CHAPTER 12: FISHERIES

I. Major issues

A. Efficient management based on biological growth function

B. Common property problem: domestic and international dimensions

1. Whale hunting disputes

2. The tuna-dolphin case between U.S. and Mexico, leading to the debate on trade and the environment.

II. The Biological models

Schaefer (1957) developed a simple biological model of the natural population growth of fish.

A. Notation

\[ S_t \] denote the stock of fish at time \( t \) and growth is

\[ G_t \equiv S_{t+1} - S_t \]

B. A compensated growth function is depicted as:

\begin{itemize}
  \item[1.] The growth rate in this case (i.e. \( G/S \)) is monotonically decreasing as a function of the stock
  \item[2.] The implications of this model can be seen in a graph of \( S \) over time.
\end{itemize}
3. $S^u$ denotes the "environmental carrying capacity" of the fishery.

4. Tietenberg also refers the $S^u$ as the "natural equilibrium". This is because from any initial stock (except $S = 0$), the fishery will naturally grow to $S^u$ and stay there.

5. **DEFINITION**: An *equilibrium* refers to a state at which there are no forces for change.

6. $S=0$ is also an equilibrium stock level.

C. A depensated growth function is depicted as:

1. Notice that in this case the growth rate is at first increasing and then decreasing.
2. The implications of this model are similar to those for the purely compensatory model, except for a change in the initial curvature of $G(S)$. There are still only two equilibrium stock levels ($S^u$ and 0). The time path for $S_t$ is similar, only now the speed of convergence is somewhat different.

D. A critically dependent growth function:

![Graph showing critically dependent growth function]

1. The implications of this model for how the stock changes over time can be seen in the following graph.

![Graph showing how the stock changes over time]

2. There are now three equilibria:
   a. $S = S^u$ which is still stable
b. \( S = 0 \) which is now stable

c. \( S = S^l \) which is unstable.
   
i. This stock level is known as the minimum viable population.

3. Example: The Blue Whale
   
a. The blue whale is the largest of the whales, and heavily prized as a result.
   
b. During the peak of whaling for this creature (1928 to 1938) approximately 26,000 of this creature were caught each year.
   
c. By 1960, only about 1600 blue whales were estimated to still exist.
      
i. It was not known if this was below the \( S^l \) for this species (i.e., below the minimum sustainable population).
      

   
   
   
   ii. In 1964, a moratorium was placed on the hunting of blue whales.
   
   
d. A problem still exists in that blue whales may be "poached" or caught during the hunting for other whales.

### III. Harvesting from the Fish Stock

#### A. Assume \( Y \) (harvest) is a constant over time

#### B. DEFINITION: The maximum sustainable yield (MSY) refers to the maximum harvest in a year that can be sustained forever.

![Graph](image)

#### C. DEFINITION: \( S_{MSY} \) refers to the stock consistent with MSY.
D. **DEFINITION:** Biological overfishing refers to fishing that results in a stock below $S_{MSY}$.

E. Consider three harvesting conditions:

1. $Y < MSY$
   
   a. In this case there are two stable equilibria: $S_2$ and $0$
   
   b. There is one unstable equilibrium: $S_1$

2. $Y > MSY$
   
   a. In this case there is only one equilibrium stock, $S = 0$.

3. $Y = MSY$
a. In this case there is one stable equilibrium, $S = 0$.

b. There is one unstable equilibrium, $S = S_{MSY}$.

F. $Y = MSY$ has been suggested as one target for policy purposes

**Question:** What is wrong with $MSY$ as a policy target?

1. $Y = MSY$ is an unstable solution. It may be difficult to detect errors in estimating $MSY$.

2. $MSY$ may change over time
3. The MSY objective does not make sense when there is interactions among species. A related species may be killed off in the process of focussing in MSY for a given species.

4. The objective ignores social and economic considerations.

IV. Static Efficient Sustainable Management: the Gordon Model

A. Historically, the problem was delineated by H. S. Gordon in the early 1950's.

1. Gordon was asked by the Canadian government to provide an economic analysis of the Canadian Fishing Industry, with an objective of explaining why fisherman had persistently low wages.

2. Gordon explained the problem in terms of the common property nature of fisheries.

B. Gordon's model starts with two assumptions.

1. Yield is proportional to
   a. The amount of effort put into fishing (e.g., number of boats) and
   b. The level of the fish stock.
   That is
   \[ Y = qSE \]

2. The fishing yield must be sustainable
   a. DEFINITION: A catch level is said to represent a sustainable yield whenever it equals the rate of growth of the population.

C. These two assumptions imply a relationship between the sustainable yield and effort, which can be derived graphically as follows:
D. Static efficiency (or dynamic efficiency with zero discount rate)

1. Let profits be given by \( P = PY - cE \).

2. Maximizing current profits: \( MR = MC \)
3. DEFINITION: The static-efficient sustainable yield is that catch level which, if maintained perpetually, would produce the largest net benefits.

4. \( Y = MSY \) is statically efficient only if \( c = 0 \) (i.e., effort is costless). Otherwise, \( Y < MSY, E < E_{MSY}, \) and \( S > S_{MSY}. \)

5. Question: What would happen if \( p \) is increased?
a. E increases
b. Y increases
c. The sustainable stock level $S_Y$ decreases.

E. Problem with this approach: discounting is not accounted for

V. Dynamic Efficient Sustainable Management

1. The dynamically efficient allocation incorporates discounting

2. With discounting, one cares less about the future than without discounting. As a result, one might depart from $E_c$ because it would be too costly in the short run to get there.
3. In general, this will lead to
   a. \( E^c > E > E^e \)
   b. \( S^c < S < S^e \)

VI. The “Common Property” Problem: continuation of Gordon model

A. Because of the common property nature of the resource, competitors will enter the market until profit = 0, so that the scarcity rent disappears.

B. Graphically, this result is depicted as:
The market will end up at $E_c$.

**Question:** What is wrong with this solution?

1. It focuses only on current generations and ignores the impact on future generations of lowering the stock of fish. The high effort level corresponds to a low level of stock.
   
   Recall how the relationship $Y(E)$ was drawn. A high $E$ corresponds to a low $S$.

2. It represents an overcommitment of resources even for the present. The same level of yield can be obtained with less effort and a greater sustainable stock level.
E. Example: The North Pacific Fur Seal

1. This seal has two harvesting phases:
   a. During the mating season, the seals are on land governed by the U. S. and Canadian governments. (i.e., private ownership)
   b. During the migration season, they travel along the west coast of North America in open waters and are not governed by U. S. or Canadian governments.

2. During the migratory season, the seals were almost fished to extinction.

3. An international ban was eventually placed upon pelagic (open water) harvesting.

VII. What has or can be done to optimally manage fisheries

A. Aquaculture

1. **DEFINITION**: *Aquaculture* refers to the controlled raising and harvesting of fish.
2. **Question: Why would this be a solution?**
   
a. Aquaculture converts fisheries from common property resources to private property resources.

b. Fish farming has worked well for shellfish

c. Japan uses fish farming extensively.

d. Fish ranching is also used for fish with strong homing instincts (e.g., pacific salmon and ocean trout).

B . Raising costs of fishing by limiting fishing methods

1. How to catch
   
a. Barricades are banned in the case of river salmon

b. Up until the 1950's, engine propelled boats were banned in Bristol Bay for gillnetters.

2. Which fish to catch: size, age, etc.

3. When to catch: mating season, etc.

4. Where to catch

5. Problems of these limits
   
a. They artificially and inefficiently raise the cost of fishing

C . Quotas

1. These are often referred to as TAC's (total annual catch)

2. **Question: What would you do if you were a salmon fisherman and were told that only 100 tons of salmon could be caught by all fisherman per year?**

   Buy the biggest boat and the best equipment to make sure that you were the person to catch the fish

3. If the goal is to help the fisherman, this will actually make matters worse.

4. Example: New England Council
   
a. Annual limits were placed on fish catches for specific species.
      
i. The limits were quickly reached

ii. Fisherman were done for the year and unhappy.
b. Semi-annual limits were put in place, and again were quickly reached.

c. Quarterly catch limits were reached with the same problem.

d. Quotas were placed on the basis of fishing effort (boat size)
   Bigger boats were bought

e. Quotas were placed on the basis of crew size
   Crew sizes suddenly increased.

D. Taxes

1. Taxes can be assessed on
   a. The level of effort
   b. The total catch
   c. Start-up or license fee.

2. While these methods can work, the problem is that they are politically unpopular -
taxing an industry already suffering.
E.  Tradeable Quotas

F.  Expand the national limits - 200 mile limit. This privatizes an important portion of coastal fisheries.