**Notes**

***Renewable resources*** generally involve biological populations that continually replenish themselves (e.g., forests and fisheries). These resources are often described as ***interactive*** since a given population is jointly determined by both biological and social considerations. As a biological consideration, the growth or decline of a biological population generally depends on the size of that population. For example, a population that is reduced below a critical level may be unable to sustain itself and therefore becomes extinct. An obvious social consideration is the rate of harvest, which affects the biological population size. In turn, the current biological population size influences future rates of harvest. Thus, our allocation decisions (how much to harvest and when) determine the flow of these renewable resources over time.

**This interrelationship raises at least two interesting questions.**

* What is the economically efficient rate of harvest for a renewable resource?
* Can markets achieve that efficient rate of harvest?

First we describe a basic model of population dynamics. Then we explore the economic efficiency implications that arise from that model.

**A Basic Model of Population Dynamics**

A generally accepted model of population dynamics was originally proposed by Schaefer in 1957. While more sophisticated models have been developed since then, Schaefer’s model first described the essential population responses to alternative harvest decisions. It is useful to us because it describes the average growth of a population without introducing the confounding influences of various counteracting forces that affect real populations. This model is graphically illustrated below.

It is important to realize that this model describes a long-term relationship that abstracts from the effects of food supply, competition, predation, and other short-term influences. Accordingly, the rate of population growth (vertical axis) is simply a function of population size (horizontal axis). This model suggests that the rate of growth increases with population up to a certain point (S\*), and decreases with population beyond that point.

The population S” is known as the ***natural equilibrium***. This is the population size that would persist through time given no outside influences such as harvesting. S” is an equilibrium because its rate of growth is zero, where births exactly offset deaths. This equilibrium is also ***stable***. A temporary decrease in population from S” would result in a positive rate of growth that would eventually return the population back to S”. Conversely, a temporary increase in population from S” would result in a negative rate of growth that would eventually return the population back to S”. The stable nature of this equilibrium allows it to persist through time through various natural perturbations.

The population S’ is also an equilibrium since its rate of growth is zero. However, this equilibrium is not stable. Any decrease in population below S’ would result in negative rates of growth that would eventually cause extinction. Therefore, this level is known as the ***minimum viable population***. On the other hand, any increase in population from S’ would cause positive rates of growth that would eventually drive the population to its natural equilibrium at S”.

We have discussed only some biological considerations that influence the availability of renewable resources. We now turn to some social considerations in the form of harvest. We harvest lumber from forests and fish from oceans. But how do these harvest activities influence the availability of renewable resources? The simple model of population dynamics presented above provides an analytical structure to answer this question. We begin by describing a ***sustainable yield*** as a level of harvest that equals the growth rate of a population. If only the growth of a given population is harvested, then that population size will remain constant, neither increasing nor decreasing. Therefore, the rate of growth illustrated in the graph above also describes the sustainable yield for various population levels. Given that, one can easily see that the ***maximum sustainable yield*** is the rate of growth associated with population S\*. In other words, S\* is the population that yields the maximum growth that can be harvested repeatedly on a sustainable basis. Larger levels of harvest are possible, but they cannot be sustained since they would lead to lower population sizes and eventually extinction.

We often hear of managing renewable resources for maximum sustainable yield as one allocation criterion. It sounds intuitive since society would produce more of the resource over time. But is it economically efficient?

**Statically Efficient Sustainable Yield**

The short answer is no – maximum sustainable yield is not economically efficient. The reason is that maximum sustainable yield as a criterion only considers the benefits of harvest and not its costs. Economic efficiency, on the other hand, is concerned with maximizing net benefits, which are benefits minus costs.

Let’s take a closer look. Consider the following graph which illustrates the concept of ***statically efficient sustainable yield***. The statically efficient sustainable yield is the level of harvest that, if maintained indefinitely, would produce the largest net benefit year after year. This concept illustrates the basic idea of efficiency without complications involving discounting.

The following simplifying assumptions are made.

* The price received for the resource (e.g., price per ton of fish in a commercial fishery) is constant – it does not vary with the total amount sold.
* The marginal cost of harvest effort (e.g., cost per vessel-day of fishing) is also constant – it does not vary with the total level of effort expended.
* The yield per unit of harvest effort (e.g., tons of fish per vessel-day) is proportional to the resource population size – larger populations yield more per unit of harvest effort than smaller populations.

Given these assumptions, the total revenue and total cost of ***sustainable levels of effort*** are represented in the graph above. Note that the horizontal axis of this graph is effort, not population. A sustainable level of effort produces a sustainable yield year after year. Consider the following.

* The shape of the total revenue curve obtains directly from the shape of the long-term population growth curve. It reflects the assumptions of a constant resource price and a proportional yield per unit of harvest effort.
* The linear shape of the total cost curve derives directly from the assumption of a constant marginal cost of harvest effort.
* An increase in harvest effort obviously results in a reduced resource population. This is represented by a leftward move along the long-term population growth curve.

E\* is the level of harvest effort that produces the maximum sustainable yield. The net benefit generated by that level of effort is given by the vertical distance on the graph between the associated levels of total revenue and total cost (i.e., total revenue minus total cost). But that distance is not maximized at E\* (you might have to use a ruler to tell from this graph). Rather, net benefit is maximized at E’. That point also happens to be where the slope of the total revenue curve (i.e., marginal revenue) equals the slope of the total cost curve (i.e., marginal cost). In other words, net benefit is maximized where marginal revenue equals marginal cost (i.e., the equi-marginal condition). Notice that the slope of the total revenue curve is positive only for levels of effort that are strictly less than E\*. Therefore, since marginal costs are always positive, the statically efficient level of harvest is always ***less*** than the maximum sustainable yield.

This analysis demonstrates that maximum sustainable yield can never be statically efficient given a positive marginal cost of harvest effort. Only when the marginal cost of harvest effort is zero (i.e., a perfectly horizontal total cost curve) would the slope of the total revenue curve equal the slope of the total cost curve at E\*, the level of effort that produces the maximum sustainable yield. That wholly unrealistic situation (zero marginal cost) illustrates why the maximum sustainable yield is never statically efficient. Technological improvements in harvest techniques might rotate the total cost curve downward, and thereby reduce the marginal cost of harvest effort. But a complete reduction of marginal costs to zero is not reasonable.

The question of whether markets can achieve the efficient rate of harvest depends on the same considerations we discussed earlier this semester. For example, if the biological population is also a common property resource such as most commercial fisheries, then individuals will not have incentives to constrain their harvest activities in order to maximize their long-term net benefit. Moreover, if the harvest activity also involves a negative externality, then individuals will not be responding to the full scope of costs associated with their harvest activities. Therefore, to the extent that these market failures are significant issues for renewable resources, normal market forces cannot be expected to achieve efficient rates of harvest.

**Conclusion**

Renewable resources generally involve biological populations that continually (or potentially) replenish themselves. The maximum sustainable yield of a biological population is the largest rate of harvest that can be maintained year after year. However, that rate of harvest is not economically efficient. Positive marginal costs of harvest effort imply an efficient rate of harvest that is ***less*** than the maximum sustainable yield. Normal market forces cannot be expected to achieve efficient harvest levels of renewable resources if market failures such as common property and externalities are present.