Synergy in the Evaluation of Natural Coastal Systems

by

Christophe Pozet

Submitted to the Department of Ocean Engineering
in partial fulfillment of the requirements for the degree of

Master of Science in Ocean Systems Management

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

February 1994

Author ....
Department of Ocean Engineering
September 10, 1993

Certified by ....
Judith T. Kildow
Associate Professor of Ocean Policy
Thesis Supervisor

Accepted by ....
A. Douglas Carmichael
Chairman, Departmental Committee on Graduate Students

Synergy in the Evaluation of Natural Coastal Systems

by

Christophe Pozet

Submitted to the Department of Ocean Engineering
on September 10, 1993, in partial fulfillment of the
requirements for the degree of
Master of Science in Ocean Systems Management

Abstract

The objective of this thesis is to enhance the evaluation of natural coastal systems by introducing the idea of synergy among the different uses of theses systems.

The notion of a natural system and its links with human activity are explained. It is then shown that it is not possible to value a subcomponent of the system, be it a geographical area, or a single use. The idea of synergy, which stems from the interrelations among the uses of the system and all the entities composing it, is introduced. Because of this synergy, a simple addition of the values of the different uses of the systems, although an unavoidable and difficult enough first step, show thus insufficient. A methodology which tries to capture the value of the synergetic effects is proposed. The difficulties arising in its implementation are discussed, and it is shown that, despite them, valuing natural systems according to the proposed methodology is necessary and helpful for decision making. The case of the Saugus River Watershed, Massachusetts is studied as an illustration of the theoretical part of the thesis. The obstacles imposed by the political structure are a major feature of this case study. To close, directions for further research are suggested.

Thesis Supervisor: Judith T. Kildow
Title: Associate Professor of Ocean Policy

Acknowledgments

My thanks go first to Professor Kildow and Professor Rothenberg, Department of Economics. The ideas in this work are theirs as much as mine. Errors, and omissions are not theirs.

I also want to thank John Teal, Professor at Woods Hole Oceanographic Institute, Doctor Diane Gould, Director of the Mass Bays Program, Peg Brady, Deputy Director, Division of wetlands and Waterways, Massachusetts Department of Environmental Protection, and Ann Monelly at the Saugus Watershed Council who accepted to dedicate some of their time to me, and were always highly competent and helpful.

To my parents.

"Perhaps that is because none of us can know something's true value until it is gone."

Prince Josua,

Memory, Sorrow, and Thorn; Book Three.

Contents

1 Introduction **11**

2 System and Uses **13**

2.1 System as a set of linked subcomponents 13

2.1.1 Notion of valuation unit 13

2.1.2 Valuation units and the policy making process 16

2.2 System as a set of uses and maintenance functions 17

2.2.1 Uses of the system 18

2.2.2 Maintenance functions 19

2.2.3 Indicators 19

2.3 Conclusion 20

3 Value and Synergy **21**

3.1 The concept of value 21

3.1.1 Non-preference values 21

3.1.2 Preference values 22

3.2 Values and economics 23

3.3 Synergy 25

3.3.1 The idea of synergy 25

3.3.2 The hierarchical order 27

3.4 Conclusion 30

4 Risk **31**

4.1 Notion 31

4.2 Natural systems and discount rates 33
4.3 Under which conditions can our methodology be favorable ? 34
4.4 Conclusion 36

5 Problems of valuation 37

5.1 How to value each use ? 37
5.1.1 Commercial production 38
5.1.2 Non-commercial matter related uses 39
5.1.3 Amenities 39
5.1.4 transcendental uses 41
5.1.5 Useless efforts ? 41
5.2 Alternative approaches to the valuation of natural systems 42
5.2.1 What alternative to economics based decision making ? 43
5.2.2 Free market environmentalism 43
5.3 Conclusion 47

6 Background data on the Saugus River Watershed 48

6.1 The Saugus river 49
6.2 The geographical watershed 51
6.3 Baseline assessment of the Saugus River Watershed 53
6.4 Conclusion 54

7 The Saugus River system 55

7.1 Description of uses 55
7.2 Relationships among the uses 59
7.3 Two developed examples 62
7.3.1 The water intake 62
7.3.2 Lake Quannapowitt 67
7.4 Conclusion 68

8 General conclusion 70

A Information for the general public about the Saugus River Watershed 72

B Net Present Value calculations and time scales 74

C Brochure edited by the Saugus River Watershed Council 76

D Detailed maps of the Saugus River 79

List of Figures

2-1 Strongly linked ecosystems have to be valued as a whole 14
2-2 Different boundaries 16
2-3 Opportunity costs neglect the dynamics of the system 18
2-4 Description of the system 20

3-1 From held values to assigned values 22
3-2 Value of synergy 27

4-1 Risk 32
4-2 Benefit-risk diagram for a given use 33
4-3 Simple benefit-risk diagram 35

6-1 The Saugus River Watershed 50

7-1 Sum up of uses for the Saugus River system 59
7-2 General benefit-benefit qualitative analysis 61
7-3 Influence of drinkable water production benefits on other uses' benefits 63
7-4 Influence of drinkable water production benefits on other uses' risk . 64
7-5 Effects of reducing the water withdrawal 65

List of Tables

3.1 Ordering of uses for wetlands 28

6.1 Watershed breakdown by town 52

B.1 DCF's for a stream of $1 with a 7% discount rate 75

Chapter 1

Introduction

Thesis objective Human activity has reached a size where its impacts on the environment cannot be neglected any more. Every day environmental issues become more critical. This is true on a global scale with threats such as global warming, but also at the local level. Coastal zones are especially put under stress because of very high population density. Decision-makers are faced with the following questions: Should society maintain the environmental integrity of natural coastal systems ? At what cost ? Which criteria should be used for decisions to spend money to preserve the environment rather than on other important issues (health care, education, research...) ?

This thesis tries to add a piece to the elaboration of an answer to these puzzling questions. It deals with the challenging problem of evaluating the benefits to society of natural systems. More precisely, it studies the existence of a synergy among the different uses of natural systems and their value to society. If indeed natural systems are the theater of synergetic effects, traditional methods of valuation, which simply add up the values of the different uses considered independently, are erroneous.

The aim of this work is to enhance the process of valuation of natural systems, so that the decisions regarding the environment more realistically reflect people's preferences and more surely result in an increase in the wealth of the society. It is designed for decision-makers but not as a tool which can be used directly: it is more a reflection which points out deficiencies, proposes enhancements, and shows the directions for further research.

Thesis structure The thesis consists of two parts. A methodology to value natural coastal systems, and a case study that illustrates the central points of the methodology.

The document is divided into chapters. Chapter 1 studies the definition of a geographical area bounding the system and conceptualizes the links between human activity and the system. Chapter 2 introduces the idea of synergy. Chapter 3 proposes a methodology which tries to avoid the loss of the synergetic value during the valuation process. Chapter 4 discusses the difficulties arising when trying to implement valuations of a natural systems. The accuracy and usefulness of such valuations are discussed. Chapter 5 and 6 are dedicated to the study of the Saugus River System (Boston area, Massachusetts). This study serves as an illustration of the first part of the thesis. The thesis concludes with suggested directions for further research.

Chapter 2

System and Uses

Before starting to value a system, the system itself has to be chosen. This encompasses the choice of a geographical area (section 1), and the clarification of the way we consider our uses of the system (section 2).

2.1 System as a set of linked subcomponents

2.1.1 Notion of valuation unit

From the point of view of ecology, it would seem dangerous to choose a geographical entity which has strong links with other systems and, more generally, the rest of the world. This should suffice to explain why one cannot value any arbitrarily chosen area. There is an obvious part to this: a reasonable analysis would not draw a boundary through a given ecosystem (we designate an ecosystem as an area showing ecological uniformity: a wetland, a saltmarsh, or a certain type of forest), cutting it into two parts. The point made here is that respecting ecological integrity is not enough: if two or more different ecosystems are *linked*, they have to be valued *as a whole*. This point is illustrated by figure 2-1.

An ecological argument would not be strong enough to convince economists, but there is some evidence [11] that economics itself requires that the system valued be as weakly linked as possible to the rest of the world. The following example

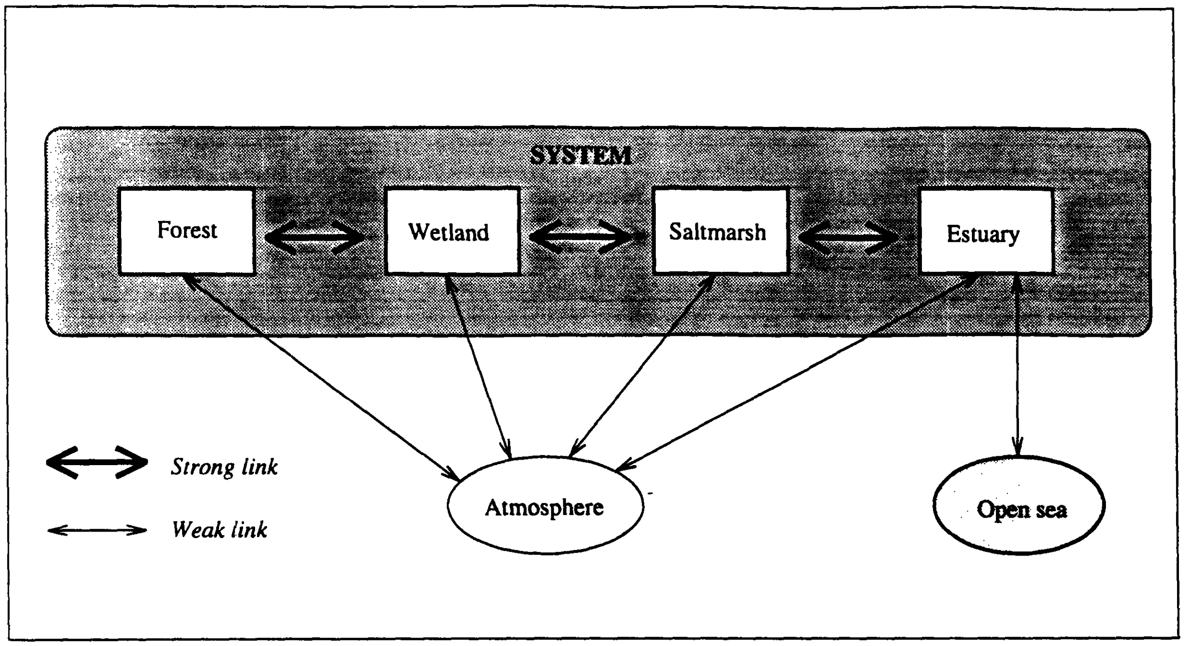


Figure 2-1: Strongly linked ecosystems have to be valued as a whole

illustrates this point. Let's imagine a watershed system composed of two ecosystems: an upstream forest and, downstream, a wetland. Let's try to estimate the value of the wetland alone. One of its functions might be to retain sediments coming from upstream, thus avoiding expensive dredging along the coast. When the amount of sediments increases, so does the value of the wetland (assuming that losses in fisheries are more than offset). The incentive is thus to increase erosion upstream without limit. A result which is somehow disturbing. Let's assume now that the rivers twisting through the forest constitutes the spawning ground of a species of fish which is caught in the wetland. The valuation of the wetland alone is by no means affected by the way the forest is managed. For example the value of the wetland will decrease if the population of fish does so. But the reason for this decrease in population may be the poor environmental quality of the forest even though the wetland would be able to support the fish. However, since the wetland is valued alone, there is no incentive to preserve the "spawning ground" function of the forest.

A stream of thought in environmental economics, called "free market environmentalism" [5], would argue that this last case is an externality problem and that the creation of property rights for the spawning ground function would insure its proper valuation through the market mechanism. We will show the many dangers of this approach later, but we can already realize that it will truly be accurate, will really match the ecological reality of the system only if the internal dynamics of the spawning function, and ultimately the system itself are fully understood (which ultimately means the overwhelming description of the cycles of the primary elements —carbon, oxygen etc. themselves). This is not a problem of stochasticity since markets can deal with uncertainty. This is not a problem of information according to the economic meaning: even though all actors have free access to all information available, if there is a gap between what we know about the system and its reality, the market mechanism will lead to a value which will certainly be coherent with itself, but nonetheless wrong as regards the ecological behavior of the system. On the contrary, by valuing the system as a whole, there is less chance of mistakes due to our ignorance of the micro-level dynamics.

In short, it is not possible to accurately value a subcomponent of a larger system. This result logically leads to the conclusion that the only accurate valuation we can reach (other problems left aside) is that of the largest system, i.e. the earth itself. This is because the very air we breath travels all over the planet, connecting all continents. For example, we shall see later that wetlands can be thought of as carbon sinks. Local communities cannot gain benefit from this feature however, because the benefit goes to humanity as a whole by influencing the amount of carbon dioxide at the global level.

Our principle, that only the global system can be valued, is useless at the local level. But it shows that errors can be reduced by valuing a system which is as weakly linked as possible to other systems. In a coastal management perspective, the smallest "valuation unit" (elementary valuation unit) consists of a watershed because of the strong upstream/downstream link. This watershed approach is not new [13] and permits insightful analysis [10]. It also seems unavoidable to extend the watershed into the sea. How far it should be is a difficult question, the answer to which varies in each case. As a matter of fact, two different watersheds may be so strongly linked in their marine part, that they have to be valued together. In any case, given the

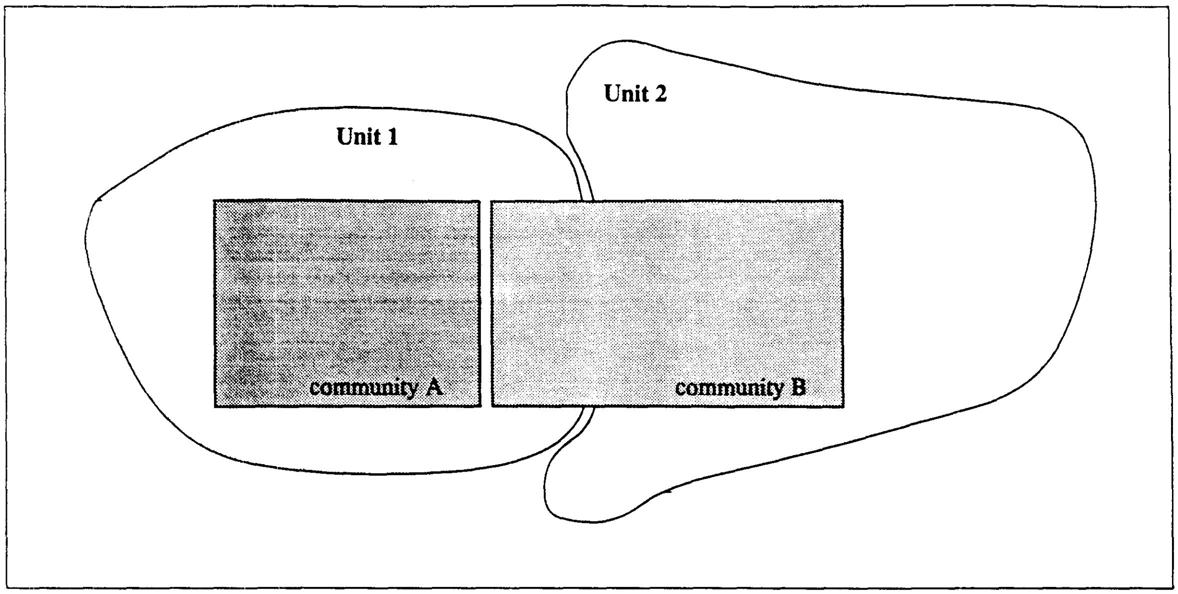


Figure 2-2: Different boundaries

mobility of marine life and the unbounded nature of marine ecosystems, some mistakes are likely to remain at this end of the system.

2.1.2 Valuation units and the policy making process

The argument we just made is by itself very important. Before going further, it seems worth discussing its consequences on policy decisions.

Of course, if legal boundaries matched that of valuation units, not only would the valuation process be simplified but its results could be taken into account more easily. In a way, communities would serve the society as a whole by defending their own interest. It is not the case though, and a systemically sound valuation can yield strange results. For example, consider figure 2-2 where unit 1 is shared by community A and community B. A socially efficient valuation has to be conducted according to the unit boundaries. If the optimal management decision coming out of this valuation goes against the interest of one of the two communities, there is little chance that it will be adopted unless both parties are compelled to sit at the same table and reach an agreement. This is possible only if all the actors realize that their true interest lies in the fate of the total valuation unit. Who wins and who loses is then a matter of negotiation. In fact, there is a research challenge to improve the negotiation processes related to the environment. The general public has to be informed as well so that officials feel compelled to succeed. An initiative such as that in appendix A show an example of action which can be undertaken at little cost.

Also interesting is the fact that, within community B, one use of the system (be it recreation or fecal matter absorption) may have different values for units 1 and 2, so that the pricing system, or the law, may vary among the members of community B. This may seem unfair but we have here a distribution problem. Ideally, it should not interfere with the optimal use of the natural assets. This is the same situation as the one we previously described but within a community. Economists always emphasize the fact that they do not deal with distribution issues [4, chapter 1]. Although they usually refer to income, the phenomenon is the same with the environment. In real life however, distribution and allocation are very often linked, maybe because allocative solutions, such as short run maximum growth (whatever the costs in the long run), permit to avoid difficult distribution decisions. For example, let's imagine that society as a whole would benefit from the limitation of the number of recreationists on a site. This limitation should be imposed. However, some classes may suffer more than others from it. Some steps have to be taken if one wants to counteract the *unfair* distributional effects of such a limitation. Indeed, it is easier to do nothing and let the number of people increase: society gets worse off but nobody can be pointed out as loser.

2.2 System as a set of uses and maintenance functions

We try in this section to clarify the interface between human activity and the natural system. This statement is already a sign that the analysis will be human-centered. Indeed, we will focus on the uses of the system (such as recreation, water filtration, food production, or flood protection). This approach is justified in the next chapter. We will also include the system itself however, thanks to the idea of maintenance functions.

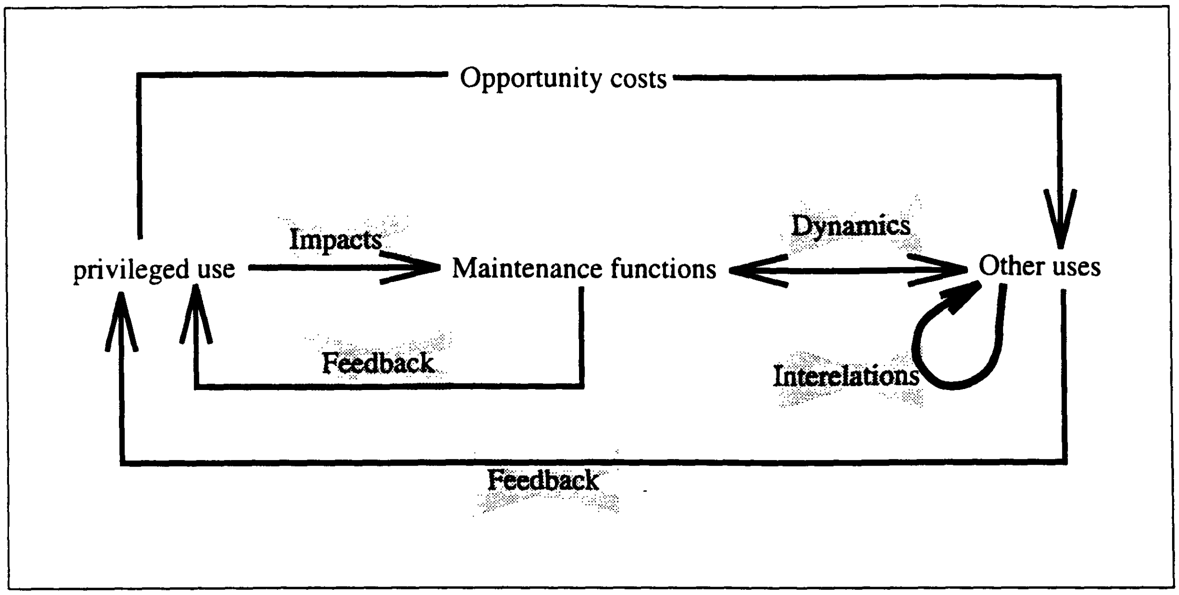


Figure 2-3: Opportunity costs neglect the dynamics of the system

2.2.1 Uses of the system

We just saw that a geographical subcomponent of a system cannot be extracted from it. It is the same for our uses of the system: it is impossible to value one without considering the others. As a matter of fact, most studies in environmental economics focus on only one use [25, 1]. In a work called "An Assessment of Methods for Economic Valuation of the Northern Spotted Owl" [30], the author points out that the analysis is complicated by the fact that people's willingness to pay for the conservation of the spotted owl is influenced by their attachment to the old growth forest. He concludes that data have to be worked on to *extract* the value of the spotted owl. But what does this value mean ? The spotted owl exiled from its habitat and deprived of its influence on this habitat is certainly not worth a lot. Tear apart your heart from your body, destroying all the connections between them, the value of your organ is not more than that of a single piece of meat.

When a cost/benefit analysis is undertaken, generally to assess the worth of intensifying one privileged use, the link with other uses is taken into account through opportunity costs. But the tendency is to simply neglect the opportunity costs of uses which are difficult to evaluate. This means attributing a null value to these uses. Moreover this approach, even if carefully undertaken, accounts for the impacts of the privileged use on the others, but forgets that the system as a whole will react and provide feedback on the privileged use and other uses, and will determine how all those uses will ultimately interact. If the maintenance of the system cannot be fulfilled, will the system remain in a dynamic equilibrium close to the background situation, or will it move to a very different state ? Figure 2-3 illustrates the shortcomings of the opportunity cost approach. If we instead value the system as a whole, with all of its uses, we do not have to worry about opportunity costs: all uses are linked and we acknowledge that fundamental feature by reassessing the value of each of them even when a change in the level of only one use is planned. To do this, knowledge of the relations among the different uses must be available. Some research is needed in this area. The optimal situation would consist in being able to determine these relations without having to understand the system at the microlevel (a black-box approach). This is likely to be only partially possible though, so that our methodology requires the study of the internal dynamics of the system. The idea of maintenance function will help in this.

2.2.2 Maintenance functions

Certain species, certain characteristics of the system are critical to its maintenance, and thus to the persistence of the uses of the system. For example, the flushing of a tidal marsh is critically important to the health of the marsh. Intensifying one use of the system will alter the efficiency of the maintenance functions which in turn will influence our degree of freedom to use the system. These maintenance functions constitute the link between the dynamics of the system and its uses. That is why they are present on figure 2-3. We will study the problem of their valuation in the next chapter.

2.2.3 Indicators

Finally, we complete our description of the system by a set of indicators, the result of monitoring. Indicators are an insight into the system. Indicators are concentrations

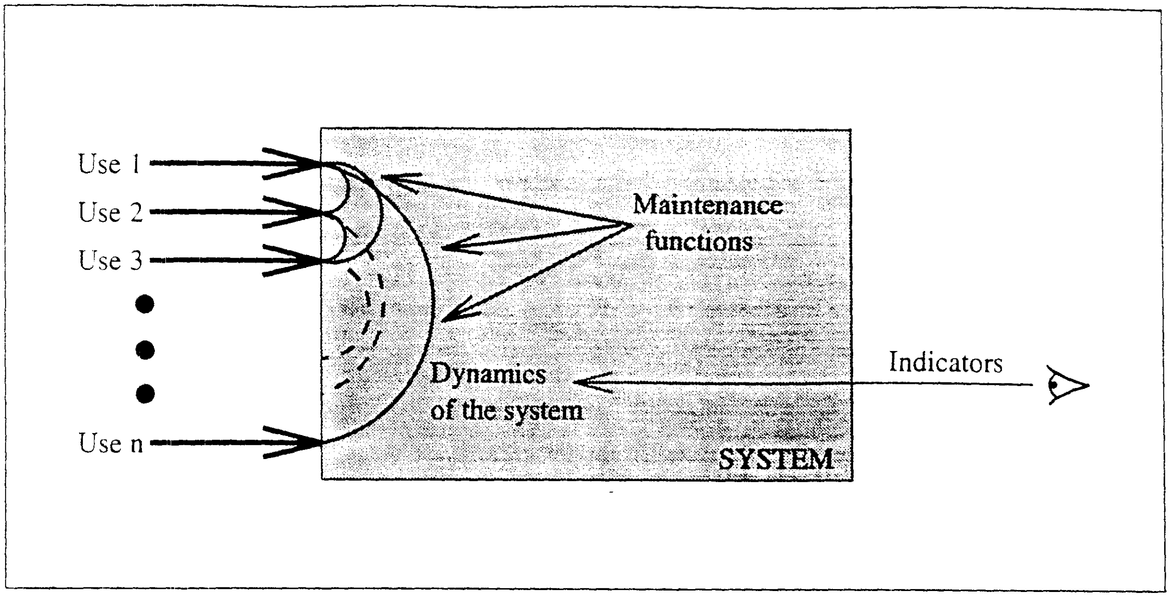


Figure 2-4: Description of the system

of certain chemical compounds, populations of certain species... We distinguish them from the level of the different uses of the system, which are not state variables but inputs. Monitoring is common in environmental management, but there are some holes in our knowledge of the intensity of our uses of the system. However, knowing what we put into the system (or remove from it) is a necessary condition to understanding the links among the uses.

2.3 Conclusion

To sum-up our description of the system:

1. The system is composed of at least one valuation unit (watershed + marine zone) as weakly linked as possible to the rest of the world.

2. The system is valued as a whole but we focus on the human uses of the system.

3. These uses are linked together by the dynamics of the system, and the system is maintained by a set of maintenance functions.

4. Indicators give information about the state of the system.

Figure 2-4 is a graphical representation of our approach.

Chapter 3

Value and Synergy

In this chapter, we first describe the concepts of value. Then we relate these descriptions to our problem. This will enable us to understand why we misvalue natural systems and suggest a way to try to enhance the situation.

3.1 The concept of value

There is not one idea of value but many. The first distinction is between non-preference and preference values. We just give definitions first, discussion comes in the next section.

3.1.1 Non-preference values

Non-preference values could be called intrinsic values. We can distinguish two kinds of intrinsic values: the intrinsic value of the system itself and intrinsic values of functions fulfilled by entities inside the system. By intrinsic value of the system itself, we mean that, independently of mankind, the system might have an abstract existence value prevailing over the economic ideal of efficiency of allocation, the existence of the system being given an absolute priority.

The other kind of non-preference values are called "functional values" [3, p. 233]. They come from the physical or chemical relationships between non-human entities (value of vegetation for a certain species, value of a predator as regulator of lower

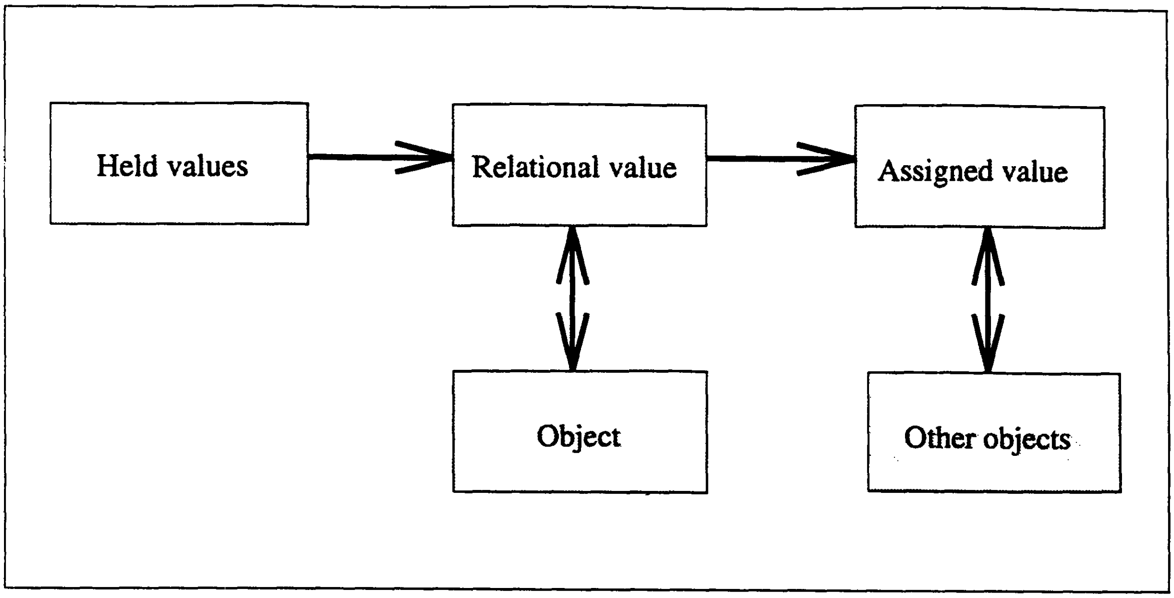


Figure 3-1: From held values to assigned values

species...). Whatever our preferences, they do exist because they play a role in the state of the system, and their importance depends on the dynamics of the system alone. This is the task of ecologists to find these relational value by studying the relationships among the entities of the system.

3.1.2 Preference values

Preference values are human related. There are three realms of preference values: held values, relational values, and assigned values.

Held values constitute an individual's conception of the preferable. Ideals such as generosity, honesty. Held values are at the basis of our conduct and function as labels for our determining of relational and assigned values.

Relational values emerges from the interaction between a subject and an object [3, p. 233]. They exist at the feeling level but generally produce an expression of value.

Given a set of relational and held values, and a certain context (information, involvement in a group, possibility to represent a group of people), it is possible for an individual to assign value to an object in comparison to other objects. A possible progression from held to assigned values is presented on figure3-1.

The slightly confusing aspect of this classification lies in the fact that it is possible to put an assigned value on held values, by saying, for instance, "altruism is better than egoism". But this valuation is still done under the norms provided by held values.

3.2 Values and economics

Economics do not deal with non-preference values. As stated by Brown [3, page 231]:

> The individual human being is seen, for all practical purposes, as the originator of preference and, therefore, of value.

We may decide that the system itself, as a whole, has an intrinsic, non-preference value. This ethical apriorism would lead to the emergence of some "natural rights", similar to human rights, or to a theory close to the concept of "imperative of responsibility" [18] toward the future generation. The former idea would mean explicit trade off between human freedom, welfare, and death against the environment, since the human rights would not be the only absolute reference any more. The latter idea leads to trading off wealth today against quality of life and lives in the future. We do not develop these ideas here because we placed this work in an economic context, close to an utilitarian decision making process.

Having chosen this economic context, we should not consider the functional values either. They have no direct assigned values but only an implicit "instrumental" value through the uses of the system. As a matter of fact, since they are part of the system, their intrinsic value should be reflected in the assigned values of the different uses of the system. It is not what happens though due to the way we value natural systems, and that is why we do have to take them into account explicitly. In fact, the maintenance functions would be valued through the uses of the system only if the system was considered as capital, the different uses being the outputs of this capital. Let's note that, in this case, there would be no reason for the total value of the system to be the sum of the values of the uses. On the contrary, what we do is value the system only through our uses of it. Instead of maximizing our capital, i.e. having the healthiest system, we maximize the outputs of the system. Of course part of this misvaluation of natural systems comes from the discrepancy between the ecological time frame and the one we use for economic purposes. Five years is the typical term for investment decisions, economic measures or political regulations. But natural systems cannot adapt to this convenient, artificial sectioning of time. They continually evolve at a very slow pace, but they can also shift from one state to another in a very short time. For example, a breach in a barrier island is a discontinuity in the evolution of a coastal system which can lead to tremendous changes within a week. So far, our valuations have focused on the short term instead of taking the long term fate of natural systems into account. On the other hand, we are not prepared to deal with very fast, exponential changes either.

We are in fact faced with a "common property" problem, not because many people use the system (like in the original description of the Tragedy of the Commons [15], but because there are many uses of the system, which we try to maximize without regard for their interrelationships and impacts on the system. In the original tragedy of the commons [15], the system collapses because the benefit each individual gains from an increase in his or her use of the system is not properly balanced by a higher cost to society. The incentive is thus to overuse the system. Here we have the same problem: an increase in a specific use is considered marginal while, in fact, it impacts the system as a whole. And this goes on as long as the resource is not scarce enough so that the economic process can become active. The problem is that this level of scarcity depends on human preferences, and not on the ecological, biological state of the system (minimum population of a species to ensure sustainability, size of habitat...). What can happen and does happen (consider the example of fisheries) is that the system collapses before the level of scarcity demanded by the economic process is reached.

Even if the time frame problem were solved, the fact that all uses are interrelated, the uncontrollable gap between human preferences and real behavior of the system would still lead to errors in valuation. In short, we can summarize the situation as follows:

- The system has no accessible economic value (assigned in an economic context) because it is a whole, while a traditional economic analysis would consider its uses separately.
- However, we have access to the economic value of the different uses of the system only (with which level of accuracy is a problem discussed in chapter 5).
- Simply adding the value of the different uses thus leads to a misvaluation of the system.

Since the use values are what we have access to, we have no choice but to start from them, when trying to value the system. In order to capture the remaining part of the value of the system — the part related to the fact that the system cannot be cut into pieces because it is an integrated entity maintained by the maintenance functions— we introduce the idea of synergy among the different uses of the system.

3.3 Synergy

3.3.1 The idea of synergy

Main stream economics either ignore the relations between economic activity and the environment, or consider the environment as external to the economic process. This is not true of new developments such as ecological economics or bio-economics [12] which try to take into account the fact that human activity is *part* of the global system. Our idea of synergy is in accord with these attempts: synergy between the different uses of the system means ultimately a better cooperation (an idea which is now as important to biologists as natural selection and competition among species) between man and the environment.

The following extract [23, page 398] is a striking example of disappearance of synergy:

> As a result of the problems associated with nutrient loading, recreational use of the bay has declined. This is demonstrated by the decline in attendance at St. Albans Bay state Park, located at the head of the

bay. In 1960 total attendance for the park was 27,456, and in 1970 it was 25,982. After 1970, as the eutrophication problem accelerated and became noticeable, attendance steadily declined to a total of 3,261 in 1979. As a result of declining use, the State of Vermont ceased active management of the park in 1980.

The synergetic effects are linked to three very important characteristics of the system:

- resistance,
- resilience, and
- persistence.

The more diverse the system, the stronger it is in these three domains. And to specialize the system in a specific use reduces its diversity. For example, overload in nutrients produces eutrophication which favors strongly one type of vegetation but destroys many other species. What do we mean here by diversity ? If the system alone were at stake, biological diversity would constitute the right concept. But once more, we placed ourselves in an economic context, so we have to consider people's preferences and uses as well. Biological diversity is independent of human preferences: it is possible to build norms based on differences in genetic heritage to measure it objectively [8]. We want a concept that links diversity to the assigned values of species, uses and characteristics of the system. The economic reality is that however important to the maintenance of the system micro-organisms are, people do not put as high an assigned value on them as on mammals or birds. Let's call *complex* a system which is diverse enough to support highly valued forms of life. Complexity can then be used as a measure of the level of synergetic effects in the system. Complexity is in fact not very far from the real biological diversity (the conceptual approach is different though), because a system where birds, mammals, or aesthetically valuable flora exist has to have a high biological diversity, and thus is the site of strong synergetic effects. For this reason, we can state that: the more complex the system, the bigger the value of the synergetic effects among the different uses.

The fact that these synergetic effects have a value is apparent when one studies

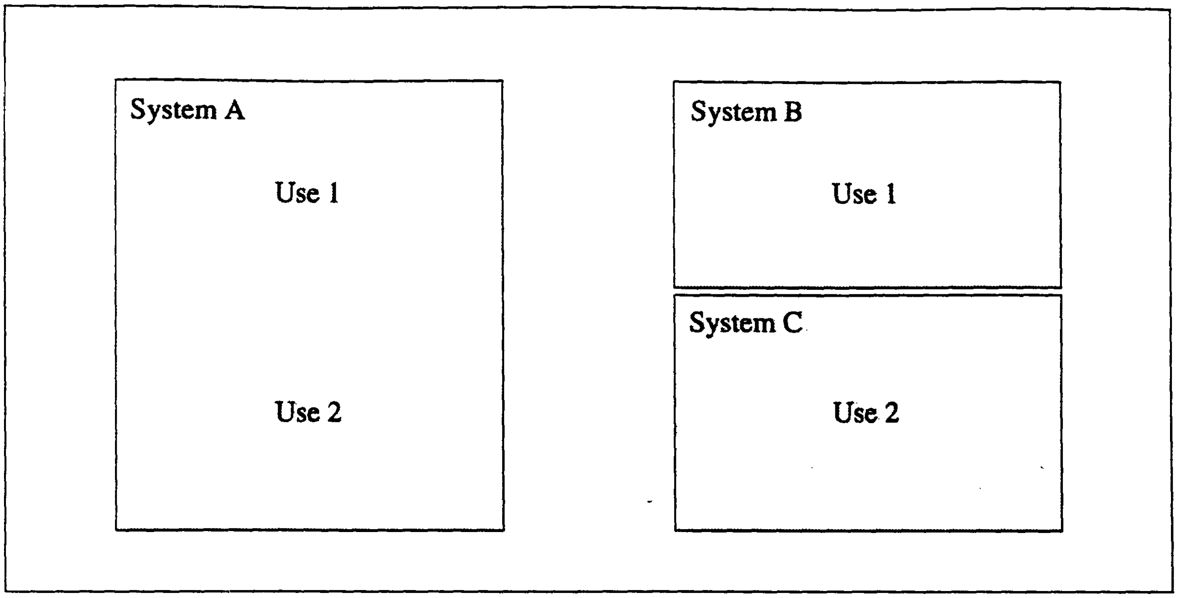


Figure 3-2: Value of synergy

the many difficulties we have in building ecosystems [31]. Very often, after a few years, an artificial wetland is nothing more than a pool with one or two dominant kind of plants but no complex food web, no mammals or birds. And these failures are not only attributable to the neglect of ecologists'specifications [24, page 1892]. All entities of a wetland develop in such a close relationship that we are unable to reproduce it. We have no reference of studies trying to capture the value of these synergetic effects.

In short, we can sum-up the idea of synergy by stating that, ceteris paribus, society is better off with system A (see figure 3-2), than with the sum of systems B and C, even though the economic benefits of A are equal to that of B and C added together. Uses 1 and 2 are less harmful to system A because the system is more complex. The two uses are more efficiently carried out. And, finally, system A is less sensitive to incremental changes in uses and to its own stochastic variations. These three reasons explain the difference. We now have to recognize that, despite our symmetrical treatment of uses 1 and 2, all uses cannot generally be put on the same level.

3.3.2 The hierarchical order

COMPLEXITY

Class 1	Ground water recharge
	Retention of nutrients from agricultural runoffs
	Retention of heavy metals and hazardous organic compounds
	Acid mine drainage
	Sulfur sink
Class 2	Carbon sink
	Flood water protection
	Sediment retention
	Storm damages protection
Class 3	Erosion protection
	Timber production
	Fur production
	Sea food production
	Nut, wild rice, blueberries, cranberries, honey production
Class 4	Spawning ground
	Research
	Education
	Aesthetics
	Swimming, boating, beaching, picknicking, hiking
	Hunting
	Wildlife watching
Class 5	Additional species support

Table 3.1: Ordering of uses for wetlands

It is much easier to create an artificial wetland dedicated to the retention of nutrients from agricultural runoffs than one which has aesthetics and recreational quality [14]. All uses of a wetland, and more generally any system, do not require the same degree of complexity. Table 3.1 shows a classification of uses for wetlands. It may not be complete and there is little chance that all these uses can be found at the same time in a given system. This table has to be built for each case.

The following example illustrates the idea behind the ordering of uses. Retention of nutrients requires only vegetation and microscopic forms of life. A system with only these forms of life would have little value to wildlife watchers: this latter activity requires the whole food-web that leads to birds and mammals. As we said, our idea of complexity is not only intrinsic to the system, but takes people's preferences into account: birds may be less important than some micro-organisms to the maintenance of the system, but they are more important to people.

This hierarchical order has impacts on the synergy among uses in the following ways. First, uses are likely to disappear in packages and not one after another, so that the loss of one use generally means the disappearance of several others (we will develop the consequences of this characteristic on our methodology in the next chapter). Second, simplifying a system for one use has different impacts depending on the class of this use in that it will destroy all uses of the higher classes. Overloading of nutrients for example, will lead to eutrophication and the likely collapse of commercial production and recreation. Two remarks must be made here: first things are not clear cut of course, it would be surprising given the complexity of the system — for example, too much boating (class 4) at the edge of a marsh can ultimately destroy the vegetation (class 1) that permits ground water recharge —; second a little increase in nutrient loading can evidently increase commercial production, but isn't it precisely an example of a synergetic effect ? The human problem is one of thresholds: at which point do we jeopardize the system (destroy the synergetic effects) by deciding to increase a specific use ? Lastly, there is some evidence that the more complex the system, the more efficiently a lower use is carried out (for example, the presence of fish and shellfish may favor the assimilation of toxic compounds by a wetland).

Increasing the level of a use in excess thus has the following consequences:

1. diminishing marginal returns on the privileged use,

2. increase of risk of seeing this use collapse,

3. loss due to the disappearance of higher uses,

4. decline in efficiency for the lower uses, and

5. decrease in synergetic effects among all the remaining uses.

This is much more than items 1 and 3 which are the only one classically considered, in the best cases.

3.4 Conclusion

Having no other economic value but the monetary benefits of our uses of the system, we have to start with them to value the system. In order to correct for the fact that this approach is intrinsically erroneous (the only relevant value is that of the system as a whole), we introduced the idea of synergy among the uses. This synergy cannot be measured in monetary terms though. We propose a measure in the next chapter.

Chapter 4

Risk

In this section, we show how the idea of risk can be used in a valuation process to avoid losing the synergetic effects provided by a natural system. We first explain what we mean by risk. We then examine the problems of time discounting, which are linked to a notion of risk. Finally, we suggest directions of research which could validate our approach.

4.1 Notion

As we saw, complexity could be a measure of the synergies among the different uses of the system. But we think that the concept of complexity remains abstract and far from the decision making process.

We introduce a notion of "risk of collapse". By collapse, we mean total disappearance or quasi-total (like in the Vermont case we saw earlier). And the kind of analysis we suggest can be illustrated as follows. Let's imagine a system with several uses. Starting at point A (see figure 4-1), we imagine that we increase one of the uses (for example nutrient retention). For a time, benefits rise without any harm to the system. But at one point (B), the synergetic effects among the uses begin to decrease because we simplify the system by specializing it: benefits continue to rise but risk does also, so that an analysis on the benefit axis alone is not valid anymore. Is society better off on point B or C ?

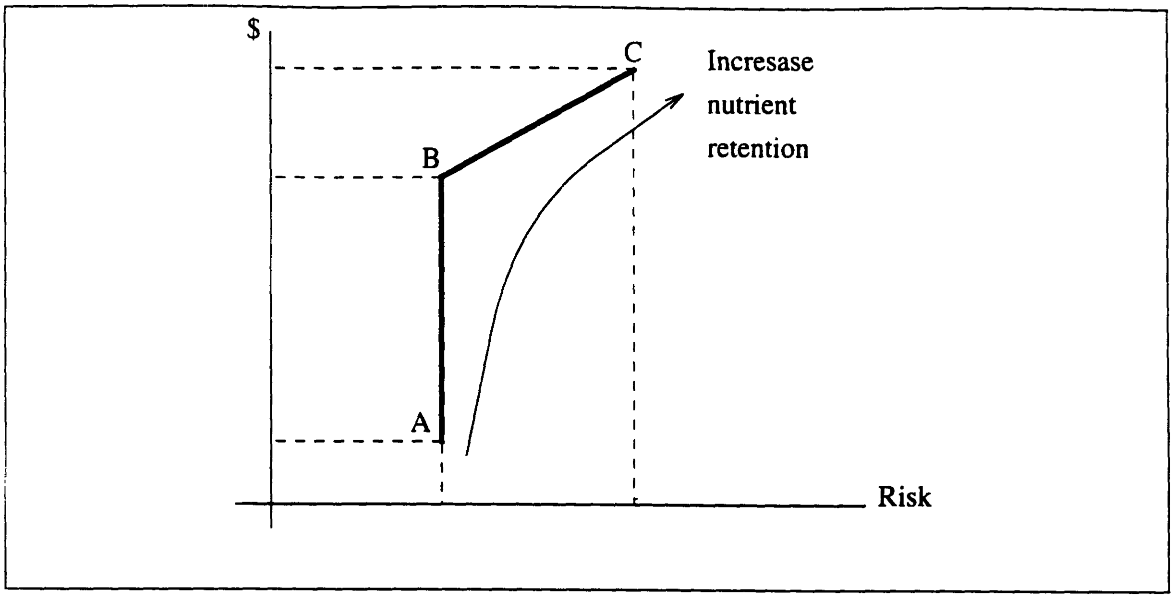


Figure 4-1: Risk

The example above does not elaborate on the idea of risk. Of course a time span has to be attached to it, so that our measure becomes "likelihood of collapse within the next n years" (we will see the advantages of this later in this chapter). Secondly we did not state by what the risk was born: collapse of the system ? Of a use ? Uses disappear one after another, the system itself changes significantly but can survive even in a very degraded environmental quality. Risk attached to each use is the only choice. Our measure is finally "likelihood of collapse of a given use within the next n years".

We thus analyze our system in a space composed, for each use, of a benefit and a risk dimension. So that even for as few as 2 uses, there are already 4 dimensions. Consequently, the decisions should be based not only on benefit vs. benefit analysis (influence of a use on the benefit of another use) but also on benefit vs. risk. For example, an increase in sediment loading can lead to turbid waters, which makes the number of recreationists decrease but it can also alter the system so that swimming becomes really unpleasant: the benefits of the recreational uses will decrease, but there is also a risk that this use may disappear completely. Opportunity costs, based on expected flows, cannot deal with this risk of collapse because it is related to a highly non-linear behavior of the system (hence the name collapse). Actually, for

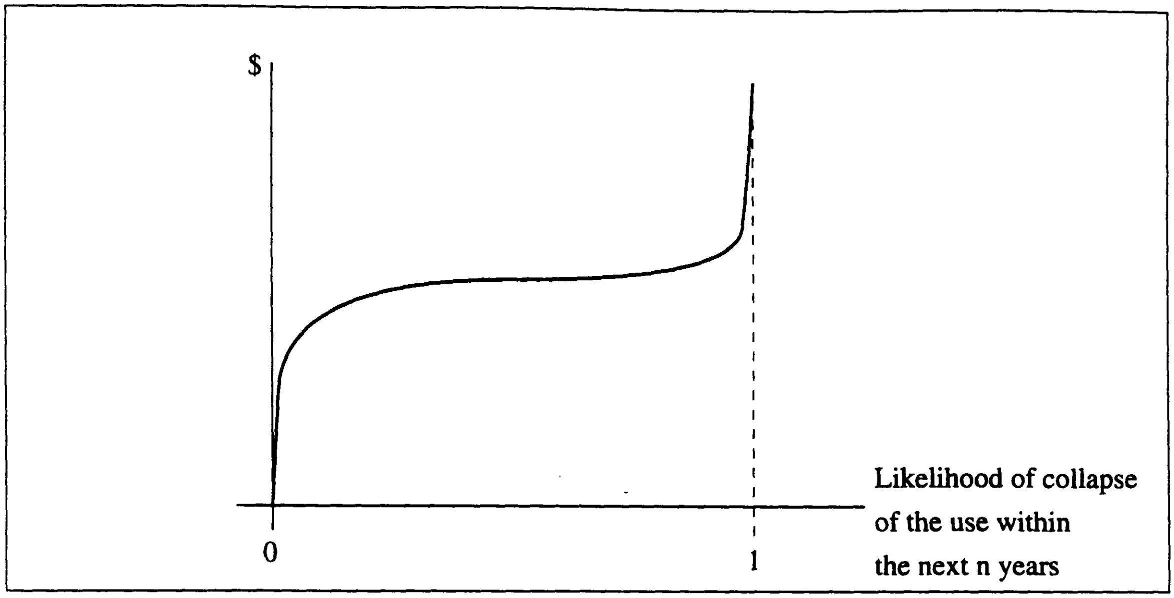


Figure 4-2: Benefit-risk diagram for a given use

a given use, the benefit-risk diagram is likely to look as shown on figure 4-2. The presentation of our methodology is now completed: a system has to be evaluated not only in terms of monetary benefits, but also in terms of risk. In fact there exist a classical way to take risk into account: time discounting. We discuss this issue in the next section.

4.2 Natural systems and discount rates

We haven't mentioned the problem of discounting the benefits of a use until now. Of course, benefits in the following years have to be discounted to be expressed in present value. We approach this subject now because discount rates are linked to the notion of risk.

The choice of the discount rate is a vast problem in environmental economics [4, page 179]. Some authors claim that the choice of the discount rate is an ethical question [12], others that this concept is just inadequate to value natural assets [17]. In theory, the discount rate is a reflexion of the time preference of the society and of the risk attached to the cash flows of the asset. The problem is that the notion of risk in the orthodox economic context is very different from the non-deterministic behavior of natural systems: it consists in variance around a mean value, with a smoothly shaped probability distribution. To compare it with the finance field, our risk is rather that of bankruptcy, total liquidation of assets. And finance students know that when such risks come into play, usual measures, such as the Net Present Value criterion, are useless [2].

Is it possible to include the unpredictable nature of ecological systems in the discount rate ? Drepper and Mansson [7] tried to do that. The result is a negative discount rate for natural systems. An astonishing result at first, but which simply mean that a natural asset tomorrow is worth more to society than the same today. Does it not make sense ? However, using their methodology requires restricting assumptions and an extensive knowledge of the system. Our approach, which does not try to aggregate non-linear risk but acknowledges its existence by the use of a new axis (risk), is more operational. Of course, since there are two axes of measures instead of one, one cannot simply read the "best" option: a choice has to be made, a trade off between benefit and risk.

Another advantage of our approach is that it requires one to choose a time-span: 5, 25, 50 years. A computation of present value is supposed to aggregate cash flows until the end of time but, in fact, the discount factors become rapidly so small that the flows past a certain year become negligible. Which year it is depends on the nature of the project (whether there are big cash flows in the near future or not) and not on the system itself. Appendix B explains the mechanics of the computation. Our measure of risk includes an *explicit* time-span which eliminates hypocrisy about the real time span used to evaluate the project. This enhancement seem significant.

4.3 Under which conditions can our methodology be favorable ?

Our methodology consists of two steps. First, the determination of the value to society of each use. Second, the study of the relationships among the uses in terms of benefits as well as in terms of risk. The second step requires more knowledge than

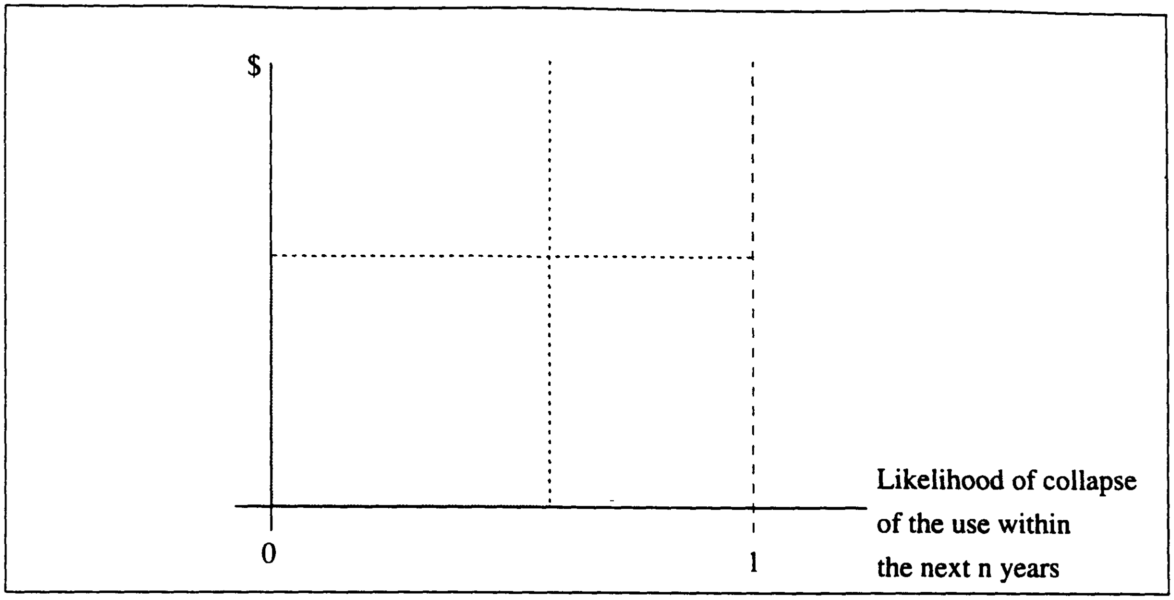


Figure 4-3: Simple benefit-risk diagram

a cost-benefit analysis. This section depicts the areas where this new knowledge is necessary.

We already said that we first have to know at which levels we use the system (which is different from monitoring as we saw). Relationships among uses are the critical part. But if it is possible to have an idea of them without having to understand minuted details of the system, the research effort is reduced. The first task is to evaluate this possibility. This is not to say that trying to understand how the system functions per se is useless. If there is a discrepancy between what we expect at the macro level and what is understood or measured at the micro level, an extreme caution has to be observed. But in our methodology, what counts are the relationships among uses. If it is possible to determine them while considering the system as a black box, we should profit from this.

The notion of collapse, and the discontinuities in behavior have to be evaluated also: When do we reach the threshold ? Are there precursors for the collapse (indicators) ? Can we predict how far from a deterministic behavior a system is ? What are the links between the stochastic variations of the system and the moment when there is an irreversible shift to a very different state ? Expecting curves as detailed as the one on figure 4-1 is not realistic. However, even as simple a diagram as that on figure 4-3 can be helpful.

While benefits can be added, it is not possible to aggregate the risks on the different uses. One has to decide which ones are the most critical to society, and the decision making process. But the hierarchical order might help simplify things, because the risk for uses of the same class might be the same. Instead of collapse of a use, we then deal with that of all the uses of a class. And we can also test an increase in a use against the change in risk of a package of other uses belonging to the same class. For example, what is the increase in risk for amenities (as a class) when increasing the nutrient load of a small lake ?

To sum up, the research needed is close to ecology, but with a bias toward studying the relationships among uses rather than trying to understand the system for itself. The risk component is another domain of study.

4.4 Conclusion

We now have the framework for our methodology. It depends on the relationships among uses, and the notion of risk of collapse. Benefit vs. benefit and benefit vs. risk relations have to be determine. The challenge is to take the dynamics of the system and the synergetic effects among the different uses into account without abandoning the advantages an economics type analysis.

We showed that research is needed to carry out step 2 of the process. But step 1 is a difficult one also. We study this problem in the next chapter.

Chapter 5

Problems of valuation

So far we have not explained how to carry out the valuation of each use. We do this in the first section of this chapter. We will see that there are many difficulties, so many that the whole process of trying to value natural systems can be criticized. The second section tries to show that, despite these difficulties, the kind of valuation we propose could be more useful than a classical economics approach.

5.1 How to value each use ?

An important part of the methodology we described consisted of valuing each use. Uses can be classified in four categories according to their valuation:

1. uses for which there exists a market (**commercial production**),
2. uses for which there exists no market but which can be valued through replacement costs (**non-commercial matter related uses**),
3. **amenities** with a broad meaning (from research to aesthetics),
4. **transcendental uses.**

We now describe each category.

5.1.1 Commercial production

This category encompasses all that is harvested, timbered, fished in the system and for which there exists a market. In reference to table 3.1, it corresponds to class 4.

In this class, the value to society seem easy to compute since there is a market for each good. The study of the market prices permit us to draw a demand and a supply curve and, thanks to them, customer surplus and other monetary values can be extracted. However, stating that the values obtained correspond to the real value to society, implies that the considered markets are perfect. It may not be the case very often for various reasons. We will just point out one. Those are markets where government intervention occurs a lot. This comes from the fact that, watching the depletion of natural resources, governments decided to intervene. They did it with their tool: regulation. Market prices are thus distorted by non-economic constraints, but, when using market prices, we depend upon an economic measure. How big is the mistake we make ? It is probably difficult to know in monetary terms. The problem lies in the relationships between the use of the system as a resource and the persistence of the ecological system as a whole. Too much fishing would lead to the extinction of fish resources but would also have further dramatic consequences on the ecology of the system. Government action tries to prevent these losses, so that the value of the system does not decrease. However, one consequence of the limitation of catch is a decrease in the value of the fishing industry, and since we tend to measure the value of the system through its uses (fishing is one of them), the value of the system *seems* to decrease according to traditional economic valuations. In fact, the real question appears to be: why was the market mechanism not able to insure the sustainable exploitation of the resource ? We will come back to this question in the next section. For now, we see that, even in the most favorable case, we are likely to make mistakes in our valuation.

5.1.2 Non-commercial matter related uses

We designate in this category of uses classes 1 to 3 (table 3.1). We called these uses non-commercial because there is generally no market value attached to them: owners of wetlands do not get money for the nutrients their land retains, or the flood protection the land provide.

However, by deriving the cost of an artificial system providing the same service to society, or by carefully accounting for the damages which are avoided thanks to the existence of the system, it is possible to estimate the benefits of this class of uses of the system. This kind of work is very practical and can be labor intensive. Very few studies of this type appear in the scientific literature.

It is possible to feel very strongly about the virtues of synergy in this category: for example when valuing the storm protection provided by a salt-marsh, one may compare that with the cost of building a dike and maintaining it (a natural system is self repairing). But one has also to realize that the dike will provide neither opportunity for bird watching, nor production of sea-food, nor a pollution buffer between the land and the sea... Of course, in a benefit/cost analysis, opportunity costs are supposed to account for these losses (when the study is done carefully), but they still do not approach the system as a whole, with all its interactive uses, the synergy among them, and the maintenance functions which maintains its integrity.

5.1.3 Amenities

Class 5 in table 3.1, are mainly recreational activities. But we include also other uses such as aesthetics and research/education. The benefits to society of research and education seem really difficult to evaluate. They are rarely even mentioned in cost/benefit analyses. No study was found approaching this problem. Most work has been carried out on recreational activities.

The amount of theoretical work on the problem of valuation of recreational activities is enormous. There are two basic ways to find the benefits of a free recreational activity which takes place in a given area: transportation costs and contingent valuation. Transportation costs assume that what people are willing to pay for enjoying a beach, a wetland, or a park, corresponds to what they spend when traveling to the area [29]. The method looks rather objective and rigorous but has been abandoned nowadays: what is measured in this method is the elasticity of recreation demand on traveling costs and nothing else. Besides, traveling procures some enjoyment in itself, the measure of which has nothing to do with the area visited.

Contingent valuation consists of carrying out a survey asking people what they would be ready to pay to preserve a recreational area (willingness to pay), or what they would accept as compensation for the loss of the area (willingness to accept). The method is widely used for its flexibility. For example, it theoretically allows the valuation of a single species, as we saw with the spotted owl. This is not really an advantage since, as we said, valuing a single species is just an empty problem. Theoretical articles deal with many aspects of the method: existence of option values (the option to chose between using or not the amenity in the future has a value, since it requires the persistence of the amenity) [28], influence of information [19], the importance of sample discrimination (surveying also potential users) [23]... The results of these surveys remain disputable. The format for the survey has a strong influence on the results, people tend to give "political" answers (I disagree with the way things are handled so I will pay nothing anyway), people understate their willingness to pay from fear of a real tax (despite the precautions taken by the surveyers) and, theoretically more troublesome, experience shows that willingness to pay and willingness to accept are never equal, while they should be of course since they are only two ways to describe a single economic transaction [16].

A very insightful study was conducted years ago by Brown [3]. Volunteers were shown pairs of pictures of the same outdoor scene in two different states of environmental quality, as well as pairs of the same consumer product with two different qualities (leading brand against very inexpensive copies for example). They were then asked to rank the differences in quality both on a dollar scale, and an "assigned importance" scale. The results were that the differences in quality of the outdoor scene were always considered more "important" than those for the commodities, but that, on the dollar side, subjects were ready to pay more for the improved quality of the commodities than the environment. The result is relevant to our valuation and very disturbing. As Brown puts it:

> It [also] suggests[, however,] that there is a concept of value regarding environmental amenities which is different from real willingness to pay.

This goes further than just saying that contingent valuation is inaccurate because people just have no idea of what they are willing to pay: it means that the economic measure is inadequate for environmental quality and benefits resulting from recreation in a natural ecosystem. This is a very strong limitation to any indirect economic valuation of environmental assets. And our methodology starts with such a valuation. But by introducing a second axis of evaluation (risk), we hope to limit the "Brownian" errors when valuing environmental amenities.

5.1.4 transcendental uses

We mean by this title a use the benefit of which transcends the frontier of the chosen system. What we have in mind is the capacity of wetlands to act as atmospheric carbon or sulphur sinks. As far as we know, this characteristic could be of great benefit to mankind. It may be a good way to mitigate global warming [14]. But the benefits go to mankind as a whole and not to the community which develops or preserves the wetlands. In neo-classical economic terms it is an externality problem. In our framework, we cannot value this use because our valuation unit is not big enough and has, through the atmosphere, a link with the rest of the global system. We reach here a limit of our methodology: although, as a part of mankind, the community considered receives a part of the benefits due to the reduction in atmospheric carbon dioxide, we cannot account for it because it goes beyond the limits of our local system.

5.1.5 Useless efforts ?

Valuing each use, a critical unavoidable first step of our methodology, requires a lot of time and work, while the results are disputable in most cases. Why make such efforts then ? And more generally, is it worth trying to carry out valuations of natural systems ? We try to show in the next section why these valuations are important. Once this importance is recognized, the voluntarist attitude consists of reaching the best available estimate of value, and trying to improve the valuation methods we just discussed. Our methodology contributes to the improvement of the valuation for each use in fact. First, uses are valued as a part of the system, so that the errors coming from opportunity costs are reduced. Second, it is not necessary to "extract" values. To be specific, the spotted owl (see chapter 3) will not be valued alone but as a part of the benefits of hiking in the old growth forest while watching all wildlife, enjoying the scenery, the noises, etc. It is the combination of all these sensations that produce the pleasure of enjoying the old growth forest. Besides, these sensations exist because the *system* exists and offers a habitat for the wildlife. Studying the spotted owl alone can indeed be useful, but only as a signal, or indicator, of the health of the larger system; not in economic terms.

5.2 Alternative approaches to the valuation of natural systems

Valuation methods such as the one we present, or more generally, the use of economic analysis in decision making can be criticized on two opposing grounds. On the one hand, one can say that economics in the broad meaning (that is to say all "orthodox" branches of economics: neo-classical, Keynesian completed by a body of environmental tools; but also branches which try to acknowledge the fact that the economic activity is part of the global ecosystem: bio-economics, post-Keynesian) are not able to handle environmental decisions. On the other hand, it can at the opposite be stated that only pure (i.e. neo-classical) economics are able to yield the true value of natural systems. We study the first argument briefly. We spend more effort to show the dangers of the second one.

5.2.1 What alternative to economics based decision making ?

On the grounds that any method based on indirect economic valuation of natural systems will be inaccurate, a view which is defensible as we saw in the previous section, decision-makers can refuse to use them. Decisions are then based on the belief that the people who make the decisions have the best information and thus are in the best place to choose for others, the aim always being to maximize society's welfare. That's what Jonas suggests in the second part of his work [18]: decisions concerning the environment should be made by a reduced committee of experts, an "élite". We deliberately placed our work in an economic context. So this alternative, with a socio-political context, goes beyond our study. However we try to justify our approach briefly in the next paragraph.

Relying on economics (in a broad sense) means that we consider that people's behavior ultimately reflects their preferences. Of course these preferences are based on the way people perceive the natural system, so the dilemma lies between 1) a society where a decision maker's duty is first to inform people as plainly as possible and then to make decisions on the basis of assigned values, measured as accurately as possible (with an acknowledged risk of errors), and 2) one where a few technocratic experts make decisions for others. The model which has more chance to derive and be the theater of disastrous mistakes is left to the reader.

5.2.2 Free market environmentalism

At the opposite end of the spectrum, some will argue that an indirect valuation process is inaccurate not because it is economics but because it is on the border of economics. Within the neo-classical theory, the *only way* to have access to an accurate economic value is through the market mechanism. A "Free market environmentalism" solution consists of creating property rights for environmental assets, just like they exist for man-made capital. The market mechanism will not only insure that they are given their true value, but also that social efficiency (allocative efficiency) is reached at the least cost.

It is true that the market mechanism has something fascinating as regards its neat way to translate people's preferences into values, and the fact that this translation is performed without any other cost than the possibility of exchanging goods. However, we think that this solution is not practical. The reasons are many and very well developed, on a global perspective, by Daly [6, 5].

- The first and obvious one concerns problems of scale: in theory, the economic system can be expanded or reduced without constraints because all the values implied are relative values. But the earth is a finite closed system, in which economic activity takes place, so that there is actually an absolute limit to growth which neo-classical economics cannot integrate.

- The second problem is one of dynamics: Whether the market approach can be applied to the environment, or is it intrinsically unadaptable to environmental issues ? Can neo-classical or even Keynesian economics, which were originally interested only in the human activity, be expanded to deal with the links between economic activity and environmental systems, or is a change of paradigm needed ? We mentioned earlier an example of market failure: the depletion of commercial fish. In this case, as in all environmental issues in fact, the "Tragedy of the Commons" [15] phenomenon shows that the market mechanism cannot handle natural resources as long as they are not scarce. As we said before, the problem is that the required level of scarcity has to do with our economic activity, but nothing to do with the ecological reality of the system providing this resource. There is no insurance that the market mechanism will come into play before the species become extinct, or before the system collapses. Moreover, the relationships among the uses which we try to put forward in this work, apply to *all* the uses of the system. A transaction of property rights (between two uses for instance) will leave many variables aside (influence on other uses through the dynamics of the system). There is no reason why a set erroneous transactions might lead to the right valuation of the system in terms of benefits to the society.

There are other reasons why the market approach is likely to fail. In the next paragraphs we present arguments which are critical at the local level. We discuss problems of discontinuous behavior, specialization, and people's welfare.

Discontinuous behavior of natural systems Can the market mechanism deal with the non deterministic behavior of natural systems ? We don't say here that traditional economics can handle only linear curves of demand or supply. This is obviously not true. But, in terms of *system*, economic entities (firms, households, government bodies) have a nicely shaped behavior: an incremental increase on the input side yields an incremental change of output. Or more precisely, if one wants a very small change in output, it is always possible to find a little enough input to achieve it. This is untrue of natural systems where it is possible to increase an input (or level of use) for a time without seeing significant changes in the output, and then reach a point where *any* incremental increase (however small) results in an tremendous change of output, with, much of the time, irreversible modifications of the system itself which switch to a totally different state and is then governed by totally different equations (see [7] for a good description of non-linear system behavior in an economic context). Discontinuities do exist in economic activity: oil crisis, financial crisis, bankruptcy. But there is always the possibility of somehow coming back and rebuilding. At this point, we do not know how to do that with natural systems [24], and they are so complex that a technological solution to this problem is unlikely. Irreversiblity is a key word: when a species is gone, it is really gone forever.

Specialization of systems If property rights are issued, there is a risk that owners will try to specialize the systems for the uses that will provide the biggest benefit for them. Specialization is a foundation of the market mechanism: normally it permits society to be better off because of the decreasing costs when specializing in one activity. For instance, if originally A and B both produce goods 1 and 2 while A can increase its production of good 1 at a lower cost than B, and B that of good

2 at a lower cost than A, they will each specialize and then exchange their goods. Overall, they are both better off. It is what happened with ecosystems on the land: we now have on one side crop fields, on the other side a few national parks where agriculture would have been very expensive. We can imagine such evolution also in the coastal zone and in the ocean where resources are in their turn becoming scarce. Some wetlands will specialize in production of sea food, others in waste treatment. However, such specializations are much more dangerous for a marine ecosystem because exchanges among the species, and all entities of the system are much more intense than on land. One cannot treat waste at one point on a river and expect to produce sea food downstream. One cannot release lead in the marine environment without expecting it to ultimately concentrate in fish tissues, maybe very far from the lead source. Much more than ecosystems on land, coastal systems are integrated, fauna and flora literally "swim" in their environment and constantly exchange matter with it.

Furthermore, specialization requires the elimination of stochastic variations of the production. For example, in a given year you may harvest a lot of shellfish but have little income from recreation because of bad weather. Since you are not specialized, risk is reduced because you have diversified sources of income. On the other hand, if you specialize in shellfish production, you will use all the possible technological tools you have to obtain a steady production over the years. You will not allow the system to oscillate around a mean value. You reduced what we can call the steady risk on the system. However, at the same time, you have increased the non-linear risk of seeing the system collapse completely. We may be beginning to witness this collapse on land: soils get poorer and poorer, and erosion reduces the total surface of cultivable land and the amount of top soil. In a coastal environment, this collapse will occur much faster.

About people's welfare It may be true that a market mechanism on environmental assets will lead to efficient allocation, and at the least cost. But this efficiency is measured within the realms of the neo-classical theory. Maybe people feel more comfortable with no prices on certain goods than with them. And this preference can not be taken into account in the economic theory since it denies the theory itself. There is some evidence that this statement is true. We already cited Brown's work. Another study was conducted by Harris and Brown. People were asked who should pay for a reduction in nongame wildlife due to land development:

1. the state with tax dollars, or
2. only people for whom wildlife is important, or
3. people responsible for the loss (i.e. developers) ?

People could also answer: the loss of wildlife does not concern me. Only 5% of the people chose this last possibility. Only 10% chose answer 2. 37% decided that only people responsible for the loss should pay (answer 3). Answers 2 and 3 can be clearly assimilated to a "property rights" approach: those who care for wildlife have to pay if they want to preserve it, and those who destroy wildlife have to buy this right. The significant finding of the study, which is closely related to our discussion, was that 53% indicated that the state should pay. A majority of the people consider that society as a whole is responsible for the loss of wildlife and do not accept the idea of market mechanisms when the environment is concerned. If increasing people's welfare is really the aim, property rights must not be issued then. Consequently, there is a need for indirect valuation processes such as the one we presented.

5.3 Conclusion

In this chapter we tried to show that, despite the values of uses we can reach are disputable, there is no other real choice but try to enhance the accuracy of these valuations. This is because orthodox economics are not adapted to the systemic reality of natural coastal systems.

Valuing each use was the missing part of our methodology which is now complete. We turn to a case study, the Saugus River System, which illustrates our methodological work and addresses the more general problems we raised.

Chapter 6

Background data on the Saugus River Watershed

In the next two chapters, we are going to try to see how our methodology can be related to a real case. This chapter concentrates on the definition of the geographical area of the "valuation unit" and presents a brief assessment of the watershed. Uses, their interrelationships, and the loss of synergetic effects are dealt with in chapter 7.

The choice of the Saugus River was motivated by the fact that its uses are diversified, which suits our framework, and the existence of a recent baseline study [27]. It does not take long to reach the heart of the problem. Here is what can be found in a brochure edited by the Saugus River Watershed Council (the brochure is reproduced in appendix C):

> Today, the Saugus River is used upstream for municipal water supply, downstream for commercial fishing operations and in between for recreational fishing and boating, open space and recreation along its banks.

Specialization seems preeminent along the river. This mean loss of synergetic value as we saw. Let us first get acquainted with the system. The following sections give background data about the Saugus River Watershed through a grid adapted to our methodology. After a brief description of the river itself, we study the geographical area of the watershed. We then give a brief assessment of the environmental quality of our "valuation unit".

6.1 The Saugus river

The Saugus river is 13 miles long. It runs mainly through urbanized areas. Small lakes cover 10% of the watershed [21]. The headwater source of the river is Lake Quannapowitt (251 acre) in an area of single family houses. People sail on and jog around the lake, but under the stress of lawn fertilizers, fecal wastes and erosion runoffs, the lake may die by eutrophication within decades.

The organically rich waters from the lake travel slowly into the Lynnfield-Wakefield marsh, which are extensive freshwater marshes, unique in such a urbanized area. In these marshes, lie the "Ready Meadows", designated a National Natural landmark, where many endangered species of bird and other typical wetland animals can be found.

A dam is built on the river, at the border between Lynnfield and Saugus. At this point, the town of Lynn has its freshwater intake (12.5 million gallons per day are diverted [26]). This is the only drinking water supply on the river, but it is a significant one: after the dam, the river is slow moving.

Further south the river passes through the Metropolitan District Commission's Breakheart Reservation. It is almost pristine at this point, with many hiking trails.

The river passes under route 1 (see figure 6-1 (source: [27]), appendix D gives more detailed maps) in a heavily commercially developed area. Downstream, the river passes through residential areas: buildings, houses, parking lots... It is however often protected by a narrow strip of wetland plants.

A short distance further downstream, after Panker's Pond and a few bending maples, the river reaches the 17th century Saugus Iron Works. This historical site, home of the first successful Iron Works of North America, is managed by the National Park Service.

Below the Iron Works, the river is muddy and slowly adapts to the marine environment. Although fetid and covered by a rich organic soup, the brackish waters are

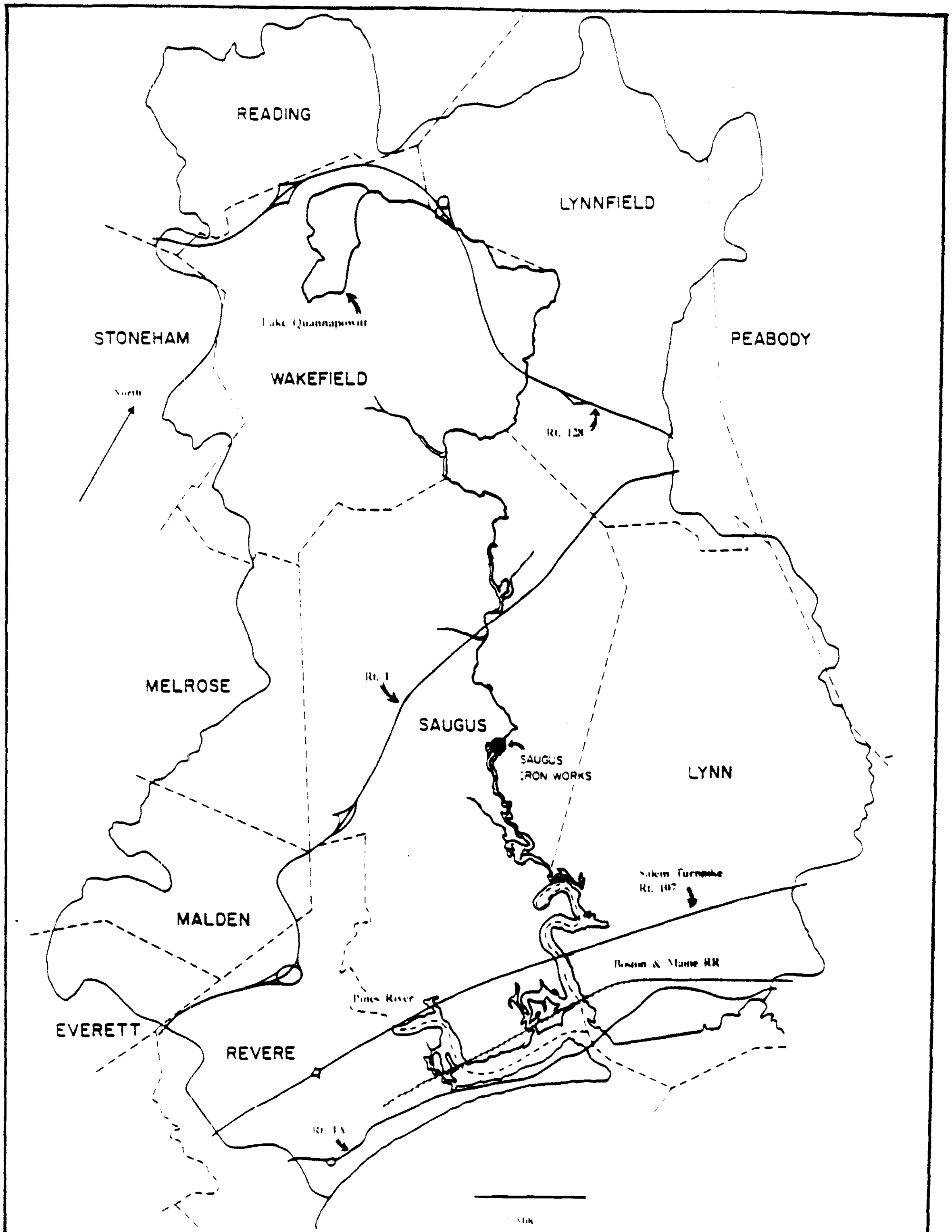


Figure 6-1: The Saugus River Watershed

considered fundamental to the ocean foodweb. However, almost all along the lower Saugus, this natural detritus is mixed with human pollutants: construction debris, yard waste, or household trash.

The last mile of the river is heavily developed with huge plants such as General Electric or RESCO. The Saugus River joins the Pines River to form the Saugus saltmarshes. These marshes contain the largest shellfish beds north of Boston. Of course they have been closed for human consumption. They constitute a nursery for many species of coastal fish and act has a pollution filter from land to sea, as well as a flood water buffer.

The coastline around the mouth of the river is mainly residential on the Revere side, while industrial on the Lynn side.

This description began to show how various are the uses and the states of the river in terms of environmental assessment. But we have to study the whole watershed, which we do in the next section.

6.2 The geographical watershed

Our methodology began with the definition of a "valuation unit" which, we said, cannot be more restricted than a watershed. The Saugus river Watershed is shown on figure 6-1. Its surface is about 47 square miles, 45% of which is an estuary. The fall from Lake Quannapowitt to sea level is only 90 feet. The rim around the watershed has an elevation of only 300 feet. That's one of the reasons why the river is so "sluggish" (except during storm events). Two other reasons are the slight gradient (90 feet over 13 miles), and the existence of many small lakes.

Despite its moderate surface, the watershed area encompasses 10 towns. We find here the two issues we discussed in section 2.1.2: not only is the valuation unit shared by several communities but some communities are only partly on the valuation unit. Table 6.1 (source: [26]) gives the list of towns and their relation to the watershed. One important number is the fraction of the town surface within the watershed. A low percentage does not necessarily mean that impacts are such however. For example,

Watershed Community	1990 population	Total area (sq. miles)	Density (pple/acre)	% of land in wtrshd
Saugus (town)	25,549	11.58	3.5	100
Wakefield (town)	24,825	7.89	4.9	97
Lynn (city)	81,245	11.21	11.3	79
Revere (city)	42,786	6.32	10.6	70
Lynnfield (town)	11,274	10.49	1.7	53
Malden (city)	53,884	5.13	16.4	45
Melrose (city)	28,150	4.80	9.2	42
Reading (town)	22,539	9.85	3.6	28
Everett (city)	35,701	3.75	14.9	21
Stoneham (town)	22,203	6.66	5.2	10
Peabody (city)	47,039	16.81	4.4	2

Table 6.1: Watershed breakdown by town

only 21% of Everett lies within the watershed — it is the smallest community (3.75 square miles) in terms of area. But this area (west part of the watershed) also has the highest density and is heavily industrial. Impacts from this area are thus significant. However, this low percentage, and the fact that the residents of Everett live far from the river itself, mean little concern from the town of Everett. This a first hint that the political structure does not favor sound environmental management. We will elaborate on this in the next chapter.

We also have to prolong our system into the ocean, to insure that it is as weakly linked as possible with the rest of the world. Since the tidal part of the river is a nursery for several species of open sea fish. This marine part should expand far from the coast (as far as the end of the continental shelf, marine ecologists would argue). To design a reasonable marine area, some hydrologic and ecological studies should be conducted, maybe the fishing grounds of the ocean fishermen from the Saugus River should be taken into account also. These studies go beyond the scope of this work. We know that designing this marine part is a difficult problem because of the nature of the marine environment: no boundaries for chemicals or species. In order to continue our case study, we can admit that a marine part has been designed, which is heavily impacted by the inflow from the watershed and which has also a strong influence on the coastline of the watershed.

6.3 Baseline assessment of the Saugus River Watershed

One striking characteristic of the Saugus River is the variation of stream during storm events. This is due to the reduced base flow during normal conditions, to the runoffs from the urbanized area and the roads, and to combined sewers overflows. During these storm events, concentrations of various chemicals can increase by a factor of 20 [27, page 28]. Sediment transportation occurs mainly during these events too, with all its consequences on the ecosystems: erosion of top-soil, concentration of nutrients, increase of turbidity...

No major industrial source of pollution can be identified. Water quality is mostly impaired by organic pollution, domestic and animal. The high coliforms densities indicate sources of pollution such as combined sewer overflows, illegal sewer connections, and failing individual septic systems. The fertilizers used for golf lawns are another source of pollution. In places in the watershed, along the non-tidal part of the river in particular, heavily polluted stagnant pools can be observed. Their assimilative capacity is extremely low, and they are very sensitive to a change of inputs.

The biological picture of the watershed is poor. The low numbers of species and individuals of fish, invertebrates, or diatoms indicate poor water quality. This is especially true of the non-tidal part of the basin. The estuarine part is in better condition due to the tidal flushing. Although there remain some natural habitats (around Lake Quannapowitt, in the Ready Meadows, in the tidal marsh), they have unusually poor populations of fish and invertebrates. As it is put in the baseline assessment of the Saugus River prepared by Hudsonia Limited [27, page 37]:

> Habitat fragmentation has reduced the areas of suitable habitats, in-

creasing the risk of random extinctions[.]

6.4 Conclusion

To sum up, the Saugus River watershed is fragmented into parts which have very different environmental quality. But even the area which look pristine are in fact affected: reduced number of species, and small populations of each species. Now that we have defined the geographical area of the system, and have a better general idea of the watershed, we turn to the uses of the system.

Chapter 7

The Saugus River system

In this chapter we describe the uses of the system. We try to show that, due to interactions among them, only a valuation such as the one we presented could lead to the most efficient management of the system. Finally we underline the difficulties of implementing our methodology.

7.1 Description of uses

The uses we have found for the Saugus River system are listed bellow. The list may not be complete. The idea is to use the case study as an illustration of the theoretical part of this work. A study useful for decision making purposes would require more time, and consider the socio-political dimensions of the system as well. We tried to order the uses according to the classification we described in chapter 3. There again, this ordering may be disputable in terms of ecological validity.

Class 1 This class contains only the ground water recharge use. We could not gather enough geological information to know whether or not this function exists in the system. Answering this question would of course be critical to a real study. For our purpose, we assume that, due to the geology of the basin, this use does not exist.

Class 2

1. **Fecal matter retention and filtration.** As a whole the Saugus River system is a huge fecal matter filter. This use is carried out by Lake Quannapowitt, by the Lynnfield-Wakefield marsh, by the tidal marsh, but also all along the river. This matter comes mainly from combined sewer overflows, illegal connections to the sewer system, deficient septic systems. But wildlife participates to the amount of fecal matter entering the system as well. It has been noticed that geese seem to enjoy the habitat provided by golf courses (1% of the watershed). Their population has increased rapidly and they do not migrate to Canada any more.

2. **Retention of nutrients and toxins.** We don't mention the origin of the pollutants. The watershed is mainly residential, but there are also several industries with discharge permits. The Saugus salt marsh encompasses a huge plant owned by General Electric and the RESCO plant. For years these companies have discharged illegal levels of toxic substances and heat. It does not seem to be true any more, and GE is now involved in environmental actions to protect the marsh [26, page 29].

3. **Drinking water production.** The city of Lynn has an historical right to divert water from the river to the last drop. This intake is outside the town boundary. We will study this use of the river in details.

4. **Waste dumping.** People use the tidal marsh, and some points along the river (around route 1 and 128) as a waste products disposal (household trash, construction debris).

Class 3

1. **Flood protection.** The Lynnfield-Wakefield marsh acts as a buffer during storms by temporarily stocking huge amounts of water coming from the upper part of the watershed. This is a non-commercial matter related use. Estimating

the avoided costs from damages should be easier than the replacement cost method because the flood control function is closely tied to the existence of the system, even if the system is in a very degraded environmental quality. Its virtual replacement would imply the study of many other uses.

2. **Storm damages protection**. The tidal marshes in the estuary protect the land from the damages caused by the sea. This is a very classical function of wetlands, but the protection does not apply to houses and buildings only: the marsh protects area where shellfish could be harvested (if pollution did not prevent this use). The study by the Department of the Army [21], although about a project of artificially improved protection, gives ideas about the extent of the natural protection.

3. **Golf courses**. Although golf is a recreational activity, a golf course requires such modifications of landscape that they can enter this class. The shape and open spaces let runoffs run freely. Fertilizers are used intensively to maintain the course. We saw that golf courses have also a function as habitat for geese which produce a lot of fecal matter.

Class 4

1. **Production of shellfish**. This use of the tidal marshes has been lost due to pollution: an example of collapse of a use. It is nonetheless a critical use of the system, the shellfish industry being a traditional one in New England.

2. **Nursery area for offshore commercial fish**. This use is transcendental unless the marine zone of the system encompasses the area where fishermen catch the fish which is spawned in the Saugus tidal marsh. This is not practicable since most species are fished far from the shore even though they spawn in the coastal marshes. The valuation of the system is thus independent of the way the fishery is managed, and because of that, there will be some errors in the valuation: a species can become extinct because of artificially at sea, even though

the Saugus river system is well managed and able to fulfill the spawning function. Besides, young fish nurturing in the tidal marsh may have a benefactory effect on the marsh (and thus on the value of the system), but their population depends on a variable extrogeneous to the valuation process: the amount of fish caught at sea. It is not possible to avoid methodological errors when valuing this use because we have to design a practicable, limited marine part of the system.

Class 5

1. **Hiking, bird watching, and enjoying natural sites**. All along the river there are some spots which still look untouched by development and pollution. The tidal marsh, the Reedy Meadows, and Lake Quannappowitt are the areas where people enjoy nature most. The number of people hiking around Lake Quannapowitt can reach 15,000 in a week-end [26, page 25]. As a comparison, the town of Saugus has 25,000 inhabitants.

2. **Fishing**. Fishermen use the estuary at the mouth of the river to fish striped bass. Freshwater fishing along the river seem to be another example of collapse of a use: the river is very poor in freshwater species. But this may change if the water quality improves, which justifies that we study the benefits of this use.

3. **Boating**. Lake Quannapowitt is a famous urban wind pocket. Sailors and sailboarders fill the water. The marine estuary part is also used as a boating area.

4. **Research and education**. The Lynnfield-Wakefield marsh as well as the Saugus salt marshes are valuable for research work and educational purposes. They both cover vast surfaces (at least compared to most marshes within urbanized areas) and are habitats to endangered species. We already said how difficult it is to assess the value of this benefit. But it must not be ignored.

5. **Aesthetics**. People living close to the river, a wetland, or on the coastline, enjoy the aesthetics of the site. This may be measured, by an increase in real

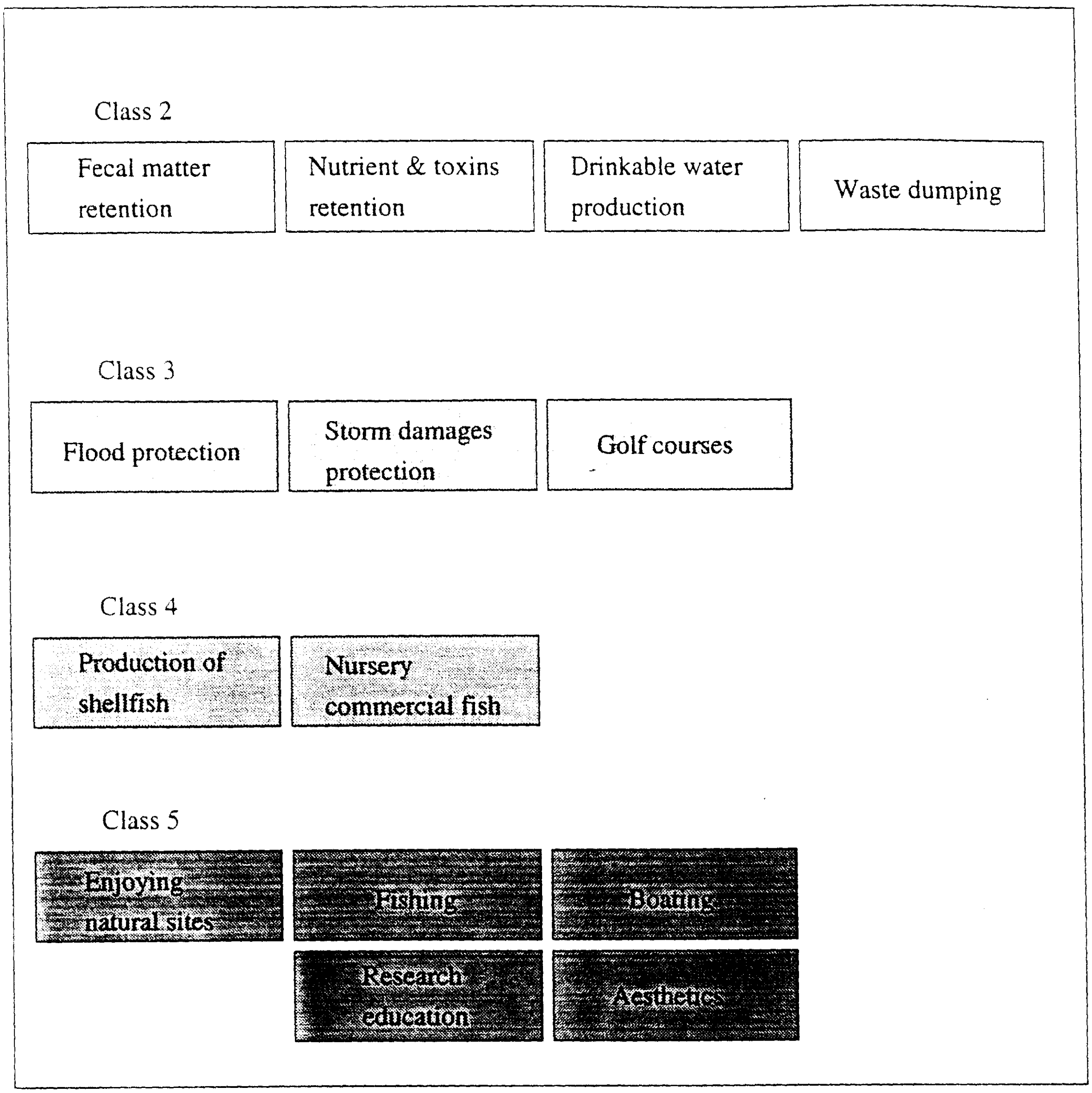


Figure 7-1: Sum up of uses for the Saugus River system

estate prices, or by contingent methods, which are more likely to capture all the aspects of the satisfaction provided by pleasant aesthetics.

7.2 Relationships among the uses

Figure 7-1 sums up the uses of the system. We now turn to the synergetic effects among the uses. The idea of synergy comes from the influence of some uses on others. These relations are in pairs: one use may influence 3, 4 or all others. We will study some relationships in more details in the next section. Here we tried to design a general benefit-benefit relation diagram. Figure 7-2 shows the result of this attempt. It is natural that the uses of the lower class end up in the middle of the diagram: we know that they have strong impacts on all upper classes. Some relations are missing on the figure: we tried to put the most obvious ones, and keep the figure readable. The relation between two uses is generally carried out by a maintenance function, but a single maintenance function serves as a link between several uses and is also part of the dynamics of the system: relationships go further than this benefit-benefit analysis. As we saw, the consequence is that a transaction between only two uses has no reason to go in the direction of the maximization of the value of the system: the impact of this transaction on other uses is external to the transaction.

Such diagrams can be drawn for benefit-risk. We can for example study the influence of an increase in nutrient retention on the risk of seeing boating disappear because of complete eutrophication of the lake. Figure 7-2 showed that, in terms of benefits, eutrophication did have an influence on the benefits to society of boating: the more algae in the water, the less pleasant it is to sail (especially when there is a risk of capsizing...). However, the benefit-risk analysis would be different: how many years from now, for a given amount of nutrient, will the system shift to a state where boating become unpleasant enough so that this use disappears completely ? Benefit-risk diagrams are likely to be even more intricate: for example, turbidity of the water is critical the survival of the vegetation which maintains the storm protection of a tidal marsh. What is the probability that, say 20 years from now, the waste dumped in the marsh will have changed the turbidity in such a drastic way that the system disappear almost completely and storm protection is no longer available ? There are many degrees of freedom in our system: each use has a monetary and a risk dimension, and all uses interact. A general risk-risk diagram would have had less meaning than the benefit-benefit one we draw. The next section contains an example of a risk-benefit diagram.

We are now going to study two examples which will show that misvaluation leads to the loss of the benefits of synergy among uses and the loss of the uses themselves.

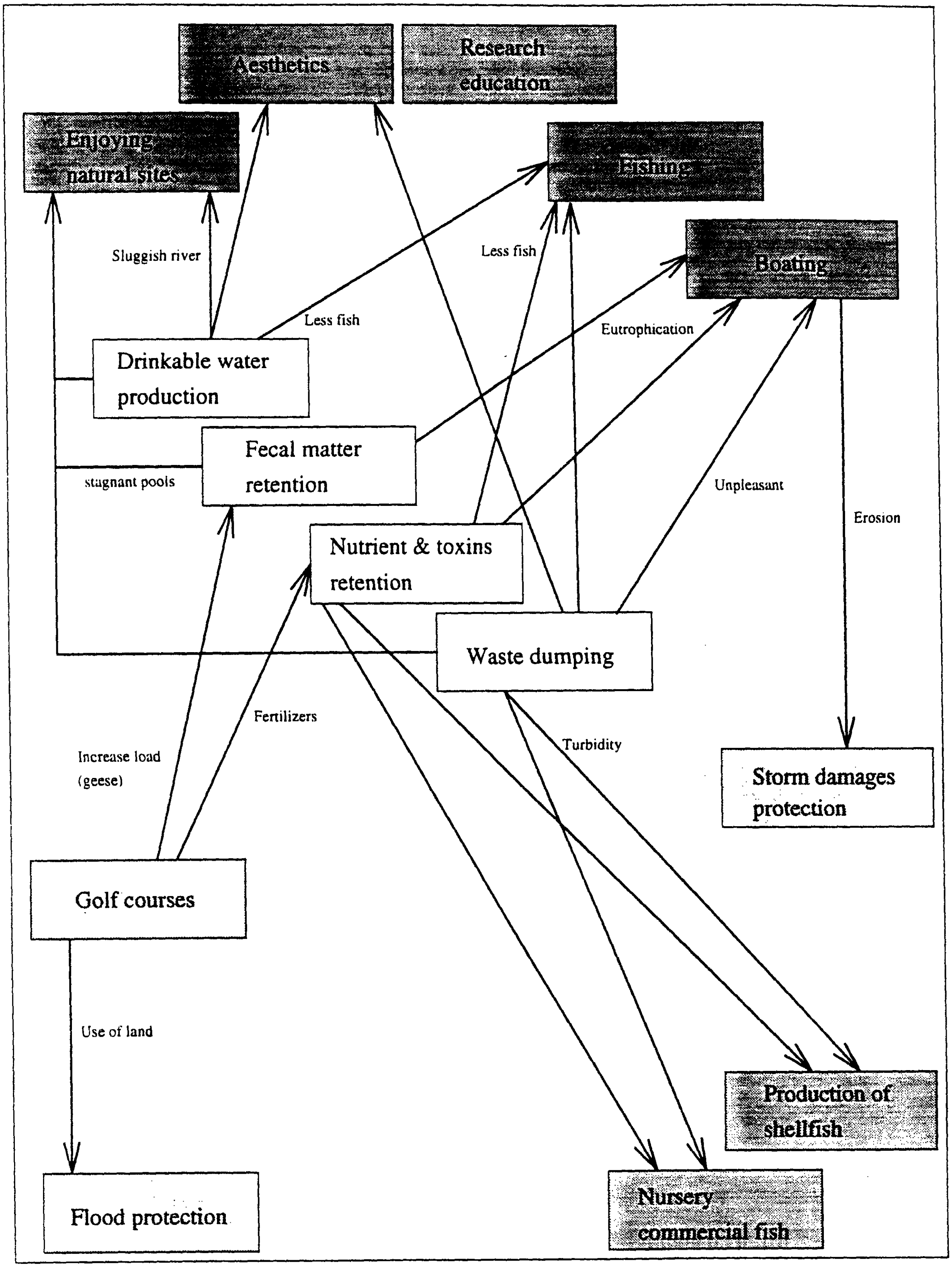


Figure 7-2: General benefit-benefit qualitative analysis

Just like we did now, the analysis will remain qualitative. For decision making purposes, quantitative data would be needed though.

7.3 Two developed examples

7.3.1 The water intake

As we said, the city of Lynn has the right to divert all the water from the Saugus River, at a point situated downstream of the Lynnfield-Wakefield marsh. In terms of property rights, the net benefit of this right equals what it would cost Lynn to use another source of drinkable water (pumping underground water for example). However, in terms of the valuation unit as a system, the consequences of this use are enormous. They are enormous not only because this use has impacts on the other uses of the system, but also because it has impacts on the risk facing the system. In figure 7-3, we tried to show the relation between the drinkable water use on other uses in terms of benefits. As we know, this is only a partial view of the system. Risk also has to be taken into account. Figure 7-4 shows the relations between the level of benefits from drinkable water and the level of risk on other uses.

On the monetary dimension, it seems that the value of the system would increase a lot if the water were not diverted any more, so that this move would have a positive Net Present Value. But things go further: the risk of seeing other functions collapse would be reduced too. As far as benefits and risk are concerned, stopping diverting water from the Saugus River seems a win-win situation *for the system*. Figure 7-5, where risk represents a hypothetical aggregated risk of the system, illustrates this situation.

As a matter of fact, a minimum flow requirement was recently imposed under the authority of the Massachusetts Department of Environmental Management, Water Resources Division. The standard was based on a study carried out on another river from the Saugus [26, page 24] and is very controversial. The real questions are the following: Why wasn't this process undertaken earlier ? Why wasn't this

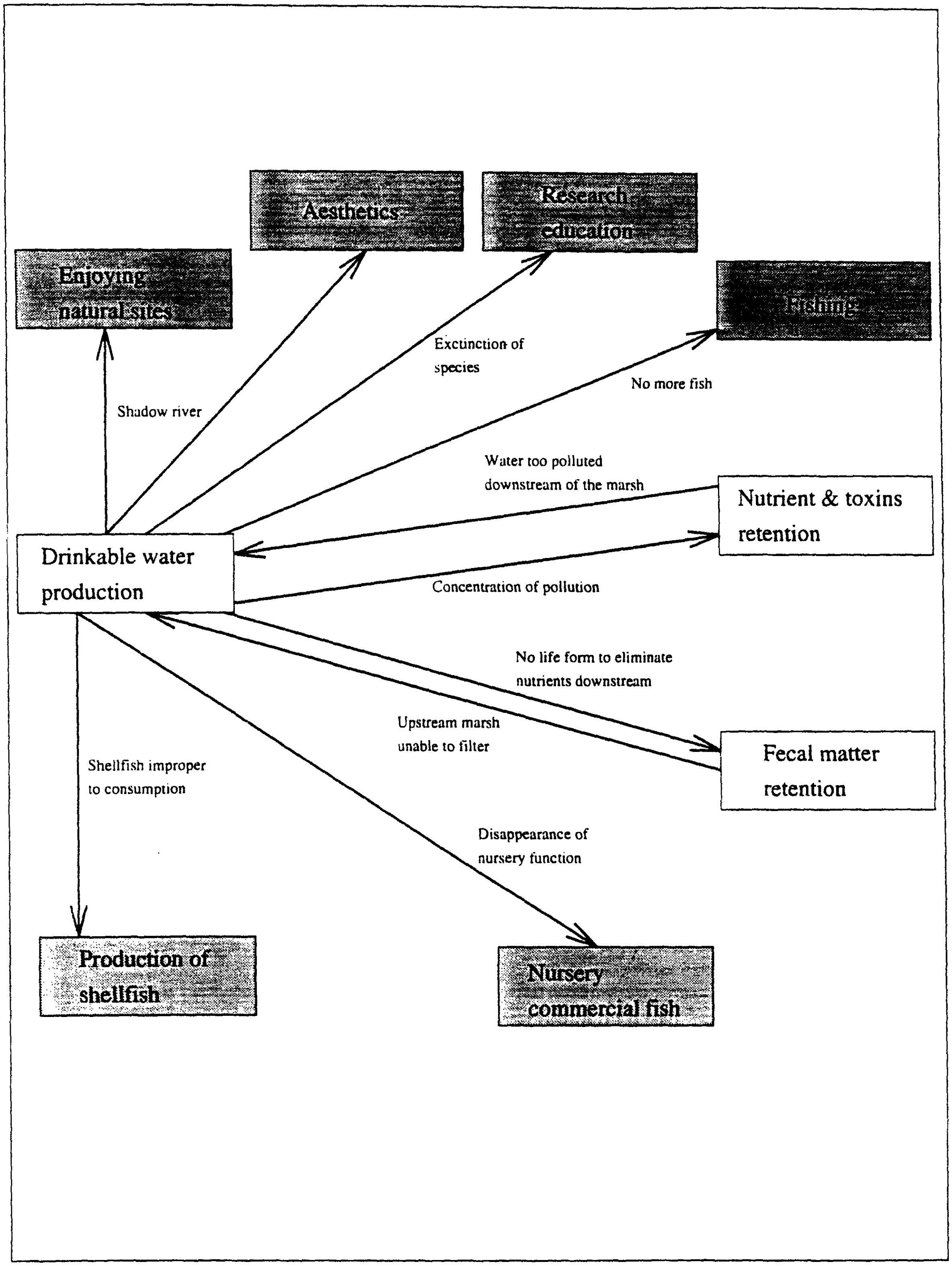


Figure 7-3: Influence of drinkable water production benefits on other uses' benefits

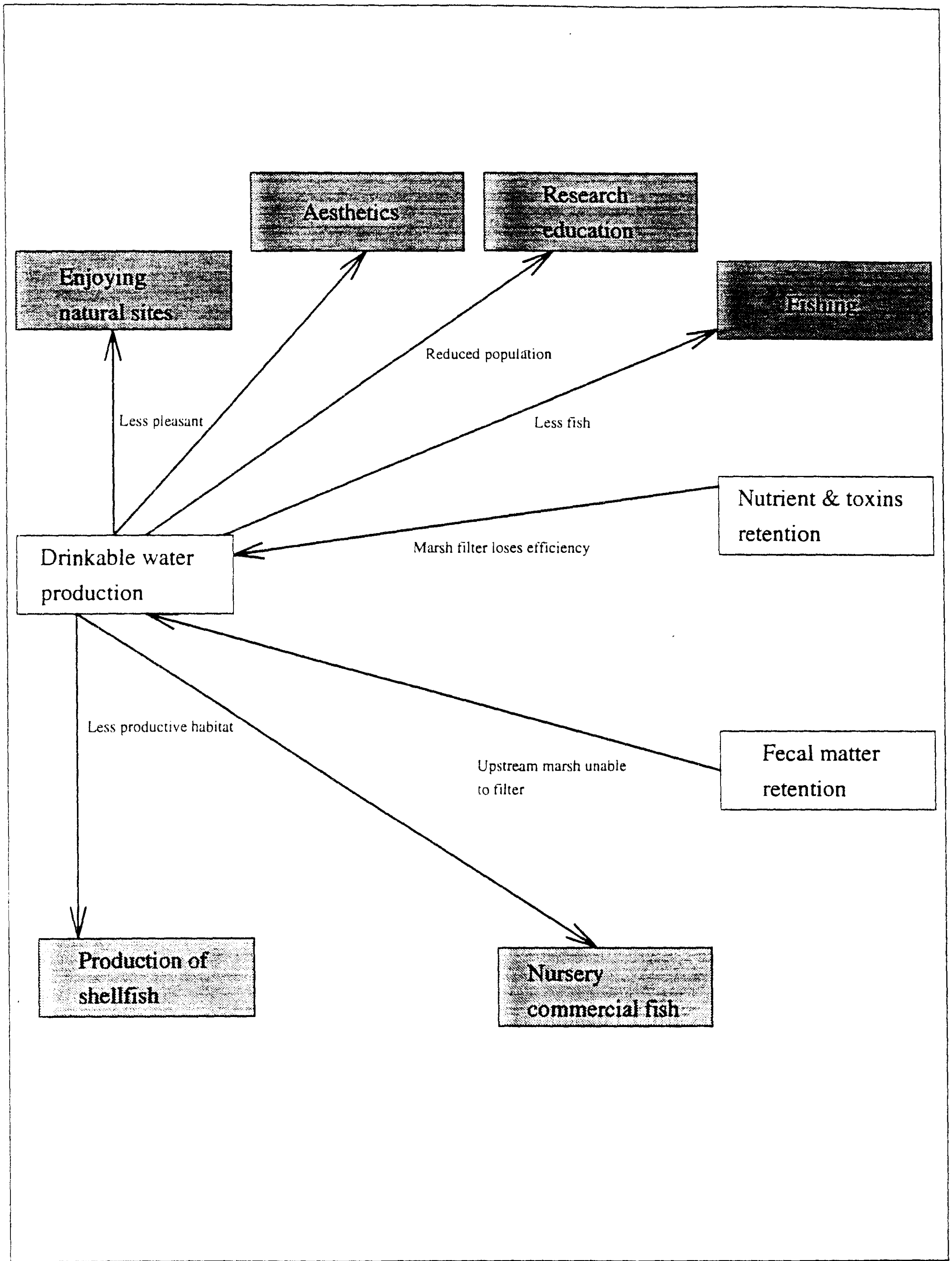


Figure 7-4: Influence of drinkable water production benefits on other uses' risk

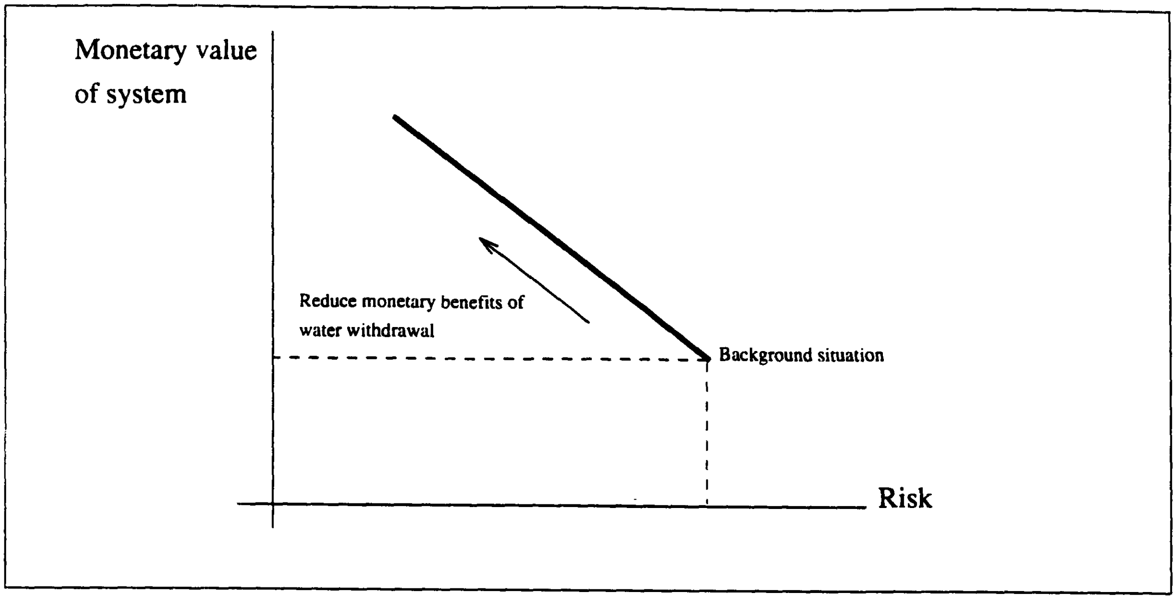


Figure 7-5: Effects of reducing the water withdrawal

standard the result of a negotiation among the communities of the watershed ? A neo-classical analysis would state that the city of Lynn has a *property right* to the water. Communities (like Saugus) having interest in a more substantial base flow along the Saugus River should then buy this property right. How would the price be determined ? From the city of Lynn side, a fair price would be the loss of benefit from withdrawing water from the river: that is, the increase in price from taking water from the river to taking it from another source. From the other communities side, a fair price may be the increase of benefits due to a bigger flow along the Saugus. Through mutual agreement, it seems that the transaction could take place. In fact, there are at least three reasons explaining why it has not and has little chance to:

1. If the increase in cost is easy to estimate, the increased benefits (recreation, aesthetics) are much more difficult to value. They are so difficult to value in fact, that communities do not compare them to the price required by the city of Lynn: they only consider this price, and it may seem high. There is a basic problem of valuation here: the transaction does not take place because of an erroneous valuation of the total benefits derived from the natural system. Conducting a process such as the one we presented may help assess the real benefits from a healthier system.

2. The benefits do not go only to one community: they are spread unevenly among many. Even though Saugus is the community geographically closest to the water intake, uses such as fecal matter filtration or recreation involve Melrose and Malden as well. However, in the short term, these two communities can enjoy the benefits of these uses without the problem of having a polluted river on their territory. All the uses interact together without regard to the jurisdiction areas, and each community tries to play the game to its own advantage, disregarding the value of the system as a whole. Only a valuation, based on the value of the entire system, with a clear view of the time span used, and on the interactions among the uses, followed by a negotiation on distribution issues, can lead to the proper decision.

3. A necessary condition for the withdrawal of water by the town of Lynn is the existence of the Lynnfield-Wakefield marsh. The water entering the marsh is loaded with nutrients, fecal matter, and other pollutants. This is true of the water coming from Lake Quannapowitt as we saw, but, more generally, all the headwater area is the site of loaded runoffs. The marsh acts as a filter and regulates the flow, so that, at its downstream point, the water can be used for municipal use. The value of the water withdrawal thus depends on the environmental quality of the Lynnfield-Wakefield marsh. Should Lynn participate in the cost of protecting this wetland since it is one of its main user ? We see that all the communities *upstream* from the water intake are also parties. This is no surprise and illustrates what we explained earlier: only a systemic approach can lead to accurate valuation and efficient management of the natural resources.

This example tried to show that, given the relationships among the uses, only a process that take the whole system into account can yield the highest benefit to society. We will see in the next section why such an approach is difficult to apply. We now turn to the case of Lake Quannapowitt.

7.3.2 Lake Quannapowitt

The process of eutrophication is a natural one. Undisturbed, Lake Quannapowitt would die slowly by a natural process. But accelerated erosion, fecal waste and other nutrients, and the fact that the water of the lake are well oxygenated due to the windy conditions, accelerate this process. Once more, not only the value of recreation decreases (eutrophication makes boating less pleasant, not to mention swimming), but there is a very tangible risk that the use will disappear altogether.

Today, the lake water is loaded with nutrients and other pollutants. Here is what can be found in the baseline assessment of the Saugus River Watershed:

> The flow of Lake Quannapowitt water into the Saugus [River] should be minimized until the lake's water quality can be assessed.

In order to preserve the Lynnfield-Wakefield marsh (which is in turn very important to the production of Lynn's municipal water), it seems natural to take this step. In the short run, the lake will continue to perform its nutrient retention function and the marsh will be preserved as a habitat for endangered species and for production of drinkable water. In fact, this decision seems to be a first step toward the specialization of two subcomponents of the system. In the short term, the lake can receive all the run offs coming from the upper part of the watershed, with reduced boating attractiveness, while the marsh will be left for lovers of pristine environment, and those who have interest in the production of drinkable water.

But how long will the lake be able to accumulate nutrients before the ecosystem collapses ? What will happen next ? There is no insurance that the value of the system is increased by this specialization. Of course the real problem lies at the source of runoffs in the upper part of the watershed. Reducing them would have a huge cost compared to the specialization solution. On one hand we have a low cost solution but which increases the risk to the system, on the other hand a high cost solution which reduces the risk. The dilemma is precisely that of figure 4-1.

The political process is important in this issue too. Reducing runoffs in the head-water would influence all other uses of the system and have beneficial effects for all the communities in the watershed. It may even make it possible to go on with deficient combined sewer systems in the downstream part of the watershed if the headwater is clean. Who shall bear the cost then ? Can the political process handle this issue ? Valuing the system as a whole, applying the decisions that the valuation implies requires either centralized power or, at least, a very close cooperation among all the communities within the system. It requires 1) an understanding of the system, 2) reasonable estimates of the value of the system, 3) a long term view by all the decision-makers involved. It does not seem that this point has been reached yet. In Massachusetts particularly, where "local rule" has a long and powerful tradition, community collaboration over watersheds will be difficult.

7.4 Conclusion

The Saugus River has been slowly segmented in pieces, each of which is specialized, losing the synergetic effects among uses and increasing the risk for each of these. Only a valuation based on the entire system, with all of its interrelated uses, can show the monetary and risk related benefits which could arise from limiting each use to a level which improves synergy within the system instead of destroying it. The political process limits the possibility of seeing such a methodology applied. We develop these three points to conclude our study of the Saugus River System. But before that, let us repeat once more that this case study serves only as an illustrative example. The information gathered during the limited time of this work is surely not sufficient to insure that all the data are precise.

The specialization of subcomponents of the system The example of Lake Quannapowitt tried to illustrate this tendency. The phenomenon is found all along the river however. It is so true that the baseline assessment of the Saugus River Watershed begins with the definition of 7 zones along the river [27, page 7], each of which has a privileged use. This specialization means:

1. loss of benefits from higher class uses: stagnant pools rich in fecal matter are not aesthetically pleasing, nor do they allow for other enjoyable activities,

2. loss of synergetic effects among uses: withdrawing water from the river yields benefits but, because the maintenance effect from a regular stream disappears, species die and the filtration of pollutants is decreasing,

3. increased risk of seeing some uses collapse: shellfish in the tidal part are no longer harvested.

Benefits and synergy. The study showed that the components of the system (different areas, uses, and maintenance functions) are so linked to each other that a neo-classical property rights/market mechanism approach would not lead to an efficient management of the system. To reach an accurate value of the system, it has to be considered as a whole. Moreover, the increase of wealth to society coming from expenses to maintain the good environmental quality of the system, and make sure that any and all the different uses do not reduce the synergetic effects of the system cannot be measured only in terms of monetary benefits: such actions would also reduce the risk of seeing uses collapse.

Problems of implementation The political structure of the system is not favorable to an approach which puts an emphasis on the system. There are more than ten towns in the valuation unit. Most of them have interest in other valuation units as well. State and federal agencies are numerous but their power is limited to a certain aspect or area of the system only. They also may have competing interests. The time frame for political life (typically 4 years) tends to promote projects with short term benefit even when they imply long term disastrous consequences. Improving the political part of the decision making and implementation process is a challenging one. Better incentive systems have to be created in the form of new structures. New ways to communicate information and better vehicles for reaching agreements have to be found.

Chapter 8

General conclusion

To conclude, let us first sum up the steps that have to be taken to apply the valuation process we described.

1. Define the geographical area of the system. It is composed of at least one watershed extended by a marine part.

2. Define the uses of the system, a set of maintenance functions, and a set of indicators.

3. Value each use (*all uses*) in monetary terms as accurately as possible.

4. Determine the relationships among the uses in terms of monetary benefits, but also in terms of risk. This may require the study of the internal dynamics of the system and the links between uses and maintenance functions.

In general, the methodology tries to keep the advantages of an economic valuation while taking into account the interrelations among uses, the fact that the system is a whole, and the existence of a valuable synergy among all the uses of the system.

The development of this work suggested more general results about the use of economic methods to help manage natural systems as well. First, traditional valuations are erroneous because they leave aside the intricate relations among uses, which come from the dynamics of the system. They are also unable to capture the value of the synergetic effects among uses. Secondly, the neo-classical approach to environmental problems is likely to lead to the specialization of ecosystems through assignment of property rights. This means the loss of the synergetic values, and also an increased risk of seeing the system collapse. This comes from the gap between economic theory and the complex dynamics of natural systems, the behavior of which becomes unpredictable when they are placed under too strong a stress. Lastly, indirect economic valuations, such as the one we tried to present, are useful since people do not seem to agree with the attribution of property rights on environmental assets. The challenge is to improve these valuations. That is what this work tried to do.

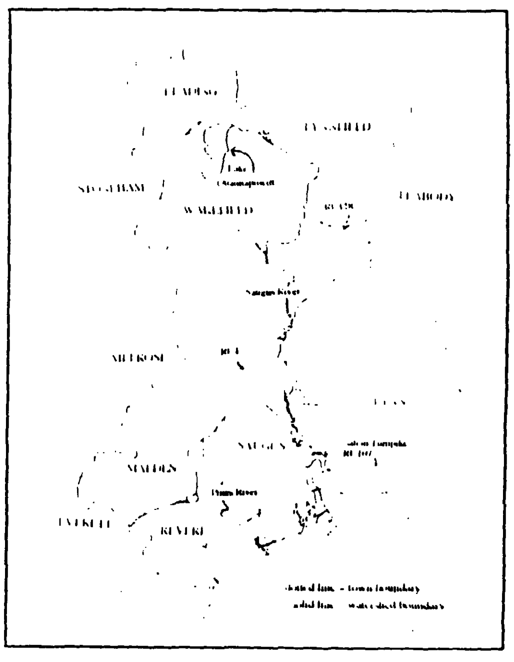
The political process is an obstacle to the use of such valuations, and the application of decisions they suggest. The multiple areas of jurisdiction, both in terms of geography and mission, have nothing to do with the ecological reality of natural systems. There is a real challenge in this domain where research would be helpful: structures have to be invented that allow the respect of natural systems. The negotiation process has to be studied and improved. Further research is of course also needed to fulfill step 3 of our process. This work would be mainly ecology but with a bias toward the uses of the system, and the determination of risk of collapse.

This study may lead to further research or it may not. This is not really what is important. Its starting point lay in the feeling that natural systems are significantly undervalued in our society. If this work helps a little to approach the true value of natural systems, and this *before* they are gone, the aim will be reached.

Appendix A

Information for the general public about the Saugus River Watershed

IF YOU LIVE HERE



YOU LIVE IN THE SAUGUS RIVER WATERSHED

WE DEPEND ON THE SAUGUS RIVER FOR:

drinking water
recreational space
commercial fisheries
wildlife habitat
scenic beauty
open space

The Saugus River depends on us to keep it clean and healthy

Be a River Keeper in any way you can.....Here are some tips:

IN YOUR HOUSE

Proper disposal of chemicals
NEVER dump chemicals down your sink or toilet. This includes: paint products, insecticides, cleaning fluids and bleach. Store unwanted chemicals in a safe place and encourage your town to organize a hazardous waste collection day.

Alternatives
Instead of: oven cleaners *Try:* baking soda & steel wool pads
Instead of: toilet cleaners *Try:* liquid castille soap, baking soda or borax, and a toilet brush.
Instead of: drain cleaner *Try:* mix and pour 1/2 cup baking soda with 1/2 cup vinegar down the drain. Cover for one minute. Rinse with boiling water.

Conserve water
Reducing water use will help septic systems and treatment plants run more efficiently. Also, several towns in the Saugus River Watershed get their drinking water from the Saugus River. If we use less, there is a greater volume of water left in the river channel and this is important for fish migration and spawning.

YOUR CAR

Maintenance
If you do it yourself, do it responsibly. Be sure to bring used motor oil to a local gas station or collection site. Just one quart of oil poured down a storm drain will pollute one million gallons of water. Never pour antifreeze or motor oil down house or storm drains. Many storm drains empty directly into the Saugus River.

YOUR PETS

Proper disposal of pet waste
Like human waste, pet waste can also be a significant contributor to water pollution. When walking your pet along waterways, such as rivers or beaches, use a pooper scooper! Scoop up your pet's waste and dispose of it in the toilet.

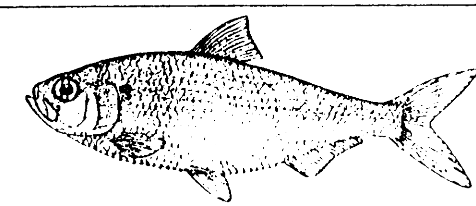
IN YOUR YARD

Fertilizers
Chemical fertilizers contain nutrients which can enter bodies of water and cause excessive plant growth. The end result is oxygen depletion which creates an environment that cannot support most aquatic life, leading to fish kills and other harmful results.

Pesticides and herbicides
These often contain harmful chemicals that can wash off of your lawn and into rivers, or seep through soil and pollute groundwater. Try mulching and weeding to control weeds. Let natural predators such as birds, bats and spiders control insect pests.

Proper disposal of leaves & clippings
Do not dump your yard waste into the Saugus River or any other body of water. Compost your yard waste, use it for mulch, or bring it to your local recycling center.

Septic system maintenance
Malfunctioning septic systems are major contributors to water pollution. Systems should be pumped out every six months.



Blueback herring, recently restocked in the Saugus River

The Saugus River Watershed Council is a non-profit group working to protect, preserve and restore the Saugus River and its watershed.
WE ENCOURAGE YOU TO JOIN US!

* Name:________________________ *
* Address:______________________ *
* City:_________________________ *
* State/Zip:__________Tel:__________ *
* I have enclosed my $10.00 membership contribution ___ *
* I'd like to help with: ____clean ups ____publicity *
* ___educational programs ____water monitoring *
* ___events Other________________ *
* Mail to: SRWC, P O Box 1092, Saugus MA 01906 *

Appendix B

Net Present Value calculations and time scales

The Net Present Value criterion consists in the following steps.

1. Evaluate expected cash flows related to the project in the years to come for each year: ECF_0, ECF_1, ECF_2... These cash flows can be positive or negative.

2. Discount each cash flow with the chosen discount rate (r) according to its year of occurrence to obtain their present value, or discounted cash flow. In year n: $DCF_n = ECF_n/(1+r)^n$.

3. Add all the discounted cashflows from year 0 to infinity to obtain the Net Present value (NPV) of the project: $NPV = \sum_{i=0}^{\infty} DCF_i$.

4. If the result is positive, the project has a positive Net Present Value, the amount of which represents the increase of wealth due to the project, expressed in today's monetary terms. If the result is negative, society is better off without carrying out the project.

Now let's imagine a project which produce a cash flow of \$1 each year. When n increases, the discount factor $1/(1+r)^n$ becomes so small that the contribution of the dollar in year n to the NPV becomes negligible. As an example we computed the

Year	0	1	2	5	10	20	30	40	50
DCF	1.00	.93	.87	.71	.51	.26	.13	.07	.03

Table B.1: DCF's for a stream of \$1 with a 7% discount rate

discounted cash flows of our stream of \$1 each year for a discount rate of 7% from year 0 to year 50. Table B.1 shows the results.

Given the incertitude on the cash flows in an environmental context, taking into account the contributions after year 40 makes no sense. Implicitly, we use a 40 years time scale. Moreover, this time scale would be shorter if the cash flows became \$.5 after say year 15, and this without any relation with the ecological reality of the system studied.

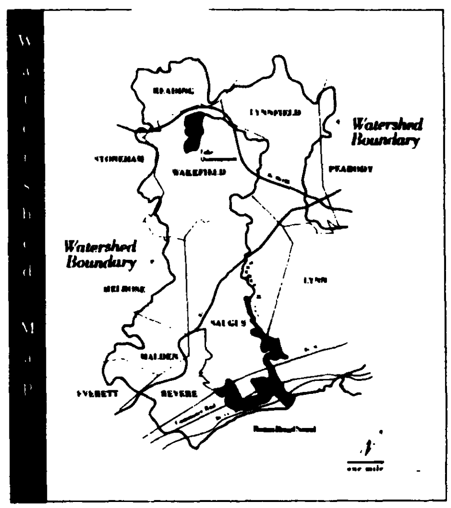
Appendix C

Brochure edited by the Saugus River Watershed Council

Watershed Breakdown By Town

TOWN	RIVER MILES WITHIN TOWN	% OF TOWN WITHIN WATERSHED	PRIMARY USES WITHIN WATERSHED
SAUGUS	8 5	100	I,R,C
REVERE	2.0	70	I,R,C
LYNN	2.0	79	I,R,C
LYNNFIELD	2.5	53	C,R
WAKEFIELD	4.5	97	I,R
EVERETT	0	21	I,R,C
READING	0	28	I,R,C
MALDEN	0	45	R
MELROSE	0	42	R,C
STONEHAM	0	10	R
PEABODY	0	2	R

I- INDUSTRIAL, R- RESIDENTIAL, C- COMMERCIAL



Map was generated by Kathleen Schmidt for the report, Baseline Assessment of the Saugus River System, compiled by Hudsonia Limited.

THE SAUGUS RIVER WATERSHED COUNCIL

"The Saugus River is a vital resource which can provide many uses to the residents of the Saugus River watershed, including fishing, canoeing, swimming or just getting back to nature. By becoming more aware of this valuable river and its history, we, as citizens, can help restore its beauty and its recreation opportunities."

Joe Vinard
President
Saugus Cooperative Bank

The Saugus River Watershed Council is a non-profit organization concerned with the health and beauty of the Saugus River and its watershed. Organized in March, 1991, as the Saugus River Advocacy Group, we have organized interpretive walks and educational exhibits, lobbied for protection of the river, inventoried the river and its banks, begun a water quality testing program, worked on fish habitat restoration, participated in river cleanups and reached out to other organizations to work together on conserving the Saugus River.

We encourage you to join us. Walk or canoe the river; get your hands muddy in a conservation/restoration project; promote the Saugus River through advocacy, education, field trips and special events. We offer many ways for you to get involved.

Please complete the membership form on the back of this panel and return to the Saugus River Watershed Council along with your contribution to support the work of the Council.

The Saugus River Watershed Council has been assisted by The National Park Service Rivers, Trails and Conservation Assistance Program.

THE SAUGUS RIVER

History

Native Americans called the river "Abousett" which means "winding stream".

Native Americans called the beach which runs from Swampscott to Revere "Saugus" which means "long and extended".

Salmon were often speared from the river by the early Native Americans.

Settlers called it "the River at Saugus," which was later shortened to Saugus River.

The first known commercial fishery in this area was constructed in 1632 on the River at Saugus. Great quantities of alewives and bass were harvested.

Small boats, which transported materials to and from the Iron Works, could navigate the river up to the Iron Works harbor and dock during high tide.

Since the Iron Works was established in the 1640's, the Saugus River has attracted industries such as grist mills, chocolate mills, wool and flannel mills and a tannery.

The original dam for Prankers Pond was built in 1642 to supply waterpower for the Iron Works. It was enlarged in 1846 by Edward Pranker to power his mills.

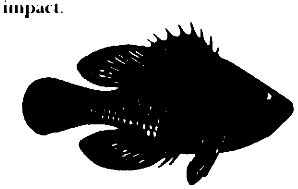
Water Quality

Today, the Saugus River is used upstream for municipal water supply, downstream for commercial fishing operations and in between for recreational fishing and boating, openspace and recreation along its banks. However, the river is also subject to outfalls for combined sewage overflows, industrial waste and storm drainage.

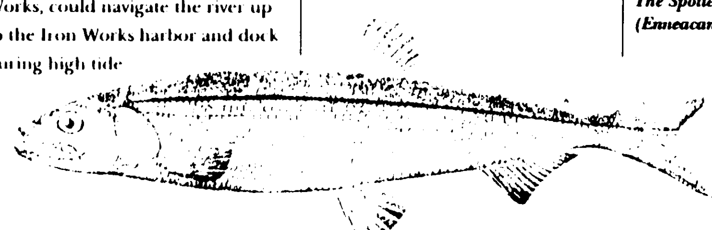
In 1982, the Massachusetts Division of Water Pollution Control established for the Saugus River System a water quality rating of B, suitable for fishing and swimming,but not drinking.

The 1982 study found the river "subject to increased pollutant loadings from stormwater runoff."

In 1989-1990, the Baseline Assessment of the Saugus System, conducted by Hudsonia Limited, determined the Saugus River may be exceeding the limits for a B rating, indicating greater pollution impact.



The Spotted Sun-fish
(Enneacanthus obesus)



Smelt (Osmerus mordax)

"We are stewards of the Saugus River. Because of its rich heritage as a working river, as well as its great recreational potential, it is incumbent upon us to preserve the River by doing all we can to reduce the stresses upon it and its watershed."

Ann Cyros
Chair
Saugus Conservation Commission

"The Saugus River has been a significant resource throughout our region's history. It is up to us to act now and provide proper conservation and preservation so that our children, and theirs, can fully enjoy all the river can offer now and in the future."

Skip Cole
Former Superintendent
Saugus Iron Works
National Historic Site

"The Saugus River is a vital part of our town; for lobstermen, sports enthusiasts and the general public"

Dick Barry
Saugus Board of Selectmen

THE SAUGUS RIVER WATERSHED

A watershed is an area of land which all drains into one river system.

The Saugus River is 13 miles long and has six tributaries; the Mill River, Bennets Pond Brook, the Pines River, Hawkes Brook, Crystal Pond Brook, and Shute Brook.

The river falls 90 feet from its source, Lake Quannapowitt in Wakefield, to its mouth at Boston Broad Sound.

The main stem of the Saugus River flows through four towns; Wakefield, Lynnfield, Saugus and Lynn. Water from six more towns joins the river via small tributaries.

The Saugus River Watershed includes all of Saugus and portions of 10 other towns.

The watershed is over 47 square miles.

The watershed is an urbanized area with commercial, industrial and residential development.

Five major transportation corridors pass through the watershed; Routes 1, 95/128, 107, 1A and the MBTA Commuter Rail line.

Even though not all towns border on the Saugus River, their actions and that of their residents impact the river because they are within the Saugus River Watershed.

Common mummichaug (Fundulus heteroclitus)

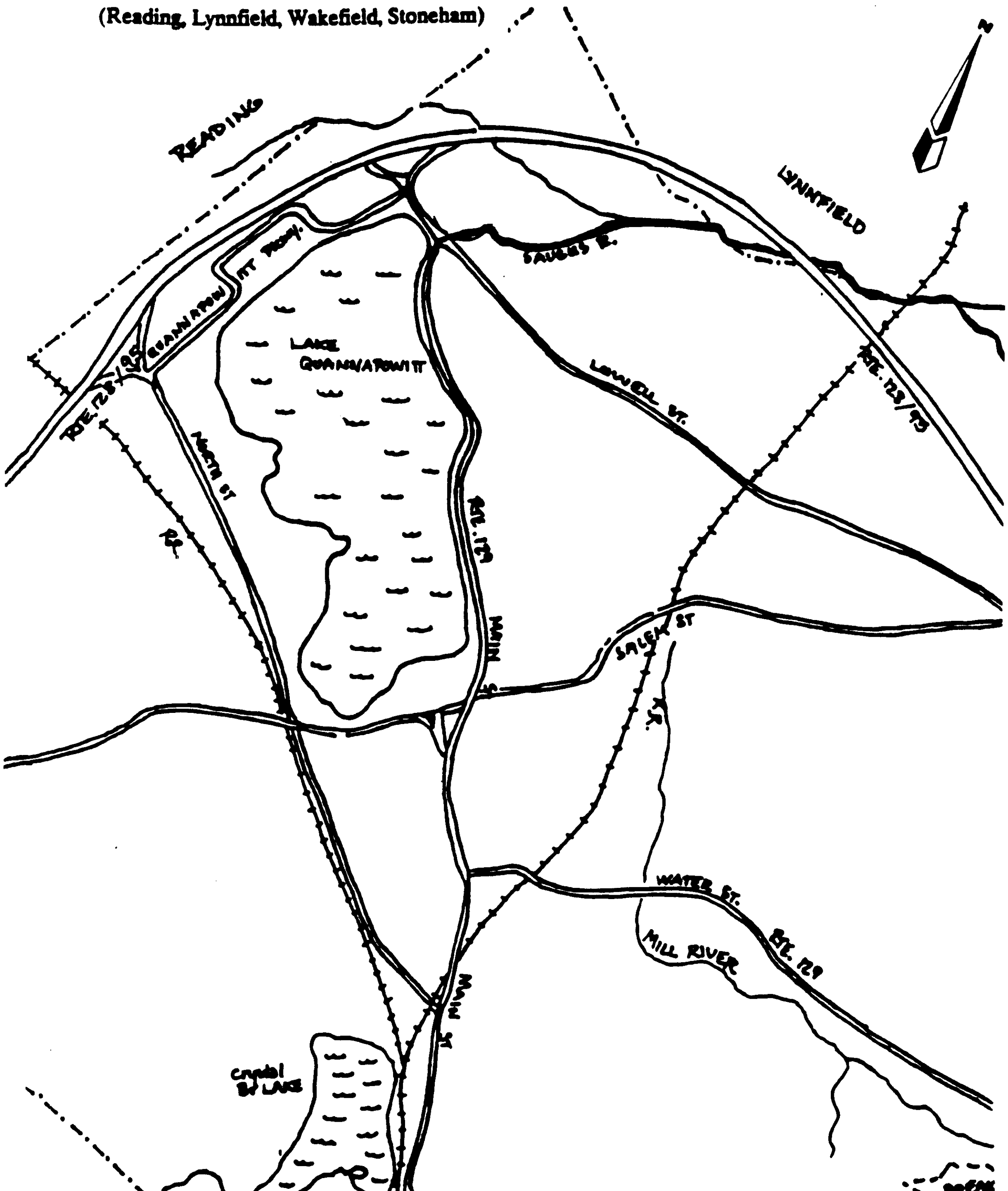
Appendix D

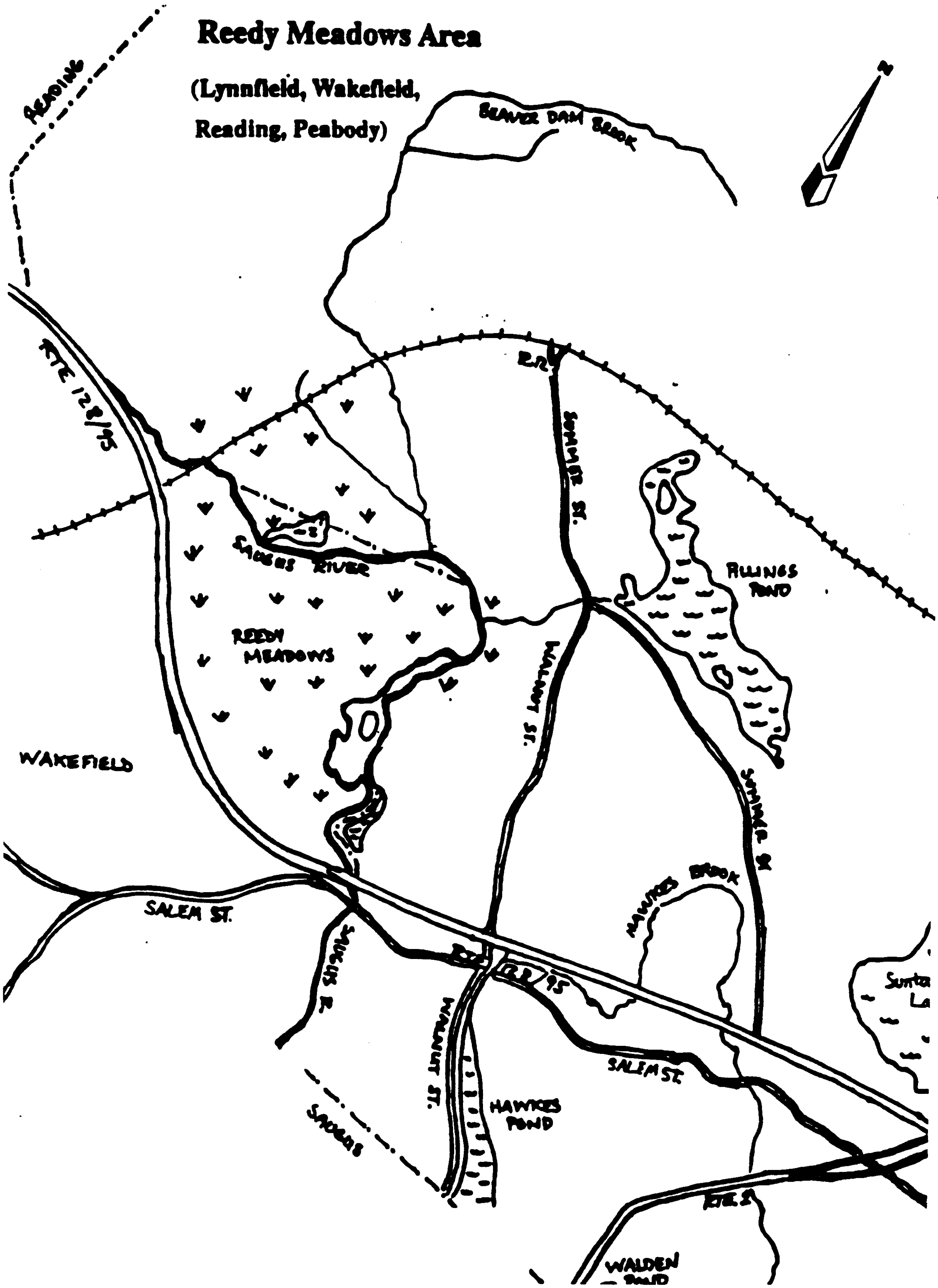
Detailed maps of the Saugus River

Source: [26]

Lake Quannapowitt and Headwater Area

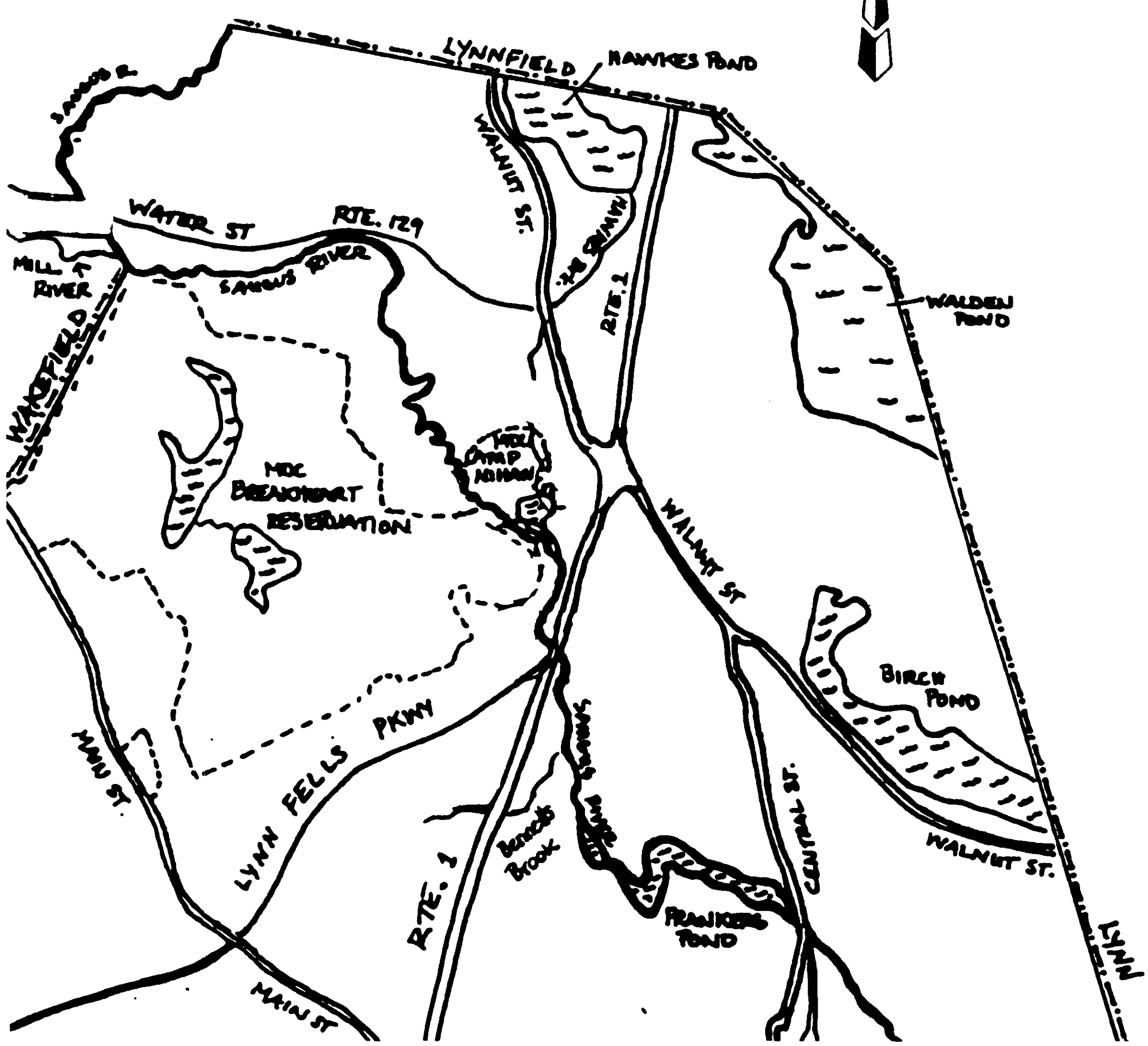
(Reading, Lynnfield, Wakefield, Stoneham)

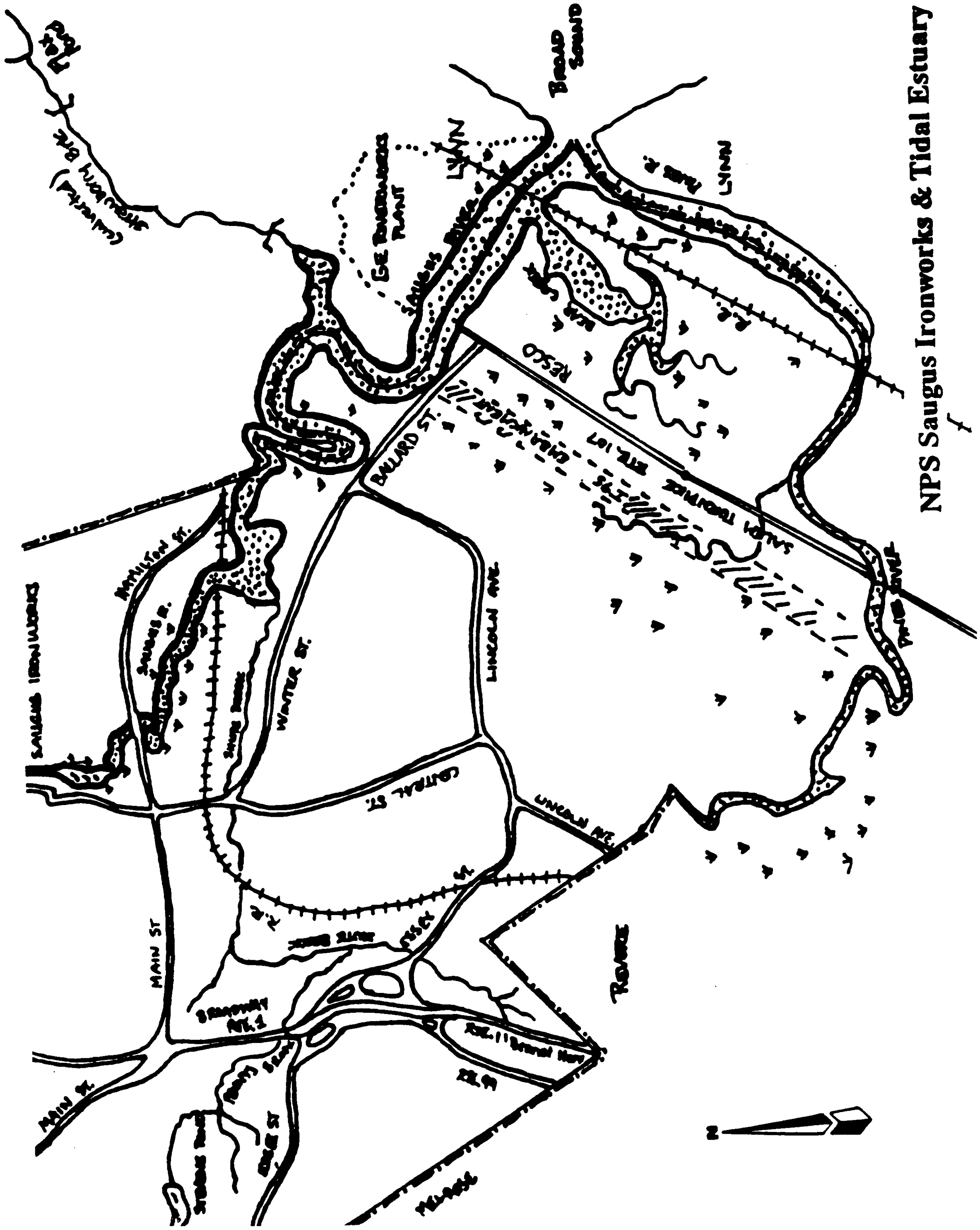



Reedy Meadows Area
(Lynnfield, Wakefield,
Reading, Peabody)
READING
BEAVER DAM BROOK
RTE 128/95
R.R.
SUMMER ST.
SAUGUS RIVER
PILLINGS POND
REEDY MEADOWS
WALNUT ST.
WAKEFIELD
SUMMER ST
HAWKES BROOK
SALEM ST.
SAUGUS R.
128/95
WALNUT ST.
SALEM ST.
HAWKES POND
SAUGUS
RTE. 1
WALDEN POND

Breakheart Reservation Area

(Saugus, Lynnfield, Lynn, Wakefield)





NPS Saugus Ironworks & Tidal Estuary

Bibliography

[1] J.C. Bergstrom et al. Economic value of wetlands-based recreation. *Ecological Economics*, 2:129–147, 1990.

[2] Richard A. Brealey and Stewart C. Myers. *Principles of Corporate Finance.* McGraw Hill, 1991. Fourth edition.

[3] Thomas C. Brown. The concept of value in resource allocation. *Land Economics*, 60(4):231–246, 1984.

[4] Michael Common. *Environmental and Resource Economics: an Introduction.* Longman, 1988.

[5] Herman E. Daly. Free market environmentalism. *Ecological Economics*, 7:173–181, 1993. Book review.

[6] Herman E. Daly and Kenneth N. Townsend, editors. *Valuing the Earth: Economics, Ecology, Ethics.* The MIT Press, 1993.

[7] Friedhelm R. Drepper and Bengt A. Manson. Intertemporal valuation in an unpredictable environment. *Ecological Economics*, 7:43–67, 1993.

[8] Mark E. Eiswerth and J. Christopher Haney. Allocating conservation expenditures: accounting for inter-species genetic distinctiveness. *Ecological Economics*, 5:235–249, 1992.

[9] S. Farber and R. Costanza. The economic value of wetlands systems. *Journal of Environmental Management*, 24:41–51, 1987.

[10] Carl Folke, Monica Hammer, and Ann-Mari Jansson. Life-support value of ecosystems: a case study of the Baltic Sea region. *Ecological Economics*, 3:123–137, 1991.

[11] Robert R. Gottfried. The value of a watershed as a series of linked multiproduct assets. *Ecological Economics*, 5:145–161, 1992.

[12] John M. Gowdy. Bioeconomics and post-Keynesian economics: a search for common ground. *Ecological Economics*, 3:77–87, 1991.

[13] H.M. Gregersen, K.N. Brooks, J.A. Dixon, and L.S. Hamilton. *Guidelines for Economic Appraisal of Watershed Management projects.* Food & Agriculture Organization of the United Nations, 1987. FAO Conservation Guide #16.

[14] Donald A. Hammer. *Creating Freshwater Wetlands.* Lewis Publishers, 1992.

[15] Garret Hardin, editor. *Managing the Commons.* W.H. Freeman, 1977.

[16] Charles C. Harris and Greg Brown. Gain, loss and personnal responsibility: the role of motivation in resource valuation decision making. *Ecological Economics*, 5:73–92, 1992.

[17] Roefie Hueting. The use of the discount rate in a cost-benefit analysis for different uses of a humid tropical forest area. *Ecological Economics*, 3:43–57, 1991.

[18] Hans Jonas. *The Imperative of Responsibility: in Search for an Ethics for the Technological Age.* University of Chicago Press, 1984. translation of Das Prinzip Verantwortung (1979).

[19] J. Walter Milon, Jonathan Gressel, and David Mucley. Hedonic amenity valuation and functional form specification. *Land Economics*, 60(4):378–387, 1984.

[20] J. Morris. Evaluating the wetland resource. *Journal of Environmental Management*, 24:147–156, 1987.

[21] U.S. Department of the Army. Saugus river and tributaries, Lynn, Malden, Revere, and Saugus, Massachusetts — flood damage reduction, 1989.

[22] Robert Repetto et al. *Wasting Assets: Natural Resources in the National Income Accounts.* World Resources Institute, 1989.

[23] Marc O. Ribaudo and Donald J. Epp. The importance of sample discrimination in using the travel cost method to estimate the benefits of improved water quality. *Land Economics*, 60(4):397–403, 1984.

[24] Leslie Roberts. Wetlands trading is a loser's game, say ecologists. *Science*, 260:1890–1892, 1993.

[25] W.T. Rumage. *The Economic Value of Whale Watching at Stellwagen Bank.* Urban Harbors Institute, University of Massachusetts at Boston, 1990.

[26] Robin Snyder. Looking to the future, an action plan for the protection of the Saugus River, 1991. Saugus River Watershed Council.

[27] Jay Shiro Tshiro, Robert E. Schmidt, Erik Kiviat, and Donald R. Roeder. Baseline assessment of the Saugus River system, Massachusetts. Hudsonian Limited, 1991. Prepared for New England Natural Resource Research Center and Massachusetts Public Interest Research Group.

[28] R. Walsh, J. Loomis, and R. Gillman. Valuing option, existence, and bequest demand for wilderness. *Land Economics*, 60(1):14–29, 1984.

[29] Frank A. Ward. Specification considerations for the price variable in travel cost demand models. *Land Economics*, 60(3):301–305, 1984.

[30] Douglas T. White. An assessment of methods for economic valuation of the northern spotted owl. Master's thesis, Massachusetts Institute of Technology, 1991.

[31] Joy B. Zedler and Abby N. Powell. Managing costal wetlands: complexities, compromises, and concerns. *Oceanus*, 36(2):19–28, 1993.