Chapter 12 - Games View of Decisions

12.1 Introduction

The studies of strategic interactions between multiple participants have lead to some operational rules that are often called "game theory". This approach divides a decision-making problem into possible choices that you can make. These are matched by decisions that your opponent or other players make. Strategies may be "pure", following one set of rules (strategy) to make each decision, or they might be "mixed", randomly choosing one strategy or the other. Similarly, the payout from each interaction may be a pre-determined number or the probability of a particular outcome. In this introduction to game theory, we will only use "pure" games in which you will be making selections from a list of strategies. The first approach will be to play the game against another player who has the same set of choices that you do. In the second example, we will modify the game to be played "against nature", in which the final outcomes are determined by the strategy that you choose and different environmental scenarios.

12.2 Simple game set up

The simplest game is when you have two choices, your opponent has the same two choices and you each have to commit to a strategy without knowing what the other is doing. A trivial example of this set-up is given in Table 1. You have to tradeoff the enjoyment of wearing your favorite shirt versus the risk of looking like a copycat. The relative values for the possible outcomes will help you to determine what you should do. This is called a dilemma because no choice is optimal all the time.

Table 12.1. A simple game for what to wear to the party. Your choices are limited to the choices in the first column. Your friend chooses independent of you. The outcome of your coolness is given in the table.

	Your friend - wears the same shirt	Your friend - doesn't wear the shirt
You - wear your favorite shirt	You both look like copycats	You look cool, he doesn't
You - don't wear your favorite shirt	He looks cool, you don't	Neither of you looks cool or dorky

In the shirt example, choosing not to wear your shirt is an example of a strategy that limits your negative outcome by choosing the strategy that steers you away from a very bad outcome. It doesn't necessarily provide you with the best outcome. We will call this strategy "avoid the worst".

12.3 Use of a common pool resource as a game

Another familiar example of this game is the "Tragedy of the Commons" scenario. The commons is a "common pool resource" in that you have no control over who uses it, and anyone who uses it decreases its usefulness to others. You have a choice of grazing your sheep on the commons either early or at the approved time. The approved time has been determined by cooperation between your neighbors and would allow both of you to graze 10 sheep all season. Your neighbor also has the same choices. You have no control of what your neighbor does and you don't know what he will do. The strategies and outcome matrix is given in Table 9.2.

Table 9.2: The tragedy of the commons expressed as a pure strategy game. The outcomes for each player are expressed both by rank and with values; best =11,

good =10, poor=0,and worst = -1. Early grazing gets you more money but wrecks the pasture.

	Your neighbor - grazes early	Your neighbor - grazes at approved time
You - graze early	You both do poorly.	Best for you, worst for neighbor
You - graze at approved time	Worst for you, best for neighbor	Good for both of you

The game outcomes show that if you cooperate with the approved time, you could very likely have the worst outcome, especially since this is the best option for your neighbor. If you choose to defect from the rules and graze early, you might end up with a "poor" rather than "worst" outcome, but there is also a chance you can have your "best" outcome. According to simple economics, the best choice is the non-cooperative strategy, which is to graze early.

This game illustrates the dilemma of cooperation in the commons in a different way than simply listing the utilities. It shows that if you both choose the non-cooperative strategy, you will both have suboptimal outcomes.

The obvious solution is to agree to cooperate. However, if you are allowed the option to talk to your neighbor and reach an agreement then that is a different game for two reasons. These are not trivial or picky points, they are very important conditions to understand. The first reason is that in a common pool resource such as this pasture, you don't control who comes in or when they graze. If you and your neighbor agree, there is nothing to keep another neighbor from coming in and grazing early. As long as it is a common pool resource, you always have the possibility that there is another "neighbor" who can show up unannounced. The second point is that even if you make an agreement with your neighbor over the fence, there are no rules that state what you would do if he broke the agreement.

Some commons are governed by rules that account for monitoring compliance and penalties for infractions. These rules need to be enforceable at a reasonable price otherwise it defeats the purpose of sharing the commons. In contrast to the impression in many of the environmental science texts, the tragedy of the commons is avoidable (i.e. it's not really a tragedy). There are many societies that govern common fisheries, pastures, woodlots and water rights very effectively. Before we jump to conclusions about the inevitability of sub-optimal outcomes in governing common pool resources or assume that all common pool resources need to be converted into private properties, we should understand how to establish and tend for institutions that favor communication and cooperation.

12.4 Playing the game against nature and the "Precautionary Principle"

Using the same type of outcomes matrix, we can define a set of choices and a set of outcomes that depend on factors out of human control. This is called "a game against nature". We don't really think that nature is our opponent, but "nature" is a stand in for the concept of uncertainty of natural events. This framework is very valuable even if you don't know the risk (or probabilities) associated with each of the possible natural events. Table 9-3 shows a simple game against nature.

There is no way to account for what all individuals might choose to do, but the most favorable choice in this situation is to take the "avoid the worst" strategy and therefore avoid any costly damage. In environmental science, this is called the "Precautionary

Principle". The principle is that if you don't know the probability of the outcomes, you should adopt a strategy that minimizes the potential harm. This principle is applied to our use of pesticides and other environmental interventions that have long-term or large impacts.

Table 9-3. Strategies for dealing with a possible tornado. You don't know the probability that a tornado will touch down on your street.

	No tornado comes down your street	Tornado comes right down your street
You - spend money to prepare for a bad tornado	You "wasted" your money	You suffered only minor damage and lived through the storm
You - spend the money on a new TV	You didn't waste your money and you have a cool TV in front of your lounger	Your house is wrecked and you can’t use battery power to watch your new TV

We are playing a similar game against nature when we respond to the threat of global warming and climate change. We can identify several strategies that we could take and we can estimate the potential outcome for different warming scenarios. The structure of the game and the favored strategy is similar to Table 9-3, take the strategy that avoids the worst possible outcome.

Although the outcomes in Table 9-4 are a bit facetious, the point is that if you take precautions in the face of uncertainty, there is a possibility that this money will be wasted. There is an opportunity for our society to look at this game and change the rules such that we invest in infrastructure and environmental protections that we want anyway, but that will protect or mitigate the effects of climate change. We should be looking for strategies to change the nature of the choices so that we can find win-win solutions. Perhaps we can find strategies that both save energy costs and reduce the threat of global warming.

Table 9-4. Global warming as a game and using the Precautionary Principle, i.e. "avoid the worst" strategy.

	Turns out, no global warming	Global warming hits hard
You - spend money to prepare for global warming	You "wasted" your money	You suffered only minor damage
You - spend the money on more highways	You didn't waste your money and now you have even bigger highways with ocean views	Your life is wrecked and you need all the highways in NY are under water

12.5 Case Study: Fisheries as a common resource

Fisheries in the open ocean are just one example of a common pool resource that can be exploited by anyone or any country. These systems are sensitive to over exploitation. Common pool resources are situations that have high subtractability (where any use subtracts the resource from any other use) and where exclusion from the resource is difficult (anyone can gain entry). There are other classifications of resources that would have different problems and appropriate solutions.

Table 9-5: Resource classification by subtractability and exclusion. Subtractability means that a use of one unit of the resource removes that unit from anyone else's use. Exclusion is whether it is easy to limit access or impossible.

	low subtractability	**high subtractability**
difficult exclusion	public goods	common pool resources
easy exclusion	toll goods	private goods

Maximum sustainable yield and over harvest. The amount of fish that is taken in any season is the "yield". Ecosystem managers calculate the maximum sustainable yield (MSY) as the maximum value of the population times the growth rate. (Ecosystem managers actually use much more sophisticated models than the “maximum sustainable yield”, but these models have essentially the same features, i.e. estimation of a population growth under conditions of high natural variability.) At low population size the number of reproducing fish limits the yield. At high populations the yield is limited by the decrease in the growth rate from inter- and intra-specific competition for resources. The maximum sustainable yield is the theoretical maximum point that is half of the carrying capacity. Over harvest can happen in two ways, either the maximum yield is an overestimate or a correct MSY could be taken too early when the population is still too small. Over harvest decreases that population such that the growth for the next season will be decreased. Thus, over harvest and early-harvest are related processes.

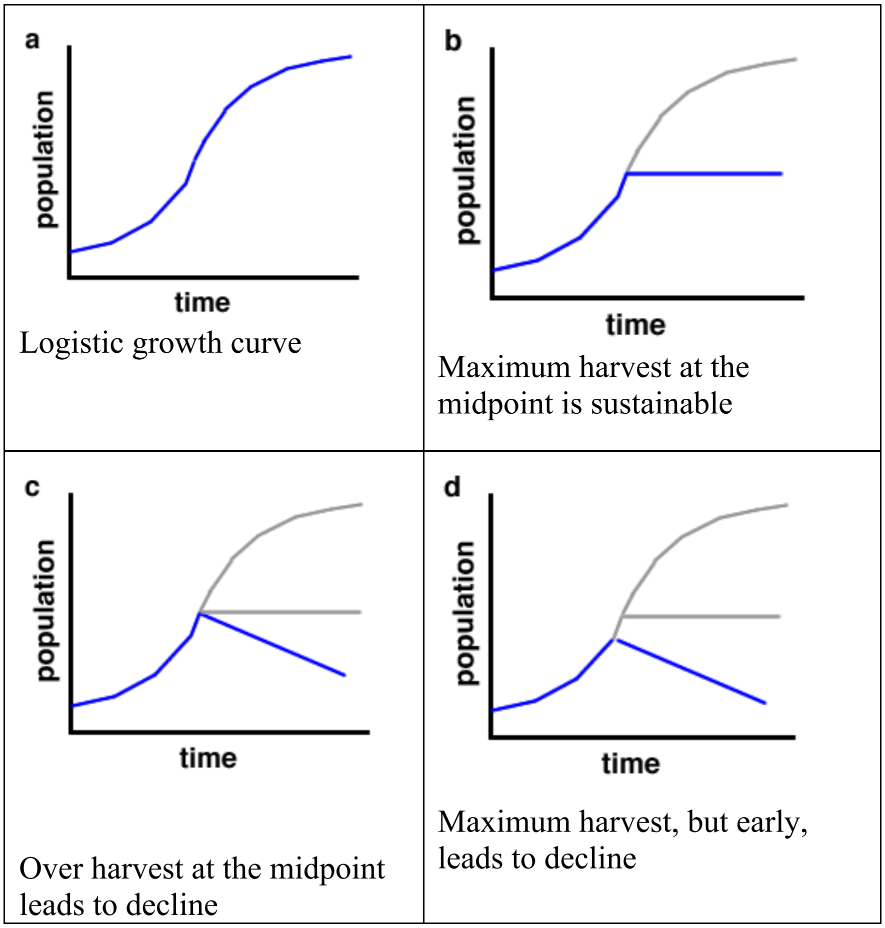

Figure 9-1 Theoretical optimal sustainable yield for a population going through a logistic growth transition. Early in the growth phase, rapid growth rate and the number of fish control the population growth. Later, the population growth (yield) is dominated the decrease in the intrinsic growth rate as the population reaches the carrying capacity. The middle of the curve (the area with the steepest slope) has the population value that will give the highest yield. b - when the maximum sustainable yield is initiated just as the population gets to the midpoint, the population will stay constant. c- if the harvest is higher than the maximum sustainable yield, the population will decrease. d- Applying the maximum harvesting rate before the population has reached the mid-point will also result in a decrease in the population.

Actual harvest rates should be below this theoretical maximum yield for several reasons. First, the process of harvesting can degrade the conditions necessary for optimal growth (see X). Too many roads in the forest, catching too many non-target fish or trampling of a pasture are examples of this type of damage. It reduces the ability of the environment to grow the resource without directly showing up in the harvest. Second, natural variability in the conditions should also be accounted for in calculating the actually yield that can be tolerated. Variations in weather or other populations in the ecosystem can result in good and bad seasons for growth. Maximal harvesting during a bad year can decrease the population below the sustainable level. Often the variability is a source of uncertainty for ecosystem managers. Still, managers need to be able to make decisions to set a harvest rate and to take precautions against the collapse of the fishery.

Variability in fishery production. Even healthy natural environments undergo swings in the overall productivity and especially growth of one species in the food web. You may recall that this variability was a key component of our attempt to understand food webs using a network view (see Chapter 7). The degree of variability can be quite large even in healthy populations. However, with artificially harvest superimposed on top of natural variability, the results can be disastrous. The following simulations (Figure 9-2) demonstrate the effects of a population that is either fished, or perturbed by a density dependent loss, or both. Each simulation run represents one possible trajectory through time with random events. There is a range of outcomes, and each can be predicted roughly from the probability of the loss (Figure 9-3). Given the dynamic nature of natural ecosystems, it may not be possible to determine the probability of loss to any degree of certainty, i.e. the loss may be uncertain no matter how much of this population is studied.

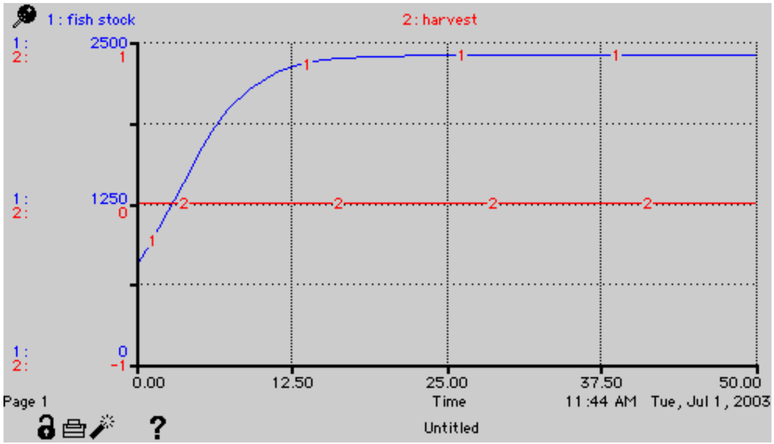

fig9-2a - no harvest

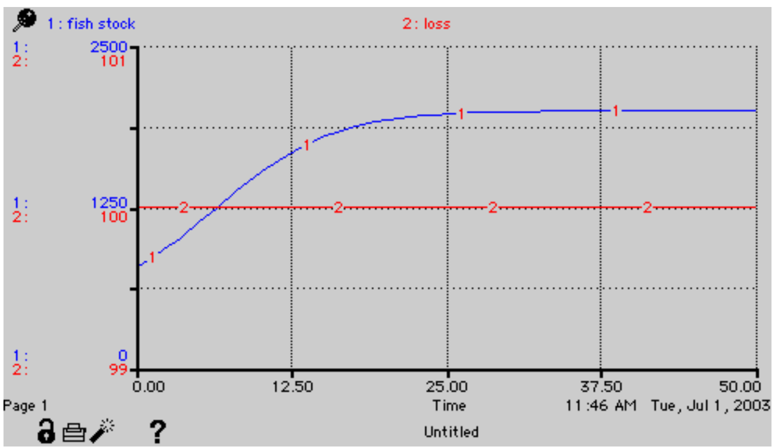

fig9-2b - harvest rate of 100

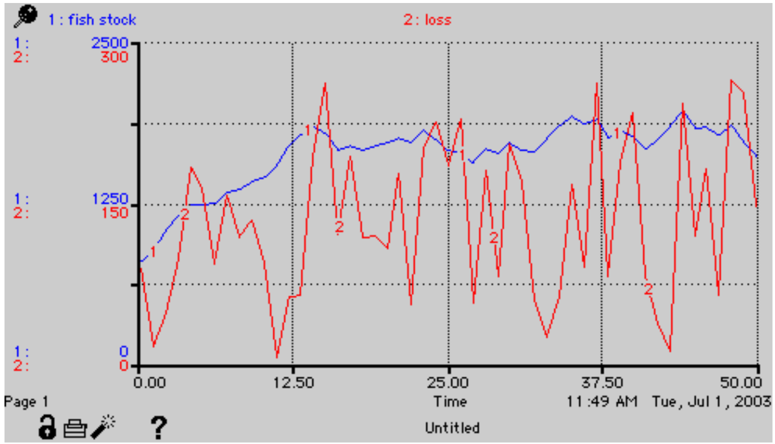

fig9-2c - one example run with a stochastic loss of up to 10% of the population per time

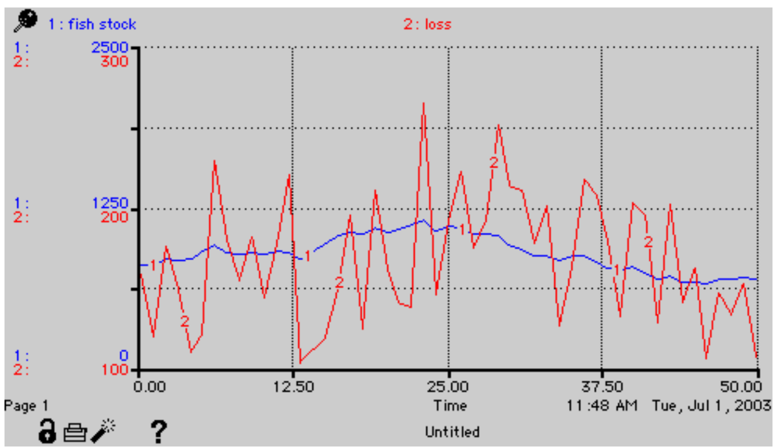

fig9-2d - another example run with both a constant harvest of 100 and a stochastic loss of up to 10% of the population per time.

Figure 9-2. Simulation results for a fish stock that is growing with and with harvest and stochastic loss terms. The parameters for all models are r=.3, K=2400, initial population =800. The population is controlled by the logistic equation. The stochastic loss is a random percent loss (up to the maximum of a 10% loss) times the population. a- growth with no fishing. b - growth with a harvest of 100. c. stochastic loss only. d- harvest and up to a 10% stochastic loss combined.

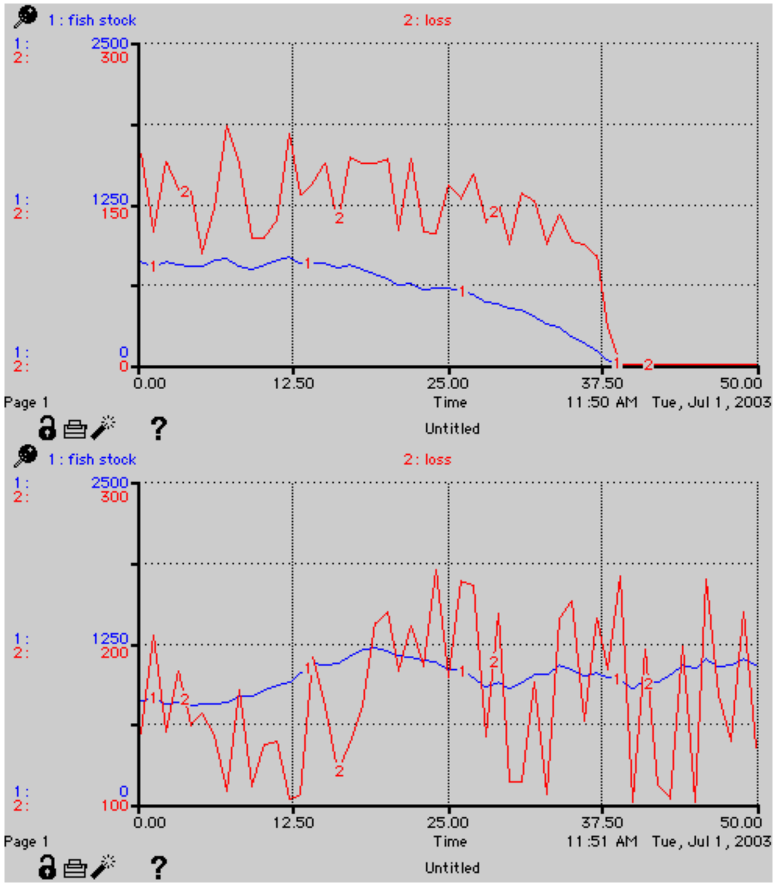

Figure 9-3. With any stochastic loss there are multiple trajectories for the population. a - one selected output that shows a collapse of the population. b - another selected output that shows increase in the population over the period shown. We would use many runs of the same model to understand what the possible risk of collapse is. It might only be one out of a hundred runs.

There are many ways to cause extinction. Just as it was claimed that "all roads lead to Rome", it seems that for our current civilization, all roads lead perilously close to causing extinction and collapse of our natural resources. Any plan to exploit natural resources (i.e. harvest for our use) must be accompanied with a plan for taking responsibility for our actions and the consequences for the environment.

Our society faces two fundamental decisions when we use natural resources. First, if the resource is a "common pool resource", we have to decide how we will adjust our use to that of other users. How will we know if we are over-exploiting the resource? The second question we face is how to deal with the uncertainty in the system and whether to make decisions based on the "precautionary principle" (which states that in the face of uncertainty, choose the path that will do the least damage).

12.6 Summary

This case study demonstrates the process of using a game matrix tool to help simplify the first steps in making a decision. This involves making a grid and filling out three different types of information. First, list the choices that you are faced with. Second, identify the major possible scenarios for environmental conditions. Third, describe the outcomes of each possible combination of choices. Analysis of this grid can help you determine if you might want to make a decision based on avoiding the worst-case outcome, in the event that it is particularly bad, or it might help you find some other strategies that could help reduce your costs and risks.

