in the policy area, and

- how economic values can be correctly used to devise and implement fishery-management policies.

This isn't 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 of what economics is about that are, to be blunt, incorrect. Certain ideas will have to be dispelled before, or concurrently with, the introduction of others.

This isn't the first document that 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 Edwards (199 1). It isn't even the fast one prepared by the Great Lakes Fishery Commission (Talhelm 1985). Other similar studies and more-advanced references are listed in the references. This publication is different, however.

The earlier reports are well prepared and useful-all get generally good grades from professional economists. These documents explain most of the topics and issues that 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 the previous works, but to do it in a slightly different manner. The other documents had preliminary chapters on definitions of values and on how they are related to demand and supply curves. Later chapters showed how these principles could be used to provide useful information to decision makers. However, in some instances, short lessons in economics don't 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. Instead, the approach here is to look at the basic problems facing resource managers and show how economic principles and economic valuation can *help* solve the problems. In the course of the presentation, all of the concepts normally introduced in an economics chapter are 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 isn't the purpose here to evaluate the biological, anthropological, or 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. It 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 section (Part I-Resource Management: Farming) doesn't focus on 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 instead of commercial and recreational harvest. The discussion will:

- focus on the role of farmers as resource managers, and

- cover the necessary economic concepts in terms of the short- and long-term decisions they must face.

A separate section (Part II-Resource Management: Fisheries) discusses how the economic concepts can be applied to fisheries-management decisions. There is a degree of repetition, but this is often useful in explaining new and complex issues. Although it is true that the problems of private individuals operating farms for their own benefit won't be the same as those of agency heads managing public resources for the public good, they are analogous in enough ways to make the comparison interesting. The differences will also be illuminating.

Stated briefly, the justification for the comparison is that farmers and fishery-agencies have certain inputs or assets under their control and both have to make decisions about how they can or should be used. Although 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 publication is to explain the rationale for an economic approach, and it is hoped that this comparison will be a useful aid in telling the story.

Farming

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, and so on. The farmer also has control over other assets such as labor, machinery, and fertilizer either through ownership or the ability to purchase them on the market. The amounts of these other inputs that can be used are limited by the farmer's current cash reserves and the ability to borrow.

Faced with a given amount and quality of land, the role of the farmer is to decide:

- 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 farmer must also 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 used most often to determine if these decisions are made correctly is the net income that is earned over the year. 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 during that period because there isn't enough time left to cultivate all of the acreage. However, future production may be increased because of a reduction in flood damage. As another example, intensive cultivation in the present may increase yields temporarily, but production may fall off in the future if the intensive culture damages soil productivity.

Fisheries

In a similar way, a fisheries manager has control over the use of living resources with unique features, such as:

- natural productivities,
- interspecies relationships,
- desirability as a source of food or recreational catch, and
- accessibility to users.

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 can't increase its current expenditures by borrowing as the farmer can.

Faced with the nature of the resources, limited amounts of other inputs that can be used to control the use of the fish stocks, and 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 the outputs and activities should (or will) be produced,
- how much of each output and activity should be produced, and
- in some instances, for whom the outputs and activities will be produced or who will produce them.

Differences Between Farm and Fisheries Management

Except for the way in which other inputs are obtained and the necessity for the manager to answer "for whom" questions, it can be argued 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 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 aren't commercial enterprises, the net value of the production from the resources and inputs under their control is also one measure of successful operation. Although 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.

Another difference is that the net income of a farmer comes only from goods and services sold on a formal market. A flow of dollars corresponds to the value of the output produced. This isn't the case for fisheries agencies, however. Some of the goods they produce and some of the services they perform aren't matched by a flow of dollars from the consumer. For example, individuals don't always purchase recreational fishing on the market. They simply proceed to the water and begin to fish. This activity is valuable, however, 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 operation of a management agency.

Summary

Before beginning the discussions, I ask the reader to bear in mind the natural limitations in undertaking this endeavor.

1) The examples used in this publication will have to be very simple and must ignore many of the niceties of the situation. The numbers will be rigid to make computations more simple.

2) 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.

3) The ease with which accuracy can be obtained and analyzed is treated rather cavalierly. In many instances, fisheries managers won't 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 those who wish to save some reading time), it is possible to start with Part II-Resource Management: Fisheries. Each section in Part I-Resource Management: Farming relates to a section of Part II-Resource Management: Fisheries. Detailed explanations of economic concepts are introduced in Part I (Farming).

PART I - RESOURCE MANAGEMENT: FARMING
ECONOMIC VALUATION AND FARMING

Introduction

The purpose of this section 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 a farmer named Jean and a contractor he has hired to advise him. The analysis is static at first, but as economic concepts are introduced, dynamic considerations are also introduced. Discussion is divided into discrete segments, each of which will introduce concepts with direct relevance to the economics of fisheries management and utilization. The discrete segments presented in Part I-Resource Management: Farming are:

- Economic Concepts
- Case Study
- Case Study Summary
- Review of the Economic Concepts
- Application to Fisheries Management
- Additional Discussion

It will be shown that-in spite of fundamental differences in the two types of organizations-the farmer and the fishery manager face the same kinds of problems and can use similar approaches to solving them.

What to Produce? A Preliminary Look

Economic Concepts:

- *Understanding and using the concept of opportunity cost.*
- *The necessity of choice when deciding what to produce.*
- *The potential for using net value as a criterion for making choices.*

Case Study:

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 made Jean the sole beneficiary of his will. The principal asset was a farm. The news put Jean in a bit of turmoil. Jean had been considering a change in career, and he wasn't 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 farming 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 with an offer of assistance. The contractor would provide the necessary labor, seed, fertilizer, and other inputs. The contractor would also provide the capital equipment to prepare the land, plant the seeds, and harvest the product for whatever kind of an operation Jean wanted. Exactly what was to be produced and how it would be produced would be decided between them. An annual operation fee would be established.

From the beginning, 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/yr in his present employment. He had already received an offer of $400,000/yr 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/yr to match the opportunities for himself and his land to earn income elsewhere. He wasn't prepared to be dogmatic about income. However, he felt that if his income was less than this, he would require something else to make up the difference.

The farm had been inactive 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 didn't know where on the land each had been planted. To get the ball rolling, Jean asked his 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 was received from the land depended to a large degree on what was put into it. Yields weren't only determined by the natural fertility of the land and the expected amount of rainfall. Yield was also determined by other factors; for example, types of seeds used, cultivation procedures, and so forth. It was agreed that a study should be undertaken under the assumption that the contractor would have $350,000 to spend on crop production. The $350,000 figure was based on average costs per hectare at other nearby farms.

The contractor's initial report is summarized in Columns l-3 of Table 1. The contractor found-except for two parcels of land-that the rest of the farm was capable of producing either wheat or alfalfa. All of the land wasn't the same in topography, soil moisture, and so on-some of the land was better suited to wheat and the rest was better suited 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 moving south the conditions changed in favor of growing alfalfa. For purposes of analysis, the contractor divided the usable land into eight strips. If all eight strips of land were used to produce alfalfa (given the allowable contracting costs), the expected production would be 4,800 t. However, if all eight strips of land were used to produce wheat, the expected output would be 5,200 t. These two land-use patterns are described in Rows 1 and 9 in Table 1. Land-Use Pattern 2 shows what would happen to expected production if the most-northern strip of land was used to produce wheat instead of alfalfa-remember, this is the strip of land best suited to wheat. By changing land-use patterns from 1 to 2, alfalfa production wouldn't fall very much (the land isn't well suited for growing alfalfa), but 1,000 t of wheat would be produced.

Table 1. Contractor’s initial report on total revenue and profit from wheat and alfalfa grown under nine different land-use patterns.

Use pattern	Wheat [1] (t)	Alfalfa[2] (T)	Total revenue ($)	Profit[3] ($)
1	0	4,800	840,000	25,000
2	1,000	4,500	987,500	172,500
3	1,900	4,100	1,097,500	282,500
4	2,700	3,600	1,170,000	355,000
5	3,400	3,000	1,205,000	390,000
6	4,000	2,300	1,202,500	387,500
7	4,500	1,500	1,162,500	347,500
8	4,900	650	1,093,750	278,750
9	5,200	0	1,040,000	225,000

1 $200/t.
2 $175/t.
‘Total revenue minus the opportunity costs of land ($400,000), Jean’s salary ($65,000), and contracting fee ($350,000).

Land-Use Patterns 3-8 in Table 1 describe other land-use patterns and show what happens to production as strips of land (moving from north to south) are taken out of alfalfa production and used for wheat production. The production of wheat goes up-but by decreasing amounts-because the land is less and less suited to produce wheat. On the other hand, the fall in alfalfa production becomes larger and larger as the land better suited for that crop is switched to wheat production.

To summarize the information presented in Table 1:

- 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.

The 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:

1) 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.

2) As more of one crop was obtained, the opportunity cost in terms of foregone production of the other was increasing.

However, this technical information wasn't enough for Jean to decide what to produce.

The goal of running a business isn't to maximize the quantity in tonnes 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 didn't 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 tonne 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 Column 4 of Table 1.

Put simply, Jean has a choice of which land-use pattern to use. Economic-value measures can provide criteria for making the choice. The following questions should, therefore, be asked:

- 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 5 yields the highest revenue. To determine which production combination is the best, relative prices are needed-physical output measures aren't enough. In additiona, 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.

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. However, for the change from Land-Use Pattern 5 to 6 this isn't true. Expanding wheat production into the range where the land is better suited to alfalfa means the gain in production of wheat will fall, and 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 wasn't necessarily a permanent thing. It would be incorrect to conclude that the northern four strips of land should always be used for wheat and the southern four strips of land should always be used for alfalfa. A change in the relative prices could mean that a different land-use pattern would yield higher revenues. As an extreme case, if the price of wheat went to $1,000/t, total revenue would be maximized by growing wheat exclusively.

Now that Jean knew which combination of crop production would produce the highest return given existing prices, he needed to find out if this return was worth all the effort. Column 5 shows the net return to the farm for each of the possible land-use patterns. The net return is total revenue less the costs of production. The costs of production include:

- $350,000 given to the contractor to grow the crops,
- $400,000 that could have been earned by leasing the land to the developer, and
- $65,000 that Jean could have earned at his other job.

The last two items are the opportunity cost of Jean's labor and land. The net return for operating with Land-Use Pattern 5 is $390,000.

Upon reflection, Jean concluded that he was coming out $390,000 ahead of the game. He also 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 couldn't 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. Therefore, if his boss was willing to pay him $65,000/yr, the value of his output must be pretty close to that amount. Similarly, if the developer was willing to pay $400,000/yr for Jean's land, the value of the annual output of the project after paying all other costs must be at least $400,000. Also, the contractor would need to hire workers and rent combines and other equipment to plant and harvest the crops. Workers would have to be paid 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 for machinery seems to be a good measure of the value of output produced.

The overall picture, then shows that the value of production on the farm would go up by $1,205,000, but 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, Jean's labor, and inputs used by the contractor could therefore be considered socially justified. However, if the maximum revenue earned by the farm was less than $8 15,000, it could be argued that the resources should be used elsewhere. The value of production would be higher if the farm was sold to the developer, the contractor used his input elsewhere, and Jean went back to his old job.

Case Study Summary:

Jean was pleased with the preliminary analysis. He was able to determine what combination of output would earn him the most money. Furthermore, when that combination of output was produced, he did very well indeed. All of Jean's costs were covered, and he came out with $390,000 more than he would have 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 farming was a good idea. He realized, however, if the prices of wheat and alfalfa were to fall, it would be possible that even using the land-use pattern that maximized revenue wouldn't produce enough dollars to cover all opportunity costs. If he expected that to happen, in terms of income, he would be wise to keep his old job and sell the farm.

Review of the Economic Concepts:

- 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.

- When 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.

- As the production of a particular good increases, the opportunity cost in terms of production reductions elsewhere goes up. This is the concept of increasing marginal cost.

- One criterion for determining which land-use pattern should be used is the maximization of the value of the resulting output.

- Using the land in a manner that maximizes gross revenue is a good start on analyzing the problem, but it is also important to consider opportunity costs. It is necessary to determine if gross revenue is greater than the opportunity cost of the land and other related inputs.

Application to Fisheries Management:

The economic principles and concepts discussed in this section are useful for fisheries-management agencies. However, to anticipate the following:

1) 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.

2) One criterion for determining which combination should be produced is the maximization of the value of output, whether it is the commercial harvest or the recreational harvest.

3) 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.

Additional Discussion

Additional discussion can be found in Part II-Resource Management: Fisheries:

- The Value of Fisheries: Allocation of Natural Resources

- The Value of Recreational- and Commercial-Fishery Production

What to Produce? A More-Detailed Look

Economic Concepts:

- *Marginal analysis to determine marginal value is useful 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.*

Case Study:

Jean was pleased with the possibility of earning an annual net return of $390,000 over and above all costs. However, he wondered if he had considered all possible ways to improve net return. Jean remembered that the contractor stated that what you get out of the land depends on what you put into it. Jean 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. Jean guessed that how he allocated the inputs for the two crops would also affect his gains. Jean questioned the contractor about the $350,000 in growing costs. He learned that, in deriving the material in Land-Use Patterns 2-8 of Table 1, the contractor had based his estimates on the assumption that exactly half of the allotted money would be spent on each crop.

Jean asked the contractor to estimate how production would change (using Land-Use Pattern 5) if the money spent on inputs was allocated in different ways for the two crops. The results are given in Table 2. The left half (the first three columns) shows how alfalfa production varies with the dollar amount of inputs used in its production. The right half (the last three columns) shows the same thing for wheat production. The asterisks indicate the allocation of input funds used in Table 1. There are 3,000 t of alfalfa and 3,400 t of wheat grown when each crop has $175,000 spent on its production. At this point, the return over contracting costs for each of the two crops is $350,000 and $505,000, respectively. The sum of the returns over contracting costs ($855,000) less the opportunity rent and wages of $465,000, equals the net return of $390,000 (which is the figure derived above).

Table 2. The effects from varying contracting costs on alfalfa and wheat on net returns,

Alfalfa (t)	Contract cost ($)	Return ($)	Wheat (t)	Contract cost ($)	Return ($)
2,025	25,000	329,375	100	25,000	(5,000)
2,250	50,000	343,750	400	50,000	30,000
2,450	75,000	353,750	800	75,000	85,000
2,625	100,000	359,375	1,600	100,000	220,000
2,775	125,000	360,625	2,300	125,000	335,000
2,900	150,000	357,500	2,900	150,000	430,000
3,000’	175,000	350,000	3,400’	175,000	505,000
3,075	200,000	338,125	3,800	200,000	560,000
3,125	225,000	321,875	4,100	225,000	595,000
3,150	250,000	301,250	4,300	250,000	610,000
3,165	275,000	278,875	4,400	275,000	605,000

*Allocation of contract cost in Table 1.

After studying the information presented in Table 2, 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. A reduction of $50,000 would reduce production from 3,000 t to 2,775 t. However, the market value of the lost 225 t is only $39,375, which means the return over growing cost increases by $10,625.

For wheat, on the other hand, the return over contracting costs would increase to $250,000 if growing costs were increased by $75,000. Production of wheat would increase by 900 t (at a market price of $200/t), which would increase revenues by $180,000. The return over contracting costs would, therefore, increase by $105,000- to $6 10,000.

Using the preceding logic, Jean realized that he should decrease alfalfa expenditures by $50,000 and increase wheat expenditures 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 $505,625. This increase in profits of $115,625 is the sum of the increase in returns over contracting costs to alfalfa ($10,625) and to wheat ($105,000). Opportunity rent and wage costs wouldn't 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. These averages may be a good guide to start with. However, what really matters is how much additional money spent on growing crops will affect production-therefore, net returns. In the case of wheat, Jean saw that increased expenditures increased net returns. In the case of alfalfa, however, he saw that increases in physical production weren't always worth their cost.

Because the total amount of contracting costs and the way in which they were allocated among the crops could affect net returns, Jean no longer had confidence in the land-allocation decision he made using the information presented in Table 1. Therefore, Jean asked the contractor to take a second look at the problem. This time, however, the contractor should 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 for each row in Table 1. A summary showing the optimal findings for each row is presented in Table 3. A comparison of Tables 1 and 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 has on revenue.

Table 3. The contractor's final report on profits from nine land-use patterns considering optimal contracting costs for each pattern.

Use pattern	Wheat (t)	Alfalfa (t)	Total revenue ($)	Contract ($)	Other costs ($)	Profit ($)
1	0	4,525	791,875	200,000	465,000	126,875
2	1,000	4,325	956,875	225,000	465,000	266,875
3	2,200	3,975	1,135,625	325,000	465,000	345,625
4	3,300	3,475	1,268,125	350,000	465,000	453,125
5	4,300	2,775	1,345,625	375,000	465,000	505,625
6	5,200	1,975	1,385,62S	400,000	465,000	520,625
7	5,650	1,075	1,318,125	425,000	465,000	428,125
8	5,850	400	1,240,000	400,000	465,000	375,000
9	5,950	0	1,190,000	375,000	465,000	350,000

Land-Use Pattern 1 is where all of the land is allocated to alfalfa. The optimal contracting cost for this allocation is only $200,000. As before, net returns can be increased by decreasing growing costs. Because the northern strips of land aren't that well suited to alfalfa, it doesn't make much sense to spend extra money on growing costs because the extra production isn't worth it. Although alfalfa production falls compared to Row 1 in Table 1, net return to the farm goes up.

Land-Use Pattern 9 is where all of the land is allocated to wheat. It makes sense to spend more money on growing costs because, up to a point, the extra production adds more revenue than it costs to produce. Compared to Table 1, contracting costs are up $25,000, but the additional 750 t of wheat increases revenues so that net returns increase by $125,000.

Land-Use Patterns 2-8 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 declines. As more land is allocated to wheat (for example, shifts from Land-Use Pattern 2 downward), it makes sense initially to increase contracting costs. However, as more and more land better suited to alfalfa production is shifted to the production of wheat, it eventually makes sense to reduce contracting costs.

When these changes are considered, Land-Use Pattern 5 no longer generates the highest net return. Although changing from Land-Use Pattern 5 to 6 increases input costs by $25,000, revenues go up by a greater amount-so net revenue increases. Land-Use Pattern 6 (where the five northern strips of land are allocated to wheat and the three southern strips of land are allocated to alfalfa) has the highest net return.

Case Study Summary:

Jean was very glad he asked the contractor for 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 return. He decided that this is how he wanted to operate. Jean made the formal agreement with the contractor and started life on the farm.

Review of the Economic Concepts:

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 only one aspect of production. In terms of the above example, the operational rule for the marginal analysis is that it might make sense to spend an extra dollar on tillage, fertilization, and so on, of a particular crop. It makes sense only if the increase in production generates more than a dollar of extra revenue.

Application to Fisheries Management:

The lessons from this section also apply to management of a fishery agency and these resource decisions can be very complex. Fisheries managers must often make decisions about how to use the resource base and how to allocate their budgets among various activities, One difference is that, although farmers can increase their operating expenditures (for example, through borrowing) if they think revenues will go up appropriately, fisheries agencies can't so easily increase their budgets. In both farming and fisheries management, marginal analysis can be used to compare gains and losses when making changes to production.

Additional Discussion:

Additional discussion can be found in Part II-Resource Management: Fisheries:

- The Value of Fisheries: Allocation of the Budget
- The Value of Recreational- and Commercial-Fishery Production

An Insect Invasion

Economic Concepts:

- *Use marginal analysis to make resource-allocation decisions by comparing proposed costs with the change in value of the desired outputs.*
- *It is important to consider all potential gains and losses that might result from a resource-allocation decision.*

Case Study:

After several years of successful operation, Jean's farm suffered from an infestation of crickets that were eating the alfalfa. The county agent indicated that the pests would probably remain in the area for the foreseeable future. The effects of this catastrophe are shown in Table 4. Before the insects came, annual wheat production was 5,200 t, and alfalfa production was 1,975 t. The net return was $520,625. The insects ate or ruined 395 t of alfalfa, which caused production to fall to 1,580 t. The result was 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 wouldn't increase net returns. Although the farm was still making a net return over all costs, Jean and the contractor decided that they should attempt to control the insects to see if their effect on net returns could be reduced.

Table 4. The benefits of insecticide treatment.

	Wheat (t)	Alfalfa (t)	Total revenue (t)	Contract ($)	Other costs ($)	Return ($)
Before insect invasion:	5,200	1,975	1,385,625	400,000	465,000	520,625
After insect invasion:	5,200	1,580	1,316,500	400,000	465,000	451,500
Insecticide treatment:						
$5,000	5,199	1,650	1,328,550	405,000	465,000	458,550
$10,000	5,198	1,700	1,337,100	410,000	465,000	462,100
$15,000	5,197	1,740	1,343,900	415,000	465,000	463,900
$20,000	5,196	1,720	1,340,200	420,000	465,000	455,200
$25,000	5,195	1,730	1,341,750	425,000	465,000	45 1,750

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 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 4. Initially, the effect on alfalfa production is quite large for each $5,000 expenditure. However, the increase in production falls off eventually. The first $5,000 expenditure on insecticide increases production from 1,580 t to 1,650 t. However, increasing insecticide expenditures from $20,000 to $25,000 would only increase alfalfa production by 10 t.

The contractor was a very careful individual and knew that insecticides sometimes had other unintended side effects. He learned that the insecticide, although beneficial to alfalfa, would actually decrease wheat production (Table 4). If more insecticide was used there would be a greater loss in wheat production. Therefore, one of the costs of using the insecticide would be the loss in the value of wheat that would be produced.

After studying the contractor's 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 $5,000 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.

Case Study Summary:

Jean and the contractor concluded that expenditures on insecticides would be useful. Although production didn't increase to the level 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 wheat production. Just to be certain that the insects didn't affect the land-use decision, Jean asked the contractor to do the analysis for Table 3 again and consider the effects from the insect infestation. Alfalfa production was affected no matter how the land was used and how the amount of crop-production money was allocated. Net returns were still maximized when the northern five strips of land were used on wheat and the southern three strips of land were used on alfalfa.

Jean was interested to learn that many other fanners 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. Although he wasn't happy with the situation, anything he tried to do would just make matters worse.

Review of the Economic Concepts:

Comparing marginal gains and marginal losses-marginal analysis-is important when making allocation decisions. For every new action or additional expenditure, it is important to consider all of the resulting gains and losses in relation to the additional costs incurred. The additional costs of implementation may not justify the change in value of the output. Marginal analysis of a given product or service must also consider potential effect on the value of related products or services.

Application to Fisheries Management:

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 aren't wasteful. It may not necessarily make sense to try to kill the last pest or to try to return the productivity of the ecosystem to what it was before the infestation.

Additional Discussion:

Additional discussion can be found in Part II-Resource Management: Fisheries:

- The Value of Recreational- and Commercial-Fishery Production

- The Attack of the Lamprey

The Construction of a Dam

Economic Concepts:

- *Marginal analysis is also used to emphasize that gains and losses can occur in different years.*

- *It is necessary to properly compare values from different time periods.*

Case Study:

In an annual report to Jean, the contractor complained that constraints on water availability were limiting potential production. The contractor indicated that construction of a small dam that could save water between growing seasons would increase production and, therefore, profits. Jean asked the contractor to determine the feasibility of this project. After studying the topography of the land and designing 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 and alfalfa would increase by 10% and 15%, respectively. Additionally, contracting costs would fall by $50,000 because the extra water could reduce cultivation and fertilizer use. The effects on net returns are shown in Table 5.

- The first line shows the production of the farm with no dam.

- The second line shows the net projected production, costs, and net returns with the dam in place.

Table 5. The dam's effect on the net value of output.

	Wheat (t)	Alfalfa (t)	Total revenue ($)	Contract ($)	Other costs ($)	Return ($)
No dam:	5,197	1,740	1,343,900	415,000	465,000	463,900
With dam:	5,717	2,001	1,493,515	365,000	465,000	663,515

The construction of the dam would increase the net return for the farm over and above all costs by approximately $200,000/yr. The real issue is deciding whether or not this extra $200,000/yr would justify the current expenditure of $1 million on a dam. To decide this issue, 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 annual gain would be spread over the future. Because most people would agree that a dollar today isn't the same as a dollar tomorrow, direct comparison of value at different points in time aren't appropriate.

It is possible to make comparisons of value across time only by using present value (PV) analysis. One way to understand PV 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 PV of $100.

To expand this example, a $100.00 deposit at 5% this year will result in $110.25 in two years. Therefore, $110.25 two years from now also has a PV of $100. It is also possible to add PVs. The PV at 5% of $105.00 next year plus the PV of $110.25 in two years is equal to $200.00.

The formula for calculating PV is:

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

X_i is an amount of money i year in the future and r is the discount rate. For example, if the interest rate is 10%, the present value of $350 in 15 years can be expressed as:

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

Whether the construction of a dam is a wise decision or not can be determined by comparing the sum of the PVs of the two series of net revenues. The contractor calculated the flow of net revenues for 15 years with and without a dam. With a dam, the net revenue in Year 1 would be -$536,100. This is the total revenue earned that year less the cost of the dam. In Years 2-15, when the dam is up and running, net revenues would increase to $663,515. The net revenue without the dam would be $463,900 every year.

With an interest rate of 10%, the net PV of net returns with the dam is $3,956,189. However, the net PV of net returns without the dam is only $3,528,460. This means that the extra value of output in Years 2 to 15 with the dam, expressed in PV terms, is more than the cost of the dam in Year 1. Otherwise, the net PV of output couldn't be higher with the dam. Another way to say this is that the sum of the PVs of the increase in the value of production in Years 2 to 15 is more than $1 million. Therefore, the net PV 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 three 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 wouldn't be sufficient to justify the cost of the dam. Similarly, a large dam could be built for $10 million. Although it would increase production more than the dam costing $1 million, a comparison of the net PVs showed that the extra value produced by the large dam wasn't enough to compensate for its $10-million construction cost. Jean was confident that the $1 million would be a good investment and it was the best possible way to invest in a dam. Neither the large nor the small dam would produce higher net PV of output.

Case Study Summary:

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. 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. However, over time the increased value of production from his farm would more than make up for that loss in value in net PV terms computed at a 10% discount rate.

Review of the Economic Concepts:

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 during the current year. Therefore, it is fairly straightforward to determine if such an allocation will be wise. If returns go up more than 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 makes economic sense if the overall gains are greater than the costs. However, if a comparison is made, it is necessary to first convert gains in future years into PV terms so that they can be compared to current costs.

Application to Fisheries Management:

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

Additional Discussion:

Additional discussion can be found in Part II-Resource Management: Fisheries:

- The Construction of a Dam

The Green Revolution Comes to the Farm

Economic Concept:

Net PV techniques are used to compare the gains and losses of a project that can have long-term effects on the productivity of the environment. Some short-term gains will be offset by future losses.

Case Study:

After the dam was built, the contractor and Jean continued to look for other ways to increase production-therefore, net returns from the farm. One day, an expert on technological farming tried to get them to consider his methods, He guaranteed 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 four years. This information is shown in the first four rows of Table 6. Now that there is a dam, current wheat production is 5,717 t and current alfalfa production is 2,001 t. 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 6,500 t and 2,250 t, respectively. Although an increase in production costs to $500,000 would be necessary, net returns would increase to $728,750 in the first year. The technology expert acknowledged that production wouldn't stay this high forever. However, over the four-year period, the net returns would be higher than without his program.

Jean didn't 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 15 years. The contractor agreed that the technology expert estimated outputs correctly for the first four years, but the predictions for Years 5 to 15 were very discouraging. Wheat and alfalfa production would fall dramatically even if production costs increased significantly. The effect on net returns was drastic.

Apparently, the 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 production fell drastically. However, by comparing the net PV of returns with and without the new technology, he found that the net PV of his production would fall if he used the proposed method. With a 10% discount rate, the net PV without enhancement (the net PV of $663,515 for 15 years) is $3,956,189. The net PV with enhancement (the net PV of the flow of 15 values in the bottom part of the last column in Table 6) is $3,832,415. The increase in the value of production during the early years was just not enough to compensate for the decrease in value in later years.

Jean also realized that if he decides to take this action there are other significant effects. Even ignoring the fact that the PV of the farm decreased by using technology, Jean could see that if he were to use it, retire in ten years, and give the land to his children, all of the gains from the technology would accrue to him. However, his offspring would have net returns that are significantly lower as a result of his gains.

Table 6. Comparison of current production and flow of production with output enhancement.

	Wheat (t)	Alfalfa (t)	Total revenue ($)	Contract ($)	Other costs ($)	Return ($)
Current yr:	5,717	2,001	1,493,515	365,000	465,000	663,515
Enhancement option (yr):						
1	6,500	2,250	1,693,750	500,000	465,000	728,750
2	6,500	2,250	1,693,750	500,000	465,000	728,750
3	6,400	2,200	1,665,000	500,000	465,000	700,000
4	6,300	2,150	1,636,250	500,000	465,000	671,250
5	6,200	2,100	1,607,500	500,000	465,000	642,500
6	6,200	2,100	1,607,500	500,000	465,000	642,500
7	6,200	2,100	1,607,500	500,000	465,000	642,500
8	6,200	2,100	1,607,500	500,000	465,000	642,500
9	5,500	1,650	1,388,750	525,000	465,000	398,750
10	4,200	1,500	1,102,500	625,000	465,000	12,500
11	4,200	1,500	1,102,500	625,000	465,000	12,500
12	4,200	1,500	1,102,500	625,000	465,000	12,500
13	4,200	1,500	1,102,500	625,000	465,000	12,500
14	4,200	1,500	1,102,500	625,000	465,000	12,500
15	4,200	1,500	1,102,500	625,000	465,000	12,500

Case Study Summary:

Based on the analysis of net PV and on the intergenerational transfer implications, Jean determined that the new scientific farming technique wasn't a good idea. Increased production during the early years wasn't worth the stress placed on his land. The stress on the land would lower production in later years.

Review of the Economic Concept:

This section shows another use for PV analysis. Certain current activities can have a negative effect on productivity in future years, and dynamic efficiency requires that gains and losses in different periods be compared.

Application to Fisheries Management:

Fisheries managers face similar problems when considering current densities for fish-stocking programs or approvals of aquaculture projects.

Additional Discussion:

Additional discussion can be found in Part II-Resource Management: Fisheries:

- Economic Valuation of a Fish Kill

The Spill of the Exxon *Demal*

Economic Concepts:

- *Economic damages from environmental accidents can be measured.*

- *Marginal gain and loss comparisons can help to understand the desirability of rehabilitation programs,*

Case Study:

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 named Mr. Overwood (who had christened his truck the *Dezval)* had too much to drink before making his run. The inevitable happened-Mr. Overwood overturned the truck into an irrigation channel in the northeastern part of the farm. The petroleum products were distributed fairly evenly over the eight strips of land. Jean was very angry that his land was affected by the spill. He was even more outraged when the contractor said it would take approximately four years for the productive capacity of the farm to return to normal.

The oil company assumed liability for the spill and agreed to pay full compensation for any losses. They asked Jean to estimate what the spill would cost him. To determine this, he requested that the contractor estimate the effect the oil spill would have on production. In response, the contractor presented the information contained in Table 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 of Table 7 shows what would happen if the farm's land was left to recover on its own. During the first three years:

- wheat production would be 4,000 t, 4,200 t, and 4,800, respectively;

- alfalfa production would be 1,000 t, 1,200 t, and 1,600 t, respectively.

Both crops would return to full production in Year 4. Although 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 $2 10,000 in Year 1. 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. There would be a reduction in the value of the farm's production, and a small increase in production elsewhere as the inputs formerly used for harvesting were freed up for other uses. To obtain an estimate of total losses, the contractor showed that with a discount rate of 10%, the PV of normal production for four years, which produced $663,515/yr, was $2,103,253. The PV 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-$9 13,324. That is, as a result of the spill, the net PV of the production of the farm would fall $913,324. If the oil company compensates Jean for the full effects of the spill, $9 13,324 is the amount that must be paid.

Table 7. The analysis of the effects of an oil spill showing a comparison of normal production, natural recovery production, and production with rehabilitation.

	Yr	Wheat (t)	Alfalfa (t)	Total revenue ($)
No damage:	1	5,717	2,001	1,493,515
	2	5,717	2,001	1,493,515
	3	5,717	2,00 1	1,493,515
	4	5,717	2,001	1,493,515
Natural recovery:	1	4,000	1,000	975,000
	2	4,200	1,200	1,050,000
	3	4,800	1,600	1,240,000
	4	5,717	2,001	1,493,515
Rehabilitation recovery:	1	4,300	1,200	1,070,000
	2	4,900	1,700	1,277,500
	3	5,717	2,001	1,493,515
	4	5,717	2,001	1,493,515

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Table 7, *continued*

Contract ($)	*Other* costs ($)	Rehabilitation cost ($)	Net return ($)
365,000	465,000		663,515
365,000	465,000		663,515
365,000	465,000		663,515
365,000	465,000		663,515
300,000	465,000		210,000
320,000	465,000		265,000
340,000	465,000		435,000
365,000	465,000		663,515
325,000	465,000	75,000	205,000
345,000	465,000	50,000	417,500
365,000	465,000		663,515
365,000	465,000	-	663,515

Jean, however, didn't like the idea of just waiting for the effects of the oil to go away. He asked the contractor if some kind of rehabilitation project could return the farm to normal production more quickly. After exploring several different possibilities, the contractor came up with a plan-the effects are described in the third section of Table 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 years would be greater than under a natural recovery scenario. The effect on net returns to the farm looked promising. Even though the net return for the first year would be lower with the rehabilitation plan, net returns would be higher for the other three years. The net PV of the flow of output under the rehabilitation plan would be $1,483,103-$293,174 higher than the net PV of production under normal recovery.

Jean showed the figures to the oil company and said that if they would pay the rehabilitation costs, he would accept a lower compensation payment. The PV 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 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.

Case Study Summary:

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

Review of the Economic Concepts:

From an economic perspective, it is fairly easy to calculate conceptually the damages resulting from environmental accidents. Damages are simply the PV of the reduction in the net value of output caused by the accident. In addition, there are many ways to react to the accident. Rehabilitation programs should be used in instances where they cause a net increase in the value of production. On the other hand, even though it sounds good, rehabilitation isn't always a sensible proposition. When rehabilitation is a sensible proposition, economic damage is the cost of the rehabilitation program plus the net PV of any remaining reductions in the net value of production.

Application to Fisheries Management:

Fisheries managers may also need to decide whether it is better to rehabilitate a fishery or to allow for natural recovery. After this decision is made, then costs can be addressed.

Additional Discussion:

Additional discussion can be found in Part II-Resource Management: Fisheries:

- Economic Valuation of a Fish Kill

The Effects of Increased Employment

Economic Concept:

Changes in the level of employment should be evaluated from an economic perspective. Changes in the level of employment are also related to the principle of maximizing the net value ofproduction.

Case Study:

After the effects of the oil spill were over, conditions returned to normal. Jean was convinced that his production combination was appropriate from both a short-term and a long-term perspective-net returns couldn't be increased in the present without unduly affecting net returns in future years. Jean felt that if he could just keep things going as they were, while staying alert for strategies that would increase the value of production, he would be doing a good job.

One day, Jean was talking to another farmer in the region and they began to compare notes on the operation of their farms. Because their lands weren't identical, Jean wasn't surprised that both farms operated in different ways, produced different outputs, and net returns were different. But as the comparisons continued, Jean was a little upset to learn that his farm had only 15 full-time employees and the other farm had 27 employees. In fact, the other farmer began to disparage Jean for not doing his social duty by providing employment. Jean had already considered the net returns he was earning for himself and the value of extra production that his farm was adding to the general economy as a measure of his success. However, he hadn't considered the number of workers that he hired as important. It was true that larger farms generally had more workers, but this wasn't always the case. Farms with more machinery sometimes employed fewer workers than farms of equal size with less machinery.

Jean met with his contractor and asked him to consider hiring more workers. The contractor said he had already carefully considered the number of employees to hire in the design of the optimal combination of production. Although the analysis in Table 2 was in terms of extra dollars spent for production costs, part of those costs were spent for labor. The contractor said that, considering 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. Therefore, it didn't make sense to hire more workers. Jean remained unconvinced and asked the contractor to report on the specific effects of adding 12 extra workers. Using 12 extra workers as efficiently as possible with respect to the two crops would increase wheat production to 5,750 t and alfalfa production to 2,020 t. The 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/yr. Therefore, Jean would have to match that salary to get them to work on the farm. 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
- Jean could now match his neighbor in terms of employment level.

Jean was impressed. In fact, he thought he might be nominated for a Chamber of Commerce Good Citizenship Award if he hired the extra workers. His chances would be especially good if he could get the selection committee to realize that the workers would spend their incomes in the area. Not only would farm income go up, but the value of output for local merchants would also increase.

While Jean was contemplating the citizenship award, the contractor urged him to look at the rest of his report. His wage bill would increase by $60,000, but revenues would only increase by $9,985. Therefore, the net return of the farm would fall by $50,015. Although 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 wasn't too pleased by the thought of the loss in net revenue to the farm.

Jean started 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. Employers in the city wouldn't 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. Because 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, although 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 wouldn't be spending their salaries there.

It was now clear to Jean 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 didn't seem to be a very good signal for determining the appropriate way to run a particular farm-and by extension, to run the economy as a whole.

Jean realized that in certain circumstances it might make sense to hire more workers :

- If the 12 extra workers would add more than $60,000 in extra output, then it could be argued that they should be hired.

- From the farm's point of view, it made sense to hire more workers because net returns would go up.

- From the point of view of the whole economy, 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 wasn't 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 weren't producing anything.

Case Study Summary:

The critical issue isn't just the number of people employed, but instead the value of goods and services produced and how the value changes when the people start to work on the farm.

Review of the Economic Concept:

From a national perspective, changes in employment in one area can come only as a result of opposite changes in another area. 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 only as a measure of success in a particular region or industry isn't correct. The important issue is how the value of production changes as workers move from one area or industry to another.

Application to Fisheries Management:

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 and recreational sectors in this or that region are often discussed in fisheries-management debates. The 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.

Additional Discussion:

Additional discussion can be found in Part II-Resource Management: Fisheries:

- The Value of Recreational- and Commercial-Fishery Production

Using the Raspberry Patch

Economic Concepts:

- *Open-access utilization of a natural resource can lead to biological and economic waste.*

- *A comparison of marginal gains and losses from different operation levels can provide useful information on appropriate exploitation rates.*

Case Study:

On one portion of the farm there was a raspberry patch that no one had tended since the previous owner had died. Jean was so busy that he didn't 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. Jean wasn't 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 that the people had been harvesting the berries for several years. Although the number of people who participated varied initially, during the past few years the same eight individuals had shown up. They only came during the harvesting period and weren't very careful workers. Although they didn't cause any intentional damage, they frequently stepped on plants to get to the ripe berries. Also, they weren't careful to leave the bud where the fruit could grow again when they picked. 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 noticed that no one made any effort to cultivate the plants or to add fertilizer to the patch.

When the pickers were asked why they behaved this way, they gave two types of answers:

1) They weren't sure when the owner (Jean) would decide to use the land for something else or to claim all the berries. Also, they didn't see any reason for being extra careful when they weren't sure that they could use the land in future years.

2) If any one of them was more careful, it was uncertain how much of the resulting return the individual 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 the contractor to see an economic analysis of raspberry growing on the plot. The contractor produced the information contained in Table 8. 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-called marginal product (MP) - is shown in Column 3. For example, a third worker would increase production by 21 cases (from 48 cases to 69 cases). However, the fourth worker would only increase production by 19 cases.

Using a berry price of $20/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-called marginal revenue-is shown in Column 5. Column 6 shows the average revenue for each worker. Because eight workers usually work the patch, the amount that each earns, assuming that they are all equally good pickers, is $360. The contractor estimated 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 eight workers and the average return fell below $360 for the one-week period, some of them must have concluded that, it wasn't worth their time and stopped picking. When the contractor 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/wk.

Table 8. The relationship of raspberry production and profits to number of pickers when the raspberry price is $20/ease and the weekly wage is $360/person.

No. of 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)

Using $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 for eight workers is $0. If Jean took over the patch, kept the same number of workers, and paid them their opportunity wage, the revenue from selling the berries would cover wages-but no more. Jean decided it wouldn't 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 were produced, an equivalent value of output was lost in the construction industry because the workers were at the raspberry patch.

Jean was ready to forget about the raspberry patch. However, the contractor pointed out that eight people were willing to come to the open patch, but 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, net returns would be maximized with four 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 $1,120. However, the opportunity cost of four extra workers would only be $1,440. Therefore, by cutting back on the number of workers, costs would fall more than revenues and net returns would then increase-from $0 to $320.. Jean would have that much extra money each year, and the workers would still have the same weekly income. The people who weren't working in the patch could find work in the construction industry.

The change in profit from the patch under this plan is matched by the change in the value output in the economy as a whole. However:

- the value of raspberry production would fall by $1,220,

- the value of output in the construction industry would increase by $1,440, and

- the value of output in the whole economy would increase 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.

Although these numbers sounded right, the principle didn't make sense to Jean. He wondered why he had to have control over the use of the patch to make sure net returns were maximized. Jean also wondered why the people who worked the patch didn't seem to be able to make the right decision After studying the material in Table 8, Jean discovered the answer.

Although net returns are maximized with 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 additional workers wanted to switch to the patch.

On closer examination, Jean could also see how the workers making independent production decisions concerning the output level of the patch could ignore the total profits. For example, a fifth worker increased production by $340. If workers were paid what they added to production, they wouldn't work at the patch because they could earn $360 in construction. A worker would lose $20 by working the patch.

What happens, however, is that a fifth worker gives up $360 intending to earn $420 - or the average revenue when there are five workers. This one worker will, therefore, increase his income by $60. On the other hand, with only four workers, each original participant made $440. When the fifth entered, their individual return fell to $420, and 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 workers would lose $80, but the new worker 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 fall on the one who is making the decision, private decision making leads 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 decided to hire four of them to work the patch. He would pay them $380 each for the week. Because they worked for $360/wk under the uncontrolled system, they would be better off Jean also was determined to give each person who couldn't continue to work in the patch $20 a week. They then could work in construction and make the same weekly salary of $380 a week. Therefore, all of the workers would have a higher weekly return than under the uncontrolled situation. The return to Jean from running the patch under this system would be $160. Because 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 still wasn't certain that this was exactly how the patch should be operated. He realized that his decisions were based on the knowledge that the workers would only spend their time picking and that there would be no effort made for bush maintenance or improvement of the patch. Bush maintenance included transplanting bushes when they were too close together and tying them to poles. He realized that with bush maintenance and cultivation output per plant would go up and it would probably be easier to pick the berries. The contractor studied the issue and found that if one worker spent one week each year on these kinds of activities, the production possibilities of the patch would be as described in Table 9. The total output would increase at every level of employment, and the extra output (the MP) produced by each worker would also go up.

Table 9. Relation of raspberry production and profits to number of pickers with extra cultivation.

No. of 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)

The figures indicated that, with cultivation, the raspberry 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. 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 that would increase the productivity of the patch, but wouldn't be done with the uncontrolled system, made sense.

Looking at Table 9, it is easy to see why cultivation wouldn't be done under uncontrolled picking. If cultivation was done, but there were no controls on using the patch, 12 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 no incentive to do that kind of work the following year.

The contractor did the same kind 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, wouldn't be enough to pay the cost of hiring the second worker.

Case Study Summary:

Jean decided that it was definitely a good idea to operate the raspberry patch. He decided to go ahead 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. The total output would increase at every level of employment, and the extra output (the MP) produced by each worker would also go up.

Review of the Economic Concepts:

Open access allows participants to enter as long as it is in their best interests to do so. Individual operators don't always consider the effects their actions have on other participants. As a result, although they will make private gains, the operation as a whole will suffer losses. The value of extra production will be less than the opportunity cost of producing it. Additionally, there will be no incentives to invest or even care for the product because any potential gains will be open to harvest by all current and potential operators.

Application to Fisheries Management:

An open-access fishery, where participants can enter as long as it is in their best interest to do so, is analogous to Jean's raspberry patch. Individual operators don't 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 production. Additionally, there are 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 push stock to very low levels. This section is a transition to the discussion in Part II. The concepts introduced are fundamental to an economic analysis of fisheries utilization even though they may be only a sideline in the operation of a farm.

Additional Discussion:

Additional discussion can be found in Part II-Resource Management: Fisheries:

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

Camping vs. Maple Syrup

Economic Concepts:

- *The concept of nonmarket values is introduced.*

- *Using the net value of output produced as an allocation criterion can lead to improper choices if both market and nonmarket values aren't considered*

Case Study:

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 that was comprised mainly of a stand of maple trees. The area was quite beautiful with hills and vales and several lovely streams that supported good fish populations. He walked through the area periodically and had looked into producing maple syrup, but he found that production wasn't high enough to pay the necessary workers.

One day Jean 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 fundraising activity, and this would be a good one because it would teach them how to use natural resources. Expected sales would be $10,000/yr, which was much more than they could make by other fundraising activities. Because the scouts and their leaders would be volunteers, they could look at labor costs differently than Jean-they didn't have to meet a payroll. Because the girls wouldn't be taking time off from other jobs during the project's duration and the project wouldn't unduly interfere with their school work, there was no real opportunity cost for their labor and no production would be given up elsewhere in the economy. Therefore, the only variable to consider was the value of the syrup that 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 to give his permission, when he opened another letter 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 couldn't 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 so he had to make a decision on who could use the land. Because both letters arrived the same day and both activities sounded useful, there was no obvious way to choose between them. Jean was in a quandary.

Jean knew using the land for syrup would produce output valued at $10,000, but he didn't know the value that would be generated if the land was used for camping. Jean called the leader of the second troop. He found that the troop had been going to another camp 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/wk. The 480 campers paid $18.75 each.

The leader said the reason that they wanted to switch the camp to Jean's land was because Jean's land was more beautiful and more conducive to their camping activities. During the discussion to make the switch, all of the campers and 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 instead of $18.75. All of the other parents agreed.

Although this information was interesting, it was also confusing. Jean had already decided that he wasn't going to use the land 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 troop interested in producing maple syrup. If he let them use the land, they would make $10,000. However, if he gave the land to the second troop, they would save $9,000. 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.

Jean then considered the fact that maybe his decision to offer the land for free was making him consider the wrong things. If the parents from the second troop really would be willing to pay $35 for each camper, the total amount that they would be willing to pay to use the land would be $16,800. Therefore, if the second troop used the land (even if Jean didn't charge for it), the girls would enjoy camping activities which-according to their own calculations-were worth $16,800. No market activity was involved, but services worth that amount were being generated. Jean, therefore, gave permission to the second troop to use the land as a campground. It wasn't easy to tell the first troop his decision because their project had many merits. But then again, if allocation decisions were between good things and bad things, they wouldn't be so hard to make.

Case Study Summary:

It is often necessary to choose between two or more good things. If only one outcome can be achieved, 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.

Review of the Economic Concepts:

The main concept developed in this section is that using the value of goods and services produced as a measure of success doesn't have to be abandoned if some goods aren't bought and sold in a formal market place. For market goods, price measures what people are willing to pay. Therefore, when there is no market for a particular item, consumers still have a willingness to pay (WTP). It is just more difficult to ascertain what that amount is. In this hypothetical example, the measure of WTP 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.

Application to Fisheries Management:

The concept of using the value of goods and services produced as a measure of success doesn't have to be abandoned when 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 WTP. It is just more difficult to ascertain what that amount is. There are many good causes that will compete for the fisheries budget. In the real world, it is much more difficult to obtain estimates, but there are many techniques for doing so. Valuation of these causes gives fisheries mangers solid ground on which to base their decisions.

Additional Discussion:

Additional discussion can be found in Part II-Resource Management: Fisheries:

- The Value of Recreational- and Commercial-Fishery Production

PART II-RESOURCE MANAGEMENT: FISHERIES ECONOMIC VALUATION AND FISHING

Introduction

The purpose of this section is to show how the concepts developed in Part I-Resource Management: Farming 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 natural-resource agency. To make the analysis analogous to the farm case, we will assume that the agency hasn't previously focused specifically on fisheries issues-the legislature wants to determine if it is time to do so. Judy, who is 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 nonfisheries issues. She is told to determine the types of things that the agency should do and to estimate what benefits will accrue to citizens as a result. She is told to base her analysis on a planned general budget of $50,000 and an enforcement budget of $20,000, Although there is general support for starting a fisheries agency, it is a time of tight budgets. The finance committee will want to be sure that scarce government funds will be well spent. As in Part I-Resource Management: Farming, the discussion is divided into discrete segments. The segments presented in Part II-Resource Management: Fisheries are:

- Case Study
- Case Study Summary
- Application to Farm Management
- Additional Discussion

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

Case Study:

Judy was eager to start work and was pleased that an analyst had been assigned to assist her. The analyst's 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, the analyst told Judy that there were two main fish species, which at present were exploited only by commercial fishermen:

1) the eschalot

2) the rhodolite

Each participant fished alone, and each used a small boat and similar gear.

The analyst was trained in biology and economics and had derived an effort-to-catch relationship for each of the two species and also had estimated the cost of producing effort (Table 10). Effort was measured in terms of participants, and the cost for each participant was $35,000 - regardless of which fishery they worked in. This covered the income of the workers, current expenses such as fuel and bait, and equipment costs.

Table 10. An economic analysis of fishery production.

Effort	cost ($)	Output: Eschalot (t)	Output: Rhodolite (t)	Net returns: Eschalot ($)	Net returns: Rhodolite ($)
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	2 10,000	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)

The catch (t) in each fishery increased as the number of participants increased. However, as effort increased, the amount of production added by the last worker declined. For example, the third participant in the eschalot fishery increased catch by 90 t, but the tenth participant only increased it by 20 t. 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 affected adversely. When Judy asked how high effort could get before this would happen, the analyst told her that total effort would have to be seven units or higher before there would be any problem.

The final two columns of Table 10 show the net returns to the eschalot and rhodolite fisheries assuming a price of $430/t for the eschalot fishery and $470/t for the rhodolite fishery. According to the data, the net returns to the eschalot fishery become negative at seven units of effort, and the net returns to the rhodolite fishery become 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. It 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 net value of output was $23,200-$5,000 for the eschalot fishery and $18,200 for 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-term problems. When these conclusions were shared 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 couldn't support enough effort to cause long-term stock reductions.

However, the analyst didn't agree with Judy's conclusions on the economics of the fishery. Conditions weren't as good as they seemed from the industrial and economic points of view. The major concern was that any increase in effort on either species would cause net returns to become negative.

The analyst thought it was important for the legislature to see an economic perspective and 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 was somewhat firmer, so its price was higher than that of the eschalot with its softer flesh. However, the amount sold of either fish species was small relative to the entire market and didn't 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, the costs of the two fleets represented the value of goods and services that could have been produced if the inputs used to produce effort had been used in other parts of the economy. Labor, fuel, and other inputs could be used to produce other products with a value of $35,000 if effort was reduced by one unit. 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 10, Judy realized that although both fisheries showed positive gains, the net returns weren't as high as they could be:

- If effort in the eschalot fishery was reduced by three units, net revenue would increase to $19,700.

- If effort in the rhodolite fishery was reduced by four units, net revenue would increase to $54,800.

Case Study Summary:

When Judy asked why the fishing industry didn't operate 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.

Application to Farm Management:

This concept was explained by the example of Jean's raspberry patch, but it is useful to review it in the context of these two fisheries. If it is assumed that three units of effort were used in each of the fisheries so 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. 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. 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 used to produce effort were transferred to other uses.

Although Judy realized that all this information was very preliminary, she felt confident about the prospects of a successful and viable fisheries agency. The current fishing industry was earning $23,200, but it could potentially earn $74,500 - an increase of $5 1,300. While Judy was encouraged, she didn't have enough information to complete her report. A decision still had to be made on 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 determine if the net gains were positive.

Additional Discussion:

Additional discussion can be found in Part I-Resource Management: Farming:

- Using the Raspberry Patch

The Value of Fisheries: Allocation of Natural Resources

Case Study:

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 the two species of fish could grow in all parts of the state. However, rhodolite usually did better in the southern part of the state, and the eschalot did better in the northern part of the state. Two questions, then, became relevant:

1) Should the use of one particular fish stock be favored in certain parts of the state?

2) How should the budget be allocated to activities related to each of the species?

Because the analyst wanted to focus on the use of state waters, he initially designed a budget where basic research and administration support were spent equally on each species.

To help consider the specialization issue, the analyst divided the state into five strips running from east to west. If the rules for commercial fishing were set up so that rhodolite fishers were given preference in all five strips, the analyst predicted that their waters could produce 405 t of eschalot and 695 t of rhodolite (Allocation 1, Table 11). At the other extreme, if the rules favored the eschalot fishers in all areas, 780 t of eschalot could be produced-but only 70 t of rhodolite would be produced (Allocation 6, Table 11). Allocations 2-5 represent the predicted output if the rules were changed to favor the eschalot fishery in the various areas-starting in the most-northern area. For example, in Allocation 2 the rules favored the eschalot fishery in the most-northern area, but favored the rhodolite in the four southern areas.

54

Table 11. The allocation of the resource base between the two species showing production and gross value of output with different allocations of the resource base.

Allocation	Output		Gross returns ($)
	Eschalot [1] (t)	Rhodolite [2] (t)	
1	405	695	500,800
2	530	620	519,300
3	630	520	5 15,300
4	705	395	488,800
5	755	245	439,800
6	780	70	368,300

1 The price of eschalot is $430/t.
2 The price of rhodolite is $470/t.

As more areas are allocated to the eschalot fishery, production increases-but at a decreasing rate. This is because eschalot stocks don't do as well in the south. At the same time, the amount of the rhodolite catch decreases-but at an increasing rate.

- Movement from Allocation 1 to Allocation 2 would increase the eschalot catch by 125 t but would decrease the rhodolite catch by 75 t. This means that each tonne of eschalot catch costs (or, comes at the loss of) 0.6 t of rhodolite catch.

- Movement from Allocation 5 to Allocation 6 would increase the eschalot catch by 25 t but would decrease the rhodolite catch by 175 t. This means that each tonne of eschalot catch costs (or, comes at the loss of) 7 t of rhodolite.

The same thing works in reverse for movements from Allocation 6 upwards (Table 11)-the cost for each tonne of rhodolite in terms of lost eschalot catch increases. These trade-off ratios are of critical importance when 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 six allocations is given in Column 3-Allocation 2 produces the highest gross revenue. When changing from Allocation 1 to Allocation 2, the value of the increase in the eschalot catch more than compensates for the decrease in the value of the rhodolite catch. However, this isn't the case for a change from Allocation 2 to Allocation 3.

Although there may be some temptation to say that Allocation 2 is the one to choose, Judy knew that it is the net value of production that is important (as in the operation of Jean's farm). Gross values don't tell the whole story. The analyst didn't provide any good information about the costs of harvesting the various levels of catch so there wasn't enough information to make a proper decision.

Judy then asked the analyst to describe the operation of the fishing industry for Allocation 2 in the same way that he described it in Table 10. The results are given in Table 12. The cost of producing effort in either fishery remains the same, but the amount that each unit of effort will catch increases. This increase is because of the stocking, habitat, and research activities performed by the agency and the way in which the natural production of the environment is allocated between the two stocks. Looking at the table, Judy determined that in order for the eschalot fishery to produce 530 t, it would need to produce six units of effort. For the rhodolite fishery to produce 620 t, it would need to produce eight units of effort. Net returns in the eschalot fishery would be $17,900. 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 wouldn't actually occur given the realities of the fishing industry. The eschalot fishery would operate at seven, not six, 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.

- The rhodolite fishery would earn $11,400.

Table 12. A revised look at the economic analysis of fishery production.

Effort	cost ($)	output Eschalot (t)	Rhodolite (t)	Net returns Eschalot ($)	Rhodolite ($)
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	2 10,000	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	3 15,000	650	640	(35,500)	(14,200)
10	350,000	670	650	(61,900)	(44,500)

*Level of effort where returns are maximized in each fishery.

Again, the open-access operation of the fishery wouldn't produce the highest net revenues. The maximum net return for the eschalot fishery ($32,600) and the rhodolite fishery ($68,900) would be produced by three units of effort in each. Therefore, if an allocation of the environment as in Allocation 2 was specified, the total net revenue for the whole fishery could be as high as $10 1,500. 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.

She then asked the analyst to revise Table 11 to show the maximum net value that could be produced from each of the allocations of the resource base. The analyst did this by creating a table similar to Table 12 for each of the allocations in Table 11. A summary of this information is presented in Table 13. The maximum net returns from both of the species (Table 13) are entered in Row 2, and the values in the other rows have a similar interpretation for the different allocations of state waters for harvesting the two species. The maximum net value is earned at Allocation 3. That is, if the regulations are such that the rhodolite fishery is favored in the northern two sections and the eschalot fishery in the southern three sections, and if stocks at both species are managed to maximize the net value of output, then the two fisheries can generate a net value of output of $112,000.

Table 13. Allocation of the resource base with fisheries management between the two species.

Allocation no.	Net returns: Eschalot ($)	Net returns: Rhodolite ($)	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

Case Study Summary:

Judy began to feel that she was finally understanding the potential net economic benefits to be obtained from a fishery-management agency. Because the fishing industry had a net value of output of $23,200 with no agency (Table 10) and there was the potential of earning a maximum of $112,000, potential gross gains from fisheries management were $88,800. This is an increase of $37,500 over the first estimate of $5 1,300 in potential gains (Table 10).

Application to Farm Management:

Judy knew the problem wasn't solved yet even though she had carefully examined the effects of allocating the natural-resource base between the two fisheries. She had not 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 depended on multiple factors:

- how much land was used for wheat and how much was used for alfalfa; and

- how much money was spent on fertilizer, seeds, and labor for each of the two crops.

Additional Discussion:

Additional discussion can be found in Part I-Resource Management: Farming

- What to Produce? A Preliminary Look

The Value of Fisheries: Allocation of the Budget

Case Study:

Judy asked the analyst to study the effects of changing the amounts of money spent on each of the fish species. In the previous analysis, it was assumed that the $50,000 budget was divided evenly between the two. The results of the analyst's work are presented in Table 14. The top half shows what would happen to maximum potential returns if the eschalot-fishery budget for stocking, habitat protection, research, and so on was increased in $5,000 increments. The row marked with an asterisk is the situation shown in Allocation 3, Table 13. 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 that results from the activities of the agency. It is the difference between the net value of production from the managed fishery and what the fishery would produce with no management less all agency expenditures. As demonstrated in Table 10, 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 less $5,000.

Table 14. The effects of incremental budget expenditures on the two species.

Net returns ($)	Budget ($)	Agency returns ($)	Marginal agency net returns ($)
		Eschalot	
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)
		Rhodolite	
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
7 1,500	40,000	13,300	500
76,000	45,000	12,800	(500)
79,500	50,000	11,300	(1,500)

*These amounts correspond to Allocation 3, Table 13.
**The allocation of the $50,000 budget that will maximize net returns.

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. She, therefore, decided that the even split of $25,000 spent on each fishery wasn't the best way to spend the proposed budget.

The bottom half of Table 14 provides a similar analysis for expenditures on the rhodolite fishery. The agency return in Column 3 is the difference between Columns 1 and 2 less the open-access value of output of $18,200 (Table 10). The row with an asterisk is the situation shown in Allocation 3, Table 13. The net agency benefits from managing the rhodolite fishery reach a maximum of $13,300 with an expenditure of *$40,000.*

Case Study Summary:

Based on the analysis of both fisheries, Judy was convinced that an equal split of the budget wasn't a good idea. Just as Jean did, she 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.

Application to Farm Management:

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 businessperson. 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 that if everything went according to plan he would make enough revenue to cover his expenses. An agency director can't do that. The action of the agency may increase the value of goods and services in the economy, but those gains won't 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). The immediate problem facing Judy was to maximize net returns given a limited budget.

Given the $50,000 budget, and assuming 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 with double asterisks in Table 14).

The total potential net returns are $115,000-$3,000 more than an evenly split budget would make possible.

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 - 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 spent on another fishery, total net benefits could be increased by taking that dollar away from the fishery where it earns the lower amount and spending it instead on the fishery where it earns the higher amount. For example, if $10,000 is spent on the eschalot fishery and $40,000 is spent on the rhodolite fishery, the last $5,000 spent on the eschalot fishery would produce a marginal gain of $2,500. However, the last $5,000 spent on the rhodolite 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 equalizing the marginal net gain from expenditures on different agency activities, the agency will always get the largest possible total gain from its budget.

The $15,000-$35,000 split was the best that could be done given the fixed budget, and 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. Judy showed that an increase in the budget would increase the net value of output in the economy. Another $5,000 spent on each of the fisheries would increase net value in the economy by a total of $1,250. The production of other goods and services elsewhere in the economy would decrease by $10,000 because of the extra inputs used in the fishery-management agency. However, the net value of output would increase by $5,750 in the eschalot fishery and $5,500 in the rhodolite fishery. The net value of output overall would increase by $1,250.

Judy's arguments fell on deaf ears. The staff didn't argue with her logic, but they simply couldn't come up with the extra money because of the current government budget.

Additional Discussion:

Additional discussion can be found in Part I-Resource Management: Farming

- What to Produce? A More-Detailed Look

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

Case Study:

Judy was now confident that she understood the allocation problems facing the fishery agency, and she needed 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 shown in Table 15. Although Table 15 is similar to Tables 10 and 12, 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 the agency would spend its budget on each of the two fisheries.

The maximum net returns to the eschalot fishery of $49,370 can be achieved when effort is equal to three units. The $66,080 of maximum net returns to the rhodolite fishery can also be produced with three units of effort. These estimates of net returns are more precise than those provided in Table 15. 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 eight units of effort. The net revenue for each fishery would be $3,370 and $8,580-a total of $11,950.

Judy could see that a significant difference existed between the maximum potential net revenue and the net revenue that would probably be produced by an unregulated industry. She asked the analyst to demonstrate the net gains to the agency under two alternatives. The first alternative provided for no controls on entry to the fishery. The second alternative would restrict effort to levels that would maximize the value of fishery output. 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 (therefore, the potential for gains), under open access these gains are dissipated.

As shown in Table 10, the net returns to the fishery with no agency and no regulation are $23,200. With the agency, the open-access net returns are $11,950-a loss of $11,250.' In addition, when the $50,000 agency budget is subtracted out, the total net economic benefit of the fisheries agency is a loss of $6 1,250.

Table 15. An economic analysis of fishery production given agency activities.

				Net returns	
Effort	Cost ($)	Eschalot ($)	Rhodolite (t)	Eschalot ($)	Rhodolite ($)
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)

In fact, the picture under open access may be worse than pictured in this quick look at the fishery. The catches are possible this year, but biologists doubt that the stocks of the two species could take the pressure exerted under open access, and so catch per effort (CPE) might fall in the future.

'If revenues and costs are 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.

Judy obviously didn't like the possibility of net losses this year with the likelihood of worse to come. She realized that some kind 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 that would cause the fisheries to move efficiently to the maximum net revenue positions.[2] The full net benefit of the agency with appropriate regulation can be calculated as follows:

$92,250 - $50,000 - $20,000 = $22,250

$92,250	the increase in net returns to the fishery -the difference between the controlled-access returns ($115,450) and the open-access returns ($23,200)
$50,000	basic agency budget
$20,000	enforcement budget

In addition, at reduced levels of effort, the stocks of eschalot and rhodolite would not be adversely affected, and the projected levels of catch could be maintained indefinitely.

Case Study Summary:

During 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 weren't affected. As long as fishers were making money and the stock wasn't damaged, should the agency really care how many people fished? In fact, wouldn't the legislature be pleased with more instead of less employment? Judy had a ready answer for this because she had talked to her cousin, Jean, about increasing employment on his farm. Unless there are no alternative employment opportunities elsewhere in the economy, allowing employment to increase in the fishery will mean workers for other industries and the value of output in the nonfishery sector of the economy will fall. Also, these extra fishers will affect the returns to existing fishers. Any expansion of effort beyond three units 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.

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2 The exact details of the management plan won't 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. Many volumes have been written on this subject and many citations can be found in the references.

Application to Farm Management:

Judy was now prepared to make an initial report to the legislature on the desirability of starting a fishery agency. As she examined the information in Table 15, she realized that Jean was right when he said that, although some significant differences existed, there were also many similarities between determining how to run a farm and how to run a fisheries agency. In both cases, decisions have to be made about the best way to allocate the natural-resource base and the operating budget. A difference is that the farmer has more flexibility in determining the size of the operating budget. Also, in both cases the allocation decisions have an effect on the net value of output produced by the economy.

The farmer also directly reaps benefits when the value of output goes up (as do the consumers of farm products) and suffers losses when they decline. This isn't true 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 taxpayer.

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 Jean originally didn't 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 described above, when agents operate in their own best interests, the fishery won't operate to maximize net returns. This is why the agency must have a regulatory budget to help determine how much will actually be harvested.

Additional Discussion:

Additional discussion can be found in Part II-Resource Management: Fisheries:

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

- The Value of Fisheries: Allocation of Natural Resources

- The Value of Fisheries: Allocation of the Budget

The Value of Recreational- and Commercial-Fishery Production

Case Study:

When Judy presented her report, the legislature was convinced that a fishery agency was a good idea. The legislature 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 earlier and instituted a management plan that 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 problems with people in the government or industry. However, one day it was discovered that the eschalot could also be taken with recreational gear. The eschalot, besides tasting good, put up a good light. As a result, the recreational fishery started to expand very rapidly. Soon Judy started to receive complaints. The commercial fishers for the eschalot complained that their livelihoods were being affected. The recreational participants in the fishery 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 kind of allocation between the commercial and recreational sectors would be necessary. She knew that many different criteria existed for making such allocations, but because 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.

Judy knew that there were benefits from commercial use of the eschalot. If the recreational sector reduced the stock available to the commercial sector, some of these benefits would be lost. On the other hand, she knew that benefits were also 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, Judy asked the analyst to determine how the eschalot commercial fishery would be affected by different levels of recreational quotas. The results of the analysis are presented in Columns l-4 (Table 16) and show the operation of the fishery with no recreational fishing. Column 5 shows how catch at each level of effort is affected if recreational participants are allowed to

Table 16. Net value of the eschalot fishery with a different level of effort and varying recreational quotas.

Bag limit	cost of effort ($)	output of eschalot fishery (t)	Net returns of eschalot fishery ($)
l	35,000	169	37,670
2	70,000	269	45,670
3	105,000	359	49,370
4	140,000	439	48,770
5	175,000	509	43,870
6	210,000	569	34,670
7	245,000	619	21,170
8	280,000	659.	3,370
9	3 15,000	689	(18,730)
10	350,000	709	(45,130)

Continued on next page

take 100 t. Note that allocating 100 t of fish to the recreational sector does necessarily decrease commercial harvest by that amount--it merely reduces commercial CPE. Column 6 shows the net returns. The rest of the table shows what would happen to landings and net revenues when the recreational catch is 200 t and 300 t.

Table 16, *continued*

Recreational quota		Recreational Quota		Recreational quota	
output 100 (t)	Returns ($)	output 200 (t)	Returns ($)	output 300 (t)	Returns ($)
160	33,800	150	29,500	140	25,200
260	41,800	250	37,500	230	28,900
350	45,500	340	41,200	310	28,300
430	44,900	420	40,600	380	23,400
500	40,000	490	35,700	440	14,200
560	30,800	550	26,500	490	700
610	17,300	600	13,000	530	(17,100)
650	(500)	640	(4,800)	560	(39,200)
680	(22,600)	670	(26,900)	580	(65,600)
700	(49,000)	690	(53,300)	590	(96,300)

With a 100-t recreational quota, the maximum net revenue still occurs at three units of effort. The returns are lower than they would be without a quota, but the maximum still occurs at the same level of effort. The same is true with a 200-t recreational quota. However, with a 300-t 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 recreational quota levels are:

- $45,500 (100-t recreational quota),
- $41,200 (200-t recreational quota), and
- $28,900 (300-t recreational quota).

Using these figures, it is easy to calculate the cost of the various quotas to the commercial sector. The 100-t quota reduces the net value of output by $3,870 ($49,370 less $45,500), so this is the cost of the quota. It wouldn't be proper to use the gross value of the 100-t recreational harvest as a measure of its cost. Although the quota will reduce catch to the commercial fishery, there isn't necessarily a one-for-one trade-off. Catch in the commercial sectors would only fall by 9 t in this instance. The value of the lost 9 t at a price of $430/t is $3,870. Following similar reasoning, the cost of a 200-t quota would be $8,170 and a 300-t quota would be $20,470.

With the 300-t quota, however, reduction in the cost of operating the fishery must also be taken into account. At the three units of effort where the fishery would normally operate, this quota will cause commercial harvest to fall by 49 t. However, 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 t. 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, the marginal cost of increasing the quota in 100-t increments should be noted. The first 100 t reduce the net value of output in the commercial fishery by $3,870. If the quota was increased to 200 t (for example, another 100 t is allocated to the recreational fishery), the extra reduction in net value is *$4,300.* A third increase of 100 t reduces net value by $12,300. This increasing marginal cost of the quota is important. It may make sense to allocate a 100-t recreational quota, but this doesn't mean that all fish should be given to the recreational sector. As more and more fish are 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 an allocation to the recreational sector was made, she wanted to know what would be gained. She had heard of economic research procedures for measuring the value of recreational fishing that could measure the value despite the fact that no product is sold on the market. The value of the product of a commercial fishery is its price-which is what people are willing to pay for it. Because 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 the activity-the result is a measure that is commensurate with the measures of net value used in commercial fisheries.

The analyst happened to be well trained in doing valuation work. After considerable effort, he developed the information contained in Table 17. The analyst explained, however, that recreational fishers participate for relaxation purposes. They don't go out strictly for the fish they obtain, but the amount of fish caught is important. That is, their catch 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 each day. The analyst determined that catch was, in fact, a very critical variable for the recreational value obtained. Consequently, catch is a very critical component of a participant's WTP in the recreational fishery for the eschalot. The analyst determined that a direct relationship existed between the quantity of fish caught each day and the number of days a participant would fish.[3] Because the analyst knew that bag limits (the legal maximum number of fish that participants would be allowed to take) would probably 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 Table 17.[4] It is noteworthy that the number of days fished for an individual declines as the bag limit is lowered. Although every participant doesn't always catch the bag limit, a reduced bag limit lowers the potential for a great day. Therefore, the relative potential gains from fishing are lowered, and people may switch to other forms of recreation. The result may be falling participation rates.

[3]Note that, although the discussion of the valuation of recreational fisheries is based on the general premises of current research methodology, it is very much simplified. 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.

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

Table 17. The valuation of recreational fishing.

1	2	3	4
Bag limit	Days fished/yr	**Annual** benefit **($)**	Catch/ participant **(t)**
15	3.87	*2.39*	*58.09*
14	3.74	2.35	52.38
13	3.61	2.26	46.87
1 2	3.46	2.12	41.57
11	3.32	1.95	36.48
10	3.16	1.75	31.62
9	3.00	1.53	27.00
8	2.83	1.30	22.63
7	2.65	1.06	18.52
6	2.45	0.83	14.70
5	2.24	0.61	11.18
4	2.00	0.41	8.00
3	1.73	0.24	5.20
2	1.41	0.11	2.83
1	1.00	0.03	1.00

Continued on next page

Table 17, *continued*

5	6	7	8	9	10
No. of participants					
100 t		200 t		300 t	
Quota	Gross benefit ($)	Quota	Gross benefit ($)	Quota	Gross benefit ($)
3,443	8,145	6,885	16,120	10,328	*23,925*
3,818	8,877	7,636	*17,549*	11,454	26,014
4,267	9,521	8,534	18,796	12,801	27,823
4,811	10,072	9,623	19,848	14,434	29,330
5,482	10,520	10,964	20,689	16,446	30,505
6,325	10,858	12,649	21,296	18,974	31,314
7,407	11,073	14,815	21,643	22,222	31,710
8,839	11,151	17,678	21,695	26,517	31,632
10,799	11,072	21,598	21,403	32,397	30,992
13,608	10,808	27,217	20,695	40,825	29,663
17,889	10,316	35,777	19,462	53,666	27,437
25,000	9,528	50,000	17,510	75,000	23,948
38,490	8,311	76,980	14,453	115,470	18,424
70,711	6,351	141,421	9,282	212,132	8,793
200,000	2,390	400,000	(2,390)	600,000	(14,340)

The analyst found that the total annual WTP for recreational fishing for each individual depends on:

- number of fish caught each day,

- number of days fished each year, and

- the feeling of being crowded if forced to fish in a congested area.

Obviously, the annual value (for example, WTP) will increase according to the number of days fished and catch each day. However, the annual value declines as congestion on the grounds increases. Column 3 (Table 17) represents the individual annual benefits from recreational fishing for various catch and participation levels if there is no congestion[5].

Column 4 in Table 17 shows the total maximum catch for each participant given the bag limit and the number of days fished each year. The numbers in this column are the product of the corresponding numbers in Columns 1 and 2. Knowing the catch for each 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 in Table 17 gives the number of people that can participate at various bag limits given a quota of 100 t. For any particular bag limit, the number of days fished for each individual can be determined. Therefore, the number of fish each participant will take each year can be determined. If it is assumed that the average fish weighs 0.45 kg, there will be a quota of 200,000 fish (remember that Judy is considering a 100-t recreational quota.) Dividing this quota by the number of fish caught by each person yields the number of participants to be accommodated.[6] As expected, the number of possible participants goes up as the bag limit declines. These calculations are repeated to determine how different quotas would affect the number of participants. Columns 7 and 9 in Table 17 show the possible number of participants at various bag limits with quotas of 200 t and 300 t, respectively.

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[5] In this case, annual benefits are assumed to be related to the bag limits in the following way: because days fished are a function of bag limits, benefits *(B)* can be expressed solely in terms of catch/day. B = 0.03125 (bag limit)* - 0.001375 (bag limit)^3.

6 This analysis is simplified by assuming that each person can always take the bag limit. When this isn't the case, the estimate of the number of people that can be accommodated will have to be revised upward.

Using the information from Table 17 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-t quota, these gross benefits are displayed in Column 6.[7] With a 100-t quota, the total recreational benefits are maximized when the bag limit is eight and the number of permissible participants is 8,839. Although a bag limit of seven will allow approximately 2,000 more people to participate, the congestion effects they impose on each other cause total annual benefits to fall.

The total recreational benefits that can be achieved with the 200-t and 300-t quotas are displayed in Columns 8 and 10, respectively (Table 17).

- When the quota is increased to 200 t, eight 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 t, the maximum potential recreational value will be achieved with a bag limit of nine fish. If the bag limit remained at eight while the allowable number of participants increased by another 8,839, the congestion or crowding factor would be very large.

Therefore, total recreational benefits can actually be increased by raising the bag limit. This raises the individual annual benefit when there is no congestion (Column 3) and reduces the number of possible participants that 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.

Because 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

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[7]To correct for the congestion, total benefits (TB) aren't just the product of participants *(P)* and individual annual benefits *(B)*. A correction factor is necessary to take into account how congestion will increase as the number of participants increases. The equation used in this hypothetical case is:
TB= $P*B-0.0004P\%$.

implemented for an annual cost of $7,000. In response to lobbying from the recreational-fishing club, the legislature 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 issued each year), the total net values shown in Table 17 are possible. When these benefits are compared with the losses that those quotas would impose on the commercial fishery, a policy that maximizes the sum of the net values from joint utilization can be determined.

With an appropriate regulation program, a 100-t quota can provide net benefits to recreational fishers of $11,151. Similarly, a 200-t quota can provide $2 1,695 in total net benefits, and a 300-t quota can provide $31,710. Using these figures, it is possible to show how value to the recreational sector changes as its allocation is increased by 100-t increments. A 100-t quota will provide $11,151. The marginal gain from increasing the recreational quota to 200 t is $10,544. The gain from increasing it to 300 t is $10,015.

From Table 16, it can be easily seen that a 300-t quota doesn't make sense if the total value of production is of concern:

- Moving from a 200-t quota to a 300-t quota increases value in the recreational fishery by $10,015. Value in the commercial sector is reduced by $12,300.

- Moving from no quota to a 100-t quota increases value in the recreational fishery ($11,151) more than it would decrease it in the commercial fishery ($3,870).

- Moving from a 100- to a 200-t quota will increase recreational benefits by $10,544 and only reduce commercial benefits by $4,300.

The complete analysis is given in Table 18. The table shows the maximum total potential net benefits to both sectors associated with various quota levels. From the discussion above, the sum of the net values is maximized with a 200-t recreational quota. The maximum possible net returns for the entire fishery are $62,895. By comparing this to the $49,370 - the maximum possible when the fishery is 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 isn't suitable for recreational fishing) and the value of the open-access utilization of the commercial fishery from both stocks is subtracted out, the increase in value of the two fisheries because of the agency's management will be $105,775. After the general agency budget ($50,000) and the enforcement budgets ($20,000 and $7,000) for both sectors are removed, the net economic benefit to the agency is $28,775. This is an increase from when there were only commercial fisheries and the agency's potential net economic benefit was $22,250 (Table 15). There is a cost to regulate the recreational fishery. However, in this case the gain in net values more than compensates for the regulation cost.

Table 18. Comparison of net values with multiple-use management.

Recreational quota	Net benefit to Recreational fishery ($)	Net benefit to Commercial fishery ($)	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

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 an increase in the quota to 300 t would allow more recreational participants. These individuals met with Judy and tried to persuade her to increase the recreational quota even more-they weren't convinced that maximizing the total net value of production was the proper criterion on which to base allocations.

Case Study Summary:

Everyone agreed that the additional participants that would be possible with a quota of 300 t would spend money on fishing gear, bait, gas, hotel rooms, and other items associated with recreational fishing. Surely, all of these expenditures represented an important component of the value of the recreational fishery. Judy wasn't 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 questioned what would happen if the price of gasoline fell. Fishers would spend less on each fishing trip, but this decline in expenditures would not necessarily mean that the value of recreational fishing would also decrease. Actually, the reverse would be true. Anglers would have the same recreational-fishing experience but they would be spending less.

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

Application to Farm Management:

As shown in the farming case studies, the concepts of marginal analysis and net value can be used as criteria for making resource-use decisions. Resources may be maple syrup, raspberries, a children's camp, or the fishery. The economic concepts can help make hard choices that are just, fair, and economically sound.

Additional Discussion:

Additional discussion can be found in Part I-Resource Management: Farming:

- What to Produce? A Preliminary Look
- What to Produce? A More-Detailed Look
- An Insect Invasion
- The Effects of Increased Employment
- Camping vs. Maple Syrup

The Attack of the Lamprey

Case Study:

Using the information collected, discussed, and displayed in the previous sections, the fishery agency established regulations to allocate the eschalot fishery among the commercial and recreational fisheries. The regulations provided the means to maximize the sum of the net benefits and allow the rhodolite fishery three units of commercial effort. With these regulations, net gains were:

- $62,895 for the eschalot fishery, and

- $66,080 for the rhodolite fishery.

After accounting for what the fishery would produce with no management and subtracting the general and two enforcement budgets, the net benefits generated by the agency were $28,775 (Column 1, Table 19).

All went well for the agency and the fisheries for several years. The stocks of both species remained healthy, and prices and costs didn't change. Therefore, there was no reason to consider any changes in fisheries policy. Trouble began, however, with the invasion of the sea lamprey *(Petromyzon marinus)*. This species prayed on the eschalot and rhodolite and the increased mortality affected the net productivity of both stocks. Therefore, the maximum net benefits that could be achieved were reduced.

The sea lamprey's effects on the net benefits produced from the stocks of eschalot and rhodolite are summarized in Column 2 of Table 19. Under the best management possible, the net benefits of the eschalot fishery declined to $3 1,448. The rhodolite fishery declined to $52,864. Apparently, the eschalot fishery was more susceptible to damage from sea lamprey than the rhodolite fishery. Given sea lamprey predation, the two fisheries would produce a net value of $11,600 with no agency activity instead of the $23,200 it had previously earned. The gross return because of agency activity (the difference between maximum gains with the agency and gains that would be produced without the agency) decreased from $105,775 to $72,712. Because this is less than the total budget ($77,000) of the agency, the net benefits to the agency were completely eliminated With the sea lamprey causing so much damage, the maximum net increase in value of the fishery that could be produced just wasn't enough to cover agency expenditures.

Table 19. Analysis of externally financed control programs.

	Before sea lamprey ($)	With sea lamprey ($)	Dollars spent on control			
			5,000	10,000	15,000	20,000
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

Judy talked to the directors of other nearby fisheries agencies and found that they were affected similarly. Not all had suffered as badly as Judy's agency-some of the agencies still showed positive net benefits. However, all agency heads were looking into control programs, and Judy decided to do the same.

Judy asked the analyst to see what would happen if a sea 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 3-6 of Table 19 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) cause net returns to the two fisheries to increase, but at a decreasing rate. As shown in Row 1 of Table 19, for example:

- a $5,000 control program increases the net returns in the eschalot fishery to $12,000,
- a $10,000 control program leads only to an additional increase of $9,000, and
- a $15,000 control program causes an even smaller increase in net benefits.

As seen in Row 2 of Table 19, the effect on the net benefits of the rhodolite fishery would be similar.

Judy studied the results of a $5,000 program. Because the net benefits of the eschalot fishery would increase by $12,000 and those of the rhodolite fishery by $6,000 (total increase in net benefits = $18,000), she knew that the $5,000 program would 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 19 shows that the net benefit of the agency would increase by $13,000 with the use of a $5,000 control program. However, because of decreasing returns to the control program, Judy knew that it wouldn't make sense to continue indefinitely to increase the amount spent on the control program. After examining the information shown in Table 19, Judy realized that the sea lamprey-control program that is economically optimal would cost $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 sea lamprey invasion. Increasing the money spent on control to $20,000 would increase the returns to both fisheries, but the gains wouldn't be enough to cover the $5,000 increase in the budget.

When Judy first went to the legislature with her results, she was very disappointed with the response. She was told:

1. Although the gains from a control program would be positive, the state didn't have the funds in the overall state budget to start one.

2. If a control 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 fund a control program. She needed to know what the cost of funding the program would be. The cost to her agency wouldn't be the money spent on control because she already had the money. Instead, the cost would be the loss in net benefits that would result from reducing other agency activities. She knew that if she was rational when deciding which programs to cut, she should cut the least-effective ones first.

The predicted effects on the two fisheries of the various programs are given in Table 20. There would be two effects:

1) Net value would decline because less money would be spent on stocking, habitat protection, and other initiatives.

2) However, the sea lamprey-control program would cause an increase in the fisheries net value.

Reducing the general budget by $5,000 would cause a loss of $4,500 to the eschalot fishery and a $1,000 loss to the rhodolite fishery. This means that even the least-effective programs that were cut were cost efficient because they were producing net benefits of $5,500 for a cost of $5,000. The estimated gain to the eschalot fishery from a control program would be $11,000. The estimated gain to the rhodolite fishery from a control program would be $5,500. This total gain of $16,500 is less than the $18,000 gain attributed to a $5,000 program described earlier. This is because the fisheries wouldn't be as productive-given the loss of $5,000 in the: general budget. However, the net benefits of the $5,000 control program funded internally would still be worthwhile. After taking into account all agency costs, the net benefits to 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, 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 that produce higher net benefits would have to be cut. In spite of all of these changes, there would still be an increase in the net benefits produced by the agency. Total control-program gains would equal $27,500. However, the loss resulting from the elimination of other programs would be $12,000. Net agency returns would increase to $11,212. The same couldn't be said for the $15,000 program, however. The loss in net benefits after cutting the general budget by an additional $5,000 would be greater than the returns of the increased sea 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.

Table 20. An analysis of internally financed control programs.

	Dollars spent on control			
	5,000	10,000	15,000	20,000
Status quo value of the eschalot fishery	31,448	31,448	31,448	31,448
Loss in value due to the budget switch	(4,500)	(9,500)	(15,500)	(21,000)
Gain in value due to sea lamprey control	11,000	19,500	25,000	26,500
Status quo value of the rhodolite fishery	52,864	52,864	52,864	52,864
Loss in value due to the budget switch	(1,000)	(2,500)	(4,500)	(7,500)
Gain in value due to sea lamprey control	5,500	8,000	10,000	10,500
Net economic benefit of the control program	6,712	11,212	10,712	4,212

Case Study Summary:

The results shown in Table 20 show that if the sea lamprey-control program is funded from the current general budget, it would still make sense to have a program-although the amount spent should be less than the $15,000 Judy initially wanted to spend. Judy made the decision to reallocate the budget. However, 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's budget.

Application to Farm Management:

As seen in the case study describing a pest invasion, it's important to compare marginal gains and marginal losses-marginal analysis-when making allocation decisions. For every new action or additional expenditure, it's important to consider all of the resulting gains and losses in relation to the additional costs incurred.

Additional Discussion:

Additional discussion can be found in Part I-Resource Management: Farming:

- An Insect Invasion

The Construction of a Dam

Case Study:

After the sea lamprey-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 19 and are repeated in Column 1 of Table 2 1. Then, just as things were settling down, Judy had to face a new issue-the legislature was considering the construction of a $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. The analyst found that during construction of the dam, significant mortality on the stocks of eschalot and rhodolite would occur and that reproduction rates would be affected for several years. Eventually however, the dam would indeed increase habitat, and the standing stocks of both species could increase. The net returns to the two stocks for the first four years after construction are listed in Columns 2-5 of Table 2 1. After those four years, the returns would continue as described in Column 5 (Table 2 1). These figures were calculated taking into account the optimal allocation of the resource base and the agency budget in addition to the optimal utilization of both fisheries.

Table 2 1. An analysis of the benefits from dam construction.

		With dam			
	Without dam ($)	Year 1 ($)	Year 2 ($)	Year 3 ($)	Year 4 ($)
Net returns to:					
Eschalot fishery	58,448	46,758	42,082	50,499	70,698
Rhodolite fishery	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

In the first two years, the net benefits of the fisheries agency would be negative. In the third year, although 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 (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 20 years of the life of the dam are shown in Table 22.

Table 22. The net effect on the value of fishery production.

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

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.

Case Study Summary:

The PV of the flow of returns over a 20-yr 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 PV of fisheries production would increase by $91,838 (even taking into account the reduction in the first three years). However, the value of goods and services elsewhere in the economy would fall by $75,000 as a result of the construction. There would be a net increase in the PV of goods and services produced of $16,838. Judy gave her approval to construct the dam.

Application to Farm Management:

Interestingly, 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 stocks recover from overfishing. In this case, it is necessary to consider the economic question of whether or not the reduction in the value of output in the present is worth the increase in value in the future. This dilemma was also explored when determine the long-term impact of a dam on Jean's farm.

The flow of net values above represents the effect of a management program that reduced 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 more than compensates for the increase in the latter part. In other words, because the net PV of the flow is positive, the program could be judged an economic success.

Additional Discussion:

Additional discussion can be found in Part I-Resource Management: Farming:

- The Construction of a Dam

Economic Valuation of a Fish Kill

Case Study:

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 a disaster occurred. 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 shown in Table 23.

Table 23. Economic valuation of a fish kill comparing natural recovery and a rehabilitation program

Yr	Net return of eschalot fishery ($)	Net return of rhodolite fishery ($)	Total net return ($)
	Without fish kill		
1-5	70,698	77,855	148,553
	Natural recovery		
1	28,279	46,713	74,992
2	38,884	54,498	93,382
3	49,489	62,284	111,773
4	60,094	70,069	130,163
5	70,698	77,855	148,553
	Rehabilitation recovery		
1	28,279	46,713	74,992
2	40,519	54,808	95,327
3	*52,760*	*62,904*	115,664
4	65,000	71,000	136,000
5	70,855	77,855	148,710

Continued on next page

Table 23, *continued*

Total agency costs ($)	Rehabilitation costs ($)	Value at open access ($)	Net economic benefit of agency ($)
		Without fish kill	
92,000		11,600	44,953
		Natural recovery	
78,200		6,460	(9,668)
81,650		7,745	3,987
85,100		9,030	17,643
88,550		10,315	31,298
92,000		11,600	44,953
		Rehabilitation recovery	
78,200	0	6,460	(9,668)
82,800	12,000	7,745	4,783
87,400	20,000	9,030	19,234
92,000	8,000	10,315	33,685
92,000	0	11,600	44,953

The analyst predicted that it would take five years for a return to normalcy. Therefore, his analysis involved comparing the five years of recovery to what would have occurred had the spill not occurred. Row 1 of Table 23 shows the net benefits that would have been generated during the five years if there had been no spill, or:

	Value produced by		agency's		amount the fisheries
Benefits =	the two fisheries	-	total	-	would have produced
	with management		budget		with no management

For the scenario with no spill, the net PV of the five years at $44,953 using an interest rate of 10% is $170,407.

The middle section of Table 23 shows the agency's net benefits over the five-year period given 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, the analyst found that stocking programs should be reduced 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 former level.

Taking the above information into account, the net value of the two fisheries during the recovery period is shown in Columns 1 and 2 (Table 23). 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 this period under a natural-recovery scenario is shown in Column 7.

- with no spill, the agency would have a net value of $44,953/yr,
- with the spill, the value in the first year would be -$9,668, and
- the net value wouldn't return to normal until the fifth year

The net PV of this flow of benefits at 10% would be $57,050. With the knowledge that the net PV of damages equals the difference between the PV of the net benefits without the spill and the PV of net benefits with the spill, Judy told the legislature that the company should pay damages of $113,357.

The company wanted to reduce its damage payments by setting up a rehabilitation program. Remember that with the oil spill on Jean's farm, such an option proved to be advantageous to all concerned. The bottom section of Table 23 shows the effects of the proposed rehabilitation program. The costs would be:

- $12,000 in the second year,
- $20,000 in the third year, and
- $8,000 in the fourth year.

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 PV of the fishery over the five-year period would increase to $60,534.

These increases aren't enough, however, to compensate for the costs of the rehabilitation program. Because the net PV of the fishery over the recovery period would increase with rehabilitation, the damage assessment against the firm would decline to $109,837. The net PV of the fishery without the kill is $170,407. The net PV with rehabilitation is $60,534. However, the net PV of the cost of the rehabilitation program would be $30,408 - wish a total cost to the firm of $140,281. It would be better for the company to allow for natural recovery and pay a higher damage assessment,

Case Study Summary:

The real point of this case study isn't just that the company would be better off without providing the rehabilitation program, but that the entire economy is better off without the rehabilitation program. The increased PV of fisheries output resulting from the rehabilitation plan wouldn't be large enough to compensate for the decreased PV of goods and services elsewhere resulting from undertaking the rehabilitation program.

Application to Farm Management:

This case study shows another use for PV analysis. Certain current activities can have a negative effect on productivity in future years, and dynamic efficiency requires that gains and losses in different periods be compared.

Additional Discussion:

Additional discussion can be found in Part I-Resource Management: Farming:

- The Green Revolution Comes to the Farm
- The Spill of the Exxon *Dezval*

SUMMARY

It isn't possible to summarize all of the concepts that have been introduced and the issues that have been addressed in this paper. 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--economic principles and economic valuation can help determine which choice is best.

Although the analogy with the farmer isn't perfect, a farmer and a fisheries manager do have a lot in common. They make decisions concerning the use of natural resources and other inputs 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 values gained and values lost because of the choice. Some of the choices described include dam construction, sea lamprey control, allocation of stocks between users, environmental rehabilitation, and natural-resource and budget allocations within an agency. However, the economic principles developed also apply to a host of other issues.

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

GLOSSARY

The following list of economic terms and general definitions were used in this publication.

Business success
Business success is most-commonly measured by how much income is earned. Total income should be greater than total expenses. The goal of running a business is not necessarily a predetermined quantity of a specific product or output.

Comparison of marginal gains and marginal losses
Comparing total benefits and total costs to determine the total net value of a product. The comparison is a means to acquire useful information for making appropriate economic decisions.

Costs of production
These costs include all explicit costs (such as materials and wages) and implicit costs (lost revenue or income by other business entities). Increased production of one output results in a decrease in another output.

Economic damage
The present value (PV) of the reduction in the net value of an output caused by an accident. Economic damage cost is calculated by combining the cost of rehabilitation plus the net PV of any remaining reductions in the net value of production.

Increasing marginal cost
As the value of a particular output increases, there is a decrease in value of an output elsewhere.

Marginal analysis
The result of a comparison between total gains/benefits and total costs/losses to produce the highest possible net return. The analysis compares the impact of input variables to determine the best allocation of available resources that will result in the highest net return.

Marginal costs
The increase in total cost required to produce one extra unit of output.

Marginal product (MP)
The increase in output as a result of one extra unit of input assuming no change to any other inputs.

Marginal revenue
The change in revenue caused by the contribution of an input (for example, the increase in revenue as a result of an additional worker).

Maximization of the value of output
One criterion for determining the optimum combination of outputs taking into account that producing more of one output results in the loss of another output.

Net gain
The value of the output minus the value of the inputs used in production.

Net income
Total income minus total expenses. It is the value of goods and services produced minus the full cost of all inputs used to produce them.

Net present value (PV) techniques
Techniques used to compare gains and losses of a project that have long-term effects on production. Some short-term gains will be offset by future losses.

Net return
Net return is total revenue minus the costs of production.

Opportunity cost
The value lost (or opportunity lost) by choosing to consume or produce one economic product or service instead of another.

Present value (PV)
The current value of a product or service that will continue to have value over a period of time.

Present value (PV) analysis
Comparing gains and losses of a product or service in different time periods in the future to determine future increases and decreases in its value. Valuation is calculated by applying a discount rate to future incomes.

Successful operation
In farming, a net gain of the value of the output minus the value of the inputs used in production. In fisheries-management agencies, successful operation is measured by the net value of the production from the resources and inputs under the agencies' control.

Trade-offs
Trade-off compares what is gained against what is lost. This trade-off ratio is used to determine how to allocate productive capacity.

Value
The worth of a product or service measured against other products or services.

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