Classes of Natural Resources

A. Nonrenewable, or Exhaustible – e.g. coal deposit, oil deposit, body of iron ore (the subject of Ec. 471)

B. Renewable – a resource that is capable of growth, or regeneration, e.g. a forest, a fishery resource, a water resource, atmosphere

The use of the term "Exhaustible" can be misleading -often impossible to exhaust physically category A natural resources. Many category B natural resources can in fact be physically exhausted -examples

ECONOMIC BASE of a REGION
(e.g. British Columbia)

-goods and services produced by the Region that are sold primarily beyond the Region’s borders

All other productive activities in the Region are seen as being dependent on this BASE.

The Economic Base of the Region that is British Columbia is heavily oriented towards Natural Resources –forestry in particular.

Natural Resources as Capital

Capital is any asset that is capable of yielding a stream of economic returns through time – as opposed to a consumer good or service.

Real capital vs. financial capital

All natural resources, non-renewable and renewable, fall within this definition of real capital

The World Bank 2005 publication: ***Where Is the Wealth of Nations?*** – based upon the fundamental idea that society's income through time is produced by its stock of real capital, which consists of:

I. Produced capital (person made capital)

II. Natural capital

III. Intangible capital (human and social capital)

Traditional national income accounting only recognizes produced capital. The World Bank and others call for "green accounting"

Development seen by the World Bank as a process of real capital portfolio management through time (portfolio – a set of assets).

Natural Capital vs. Produced Capital (person made capital)

a. Natural capital assets come as endowments of nature

b. Can be optimal –within limits –to deplete, to disinvest in, Natural capital
   - deliberate disinvestment of Produced capital never discussed. No nation is ever seen as having more than enough Produced capital.

Since, we as economists view all natural resources as forms of real capital, it follows that the economist's Theories of Capital and Investment *lie at the heart of* Natural Resource Economics, as applied to both renewable and non-renewable natural resources.

The Theory of Capital vs . The Theory of Investment

Theory of Capital – about determining the optimal ***stock*** of capital.

Theory of Investment –concerned with flows –

positive investment – building up a stock of capital through time.

negative investment (disinvestment) - reducing a stock of capital through time.

The Theory of Investment is designed to tell us how rapidly we should approach the optimal stock of capital. Should the ***rate*** of investment be fast or slow.

Resource Investment and Sustainable Harvesting: A Crude Example

<u>A Forest</u>

At the end of period **t**, the volume of wood in the forest is estimated to be equal to **X** cubic metres.

If no harvesting (logging) were to occur in the forest over the following period: **t + 1,** the volume of the wood in the forest at the end of period **t + 1** would be estimated to be equal to:
X + Y cubic metres.

The additional **Y** cubic metres accounted for by the net natural growth of the forest.

Now suppose that there is harvesting, over **t + 1**, equal to exactly **Y** cubic metres. The volume of wood in the forest at the end of **t + 1** would, other things being equal, be **X** cubic metres: (**X + Y) – Y = X.**

In theory, **Y** cubic metres could be extracted from the forest, period after period, with the volume of wood in the forest remaining stable. We would talk about harvesting the forest on a **"Sustainable Basis"** - "cropping the growth", or "skimming off the growth".

-Size of the sustainable harvest will be influenced by the size of the forest (measured in cubic metres of wood).

Sustainable Yield (or harvest) – a concept that we shall see coming up over and over again in the management of renewable natural resources.

In the case of a given non-renewable natural resources, sustainable harvesting (exploitation) is not possible, since the growth of the resources is equal to zero.

Return to our example, but now suppose that harvesting of the forest in **t + 1,** is *less than* **Y** cubic metres. The size of forest asset, measured in terms of volume of wood, would increase. We would say that **positive investment** in the forest over **t + 1** occurred. Obviously, we would get the maximum rate of investment in the forest by reducing the rate of harvest to zero.

If the harvest over **t + 1** should exceed **Y** cubic metres, we would have negative investment in the forest asset – also known as disinvestment.

If we are harvesting the forest on a **"Sustainable Basis"**, the rate of investment in the forest is equal to *zero*. The forest asset will neither increase nor decrease.

We next need to note that our ability to manage these resources is strongly affected by the existence, or lack of existence, of resource property rights. The property rights, if they exist, may be private, or they may be public (i.e. state). As a first step, we must define what we mean by property rights.

Property Rights – Text definition

> **"A bundle of characteristics that convey certain powers to the owner of the right"**

Key characteristics

I. Exclusivity

II. Enforceability

III. Transferability

IV. Divisibility

Characteristics I and II are crucial

-the Text's example of a farmer holding a deed to farm land.

Absence of property rights:

"common pool" resources

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As we shall come to see, the absence of effective property rights can easily lead to massive economic waste and the outright destruction of natural resources.

We now return to the Theories of Capital and Investment. Before we can say anything further about these theories that lie at the heart of natural resource economics, we have to review the concepts of Present Value and Future Value.

The Interrelated Concepts of Present Value and Future Value

Present Value (PV) used to express the current, or present day, value of an asset (or return) to be received at a certain future date.

Future Value (FV) relates to value of an asset, if held, at a certain date in the future.

Key link between PV and FV provided by the **interest rate** – also referred to as the **rate of discount**.

Our examples will be in discrete time. Later on, we shall encounter examples in continuous time (we will provide a link between the discrete and continuous time examples).

Example:

$1,000 held to day - Present Value

Suppose that the relevant annual rate of interest is 5.00% (no compounding within the year)

At the end of one year, the $1,000 will be worth:

$1,000(1+0.05) = $1,050 ,which is the Future Value (I year) of the original $1,000

Denote the relevant interest rate in decimal terms as: δ.

In general terms: Future Value (I year) is:

$$FV = PV(1+\delta)$$

and

$$PV = \frac{FV}{(1+\delta)}$$

in our example, we have $\delta = 0.05$

Suppose now that I am to receive $100 at the end of 1 year. Then:

$$PV = \frac{\$100.00}{(1+0.05)} = \$95.24$$

Suppose that I was to receive the $100 in two years time, what then would the PV of the $100 be? We would have:

$$PV = \frac{\$100}{(1+0.05)^2} = \$90.70, \text{ why?}$$

To generalize, let R be the amount to be received at a future time t. Then:

$$PV = \frac{R}{(1+\delta)^t}$$

The present is: t = 0.

Now suppose that we were to receive a series of equal payments of \$100.00 from t = 1 to t = 5, and continue to suppose that δ = 0.05

$$PV = \frac{\$100}{(1+0.05)^1} + \frac{\$100}{(1+0.05)^2} + \frac{\$100}{(1+0.05)^3} + \frac{\$100}{(1+0.05)^4} + \frac{\$100}{(1+0.05)^5} \simeq \$432$$

R = \$100 is now the amount to be received period after period.

When R is constant, period after period, we can generalize and express PV in equation form as:

$$PV = \frac{R}{\delta}\left(1 - \frac{1}{(1+\delta)^n}\right)$$

where ***n*** is the last period in which R is received. In our example, we have ***n*** = 5.

<u>Two Extreme Cases</u>

a) ***n***=1

b) ***n***=∞

a) $PV = \frac{R}{(1+\delta)}$

b) $PV = \frac{R}{\delta}$

Some Investment Decision Rules

To begin, a bond that pays interest forever and ever, and is never redeemed, is called a *Perpetual* (example – Consols – Britain, late 19^{th} Century).

The value of such a security is equal to the PV of the stream of interest payments over time.

Consider such a *Perpetual* and suppose that R = \$100, and that $\delta = 0.05$

Since, ***n*** = ∞, we can say that:

$$PV = \frac{\$100}{0.05} = \$2,000$$

When would it pay me to buy the security? – clearly, it would pay me to buy the security, if the cost were less than \$2,000.

If the cost is \$1,500, BUY. If the cost is \$2,500, IGNORE.

If the cost is \$2,000, I will be on the margin of indifference.

Denote the cost of a marginal investment – addition to the stock of capital - as **C**

An investment decision rule, which provides an answer to my Theory of Capital question:

Invest up to the point that:

C = PV, where **PV**, in this case, is the present value of the stream of economic returns from this marginal addition to the stock of capital, from $t = 0$ to $t = \infty$.

In the case of the *Perpetual* bond, we have

PV = \$2,000.

So invest up to the point that **C = \$2,000**

In the bond market, the price of the bond (C) would, in fact, be driven up, or down, to C = \$2,000

Next, the yield, rate of return, or "own rate of interest" on a marginal investment.

In all of the cases that we shall come to deal with, the period by period return from a marginal investment (positive) will be constant and go on forever, just like our *Perpetual* bond. This will greatly simplify life for us.

Denote the yield on a marginal investment as ***y***

We have: $y = \frac{R}{C}$

Suppose that we have, as before:

C = $2,000; and R = $100

then:

$$y = \frac{\$100}{\$2,000} = 0.05$$

or *y* = 5.0%

A condition for capital asset portfolio equilibrium is that all assets of a common risk class be found to offering the same yield, or rate of return.

It is reasonable to suppose that this common rate of return is the same as our discount (interest) rate, δ

The gives us another Investment Decision Rule.

If $y > \delta$, go on investing in the capital. Invest up to the point that:

$$y = \delta$$

In our case, where R is constant and goes on forever and ever, it easy to show that the two Investment Decision Rules are identical:

$C = PV$, our first Investment Decision Rule; but

$$PV = \frac{R}{\delta}$$

hence:

$$C = \frac{R}{\delta}$$

$y = \delta$, our second Investment Decision Rule; but

$$y = \frac{R}{C}$$

thus we have:

$\frac{R}{C} = \delta$, which, upon re-ordering terms, is:

$$C = \frac{R}{\delta}$$

We shall encounter just these sorts of Investment Decision Rules in our discussion of the economics of fisheries management, and of the economics of forestry management.

The stocks of capital will be seen to consist of stocks of fish and stands of trees.

Fisheries

Some distinctions;

Marine vs. Inland Fisheries

Capture (wild) Fisheries vs. Aquaculture

Types of Fishery Resources

I. True fish:

   a. Finfish ,e.g. Pacific salmon, Pacific halibut

   b. Shellfish, e.g. shrimp, crab

II. Sea mammals, e.g. seals, whales

III. Marine plants – seaweed, e.g. kelp. Irish moss

We will confine our discussion to marine (ocean) capture fisheries – reasons for.

World marine capture fisheries have a total annual harvest of approx. 90 million tonnes, with a “first” value in the order of US$95 billion.

Employment, direct and indirect, over 120 million, world wide –conservative estimate.

Developing fishing states are playing an increasingly important role in these fisheries. Of the 10 leading capture fisheries producing states in the world, 7 are developing fishing states, e.g. Indonesia and Peru.

(Source: Food and Agriculture Organization of the UN [FAO])

These fisheries are overwhelmingly base on Type I resources.

<u>Difficulties in the Economic Management of Capture Fisheries</u>

1. The fish, and their interaction with the surrounding aquatic environment, are very difficult to observe.
   -species interaction:
   (a) competition for food resources

   (b) predator-prey relationships.

2. The fish are, in most instances, mobile. Some species may travel over several thousand kilometers during their life cycle – the example of Pacific salmon

The consequence has been, in the past at least, that it is/was very difficult ,or more to the point, very costly to establish effective property rights to these resources, be the property rights private or public.

Capture fishery resources historically seen as the classic example of “common pool” resources.

By the middle of the 20th century, the “common pool” nature of these resources was being seen to lead to serious problems – overexploitation and severe economic waste. Capture fisheries will provide our key example of the economic consequences of ineffective resource property rights.

“Everybody’s property is nobody’s property”

Today, the environment –oceans, atmosphere –have similar problems.

BUT – up until just before the outbreak of World War II, “common pool” nature of capture fishery resources did not seem to matter all that much, other than in a few isolated cases.

Thomas Huxley, one of the greatest biologists of 19th century Britain, stated in 1883 that the great ocean fishery resources of the world are "inexhaustible". The best fisheries management, he argued, is no management at all.

This view was enshrined in international law, in the form of the doctrine of the Freedom of the (High) Seas – goes back to the 17th century.

Legal distinction between coastal state Territorial Sea and the High Seas. (coastal state –state with significant marine coast line, e.g. Canada, vs. landlocked state ,e.g. Austria).

Coastal state exercised full property rights within the Territorial Sea, but the Territorial Sea was very narrow, historically 3 miles – roughly 4.8 kilometers. Everything else constituted the High Seas.

Under the doctrine of the Freedom of the Seas, fishery resources in the High Seas are open to exploitation by all - fishery resources true "common pool".

Justification: up until the 19th century too costly to exploit these resources extensively. The resources were protected by economics. The natural capital was "free" capital.

The economic protection of these great ocean fishery resources was undermined by advances in fisheries technology, which lowered harvesting costs – economic protection was beginning to fray, even as Huxley spoke in 1883 – e.g. shift from sail to steam. All of this took time

-the two World Wars and fish stocks in the North Sea.

First major attempts, after World War II, to regulate ocean fishery resources through international agreements – very limited success.

Following World War II, coastal states began extending their jurisdictions over ocean resources unilaterally. UN intervened to try and put some order into the process. Convened the First UN Conference on the Law of the Sea in 1958, and a second conference in 1960. The two conferences did little about capture fisheries management.

The Third UN Conference on the Law of the Sea was held between 1973 and 1982. This conference revolutionized the management of world capture fisheries.

The Conference brought forth the **1982 UN Convention on the Law of the Sea**.

-Under the 1982 UN Convention, coastal states, such as Canada, given the right to establish 200 nautical mile (370 km., approx.) Exclusive Economic Zones (EEZs). Within the EEZ the coastal state, to all intents and purposes, has property rights to the fishery resources contained therein. Whether the coastal state can make these property rights effective is a different matter.

-The EEZ regime is now almost universal. Canada has EEZs off its Atlantic and Pacific coasts – Arctic EEZ not fully settled.

-Estimated in 1982 that, if EEZ regime became universal, the EEZs would encompass 90% of the commercially exploitable capture fishery resources of the world - massive reduction in Freedom of the Seas, as applied to fisheries, or so it seemed in 1982.

The EEZ regime has mitigated the “common pool” problem of world capture fisheries, but it certainly has not eliminated it. Many coastal states find that their intra-EEZ property rights are difficult to implement. Still have overexploitation and economic waste within EEZs.

Furthermore, because of the mobility of most capture fishery resources, many of the fishery resources cross the EEZ boundary into EEZs of neighbouring coastal states, or into the remaining High Seas –the Shared Fish Stock problem, which we shall discuss at a later point.

It was assumed by many in 1982 that High Seas fishing would be at most a minor problem. This assumption has proven to be dramatically wrong. UN forced to convene another international conference to deal with the problem – biggest problem – fishery resources crossing the EEZ boundary into the High Seas – so called Straddling Stocks

Common pool characteristics of fishery resources now invariably lead to overexploitation and economic waste.

Contrast fishery resources with forestry resources. Trees are visible and stationary. Relatively easy to establish and enforce property rights – private or public.

On the other hand, the environment –narrowly defined –has common pool problems similar to fisheries.

In any event, overexploitation of world capture fishery resources continues to be a serious problem, although one that is hopefully leveling off.

Some More Description

Classes of Finfish Species:

A. Demersal Species (groundfish, or whitefish), e.g. cod, halibut

B. Pelagic Species, e.g. herring, tuna

C. Anadromous Species ,e.g. salmon

Classes of Gear in Capture Fisheries

1. Lines and hooks

2. Traps and pots

3. Encirclement gear

4. Entanglement gear

Historically, Pacific salmon was the most important species harvested by the B.C. fishing industry. This has now changed. Demersal species (groundfish) are now the most important, followed by shellfish.

Bioeconomics

Every respectable Economic Model of the fishery has a Biological Model as its foundation.

If the biological model is misspecified, the economic model built upon the biological model will, at best, be worthless

So close is the link between biology and economics in fisheries economics that we now talk in terms of ***Bioeconomics***

This Fundamental Proposition requires a brief overview of biological models of fishery –

> -a still useful over 50 year old source, by two famous marine biologists, R.J. Beverton and M.B. Schaefer
>
> Schaefer and Beverton (1963), *"Fishing Dynamics- Their Analysis and Interpretation"*

The focus is on a stock of fish of a particular species (a single species model), in particular region
-stock measured in terms of weight – ***biomass.***

-concentrate, not on the total biomass, but on: **Fishable Biomass.** Later, we will talk simply about the biomass, but what we will be referring to is really the *fishable biomass*.

-through time Fishable Biomass (FB) will increase, due to:

(a) recruitment
(b) growth of individual fish in FB

-through time the FB will be depleted due to:

(i) natural mortality
(ii) fishing mortality

-a diagrammatic representation

Now let **x** denote the FB. The % rate of growth of x can be represented as follows:

(I) $(dx/dt)/x = z(x) + g(x) - M(x) - f(E) + \eta$,

where z, g, M and f denote the rates of recruitment, growth of individual fish in FB, natural mortality and fishing mortality respectively. Note that z, g and M are assumed to be functions of x.

f is seen as a function of E – fishing effort, which we can interpret as a combined flow of labour, produced capital and ancillary services devoted to harvesting (often measured in standardized vessel days).

η denotes a noise term, with mean = 0

Setting η = 0, a Steady State ,i.e. (dx/dt)/x = 0, will have been achieved when:

(II) f (E) = z(x) + g(x) – M(x)

refer to the Right Hand Side (R.H.S.) of Eq. (II) as the "net natural rate growth of the FB" . Eq.(II) then just says that a steady state will be achieved when the rate of fishing mortality is equal to the net natural rate of growth of the stock (FB)

Now take (II) and multiply both sides by x, so that we have:

(III) f(E)x = [z(x) + g(x) – M(x)]x

implying that, at the steady state, the harvest – f(E)x is equal to the net natural growth of the stock – essentially skimming off the growth of the resource.

But this Steady State situation means that the resource is being harvested on a “sustainable” basis.

Beverton and Schaefer tell us that, ideally, biologists would like to be able to estimate all of the parameters in (I), for given fishery resources, but that this has proven to be very difficult – no evidence that these difficulties have vanished over the intervening 50 years.

Simplifications required. Two broad approaches:

A. Beverton – Holt – attempts made to measure the parameters in context of a discrete time model, but it is usually assumed that the period by period rate of recruitment remains constant. Then focus on behaviour over time of individual sets of recruits – cohorts or year classes.

For analytical purposes, economists find that the B-H type of model is just what they want in analysing the management of aquaculture resources. The B-H model is used extensively in capture fishery management.

In developing analytical economic models of the management of capture fisheries, however, B-H models create intractable difficulties – reasons for. Having said this, it will be seen that economists do in fact make extensive use the B-H models in empirical analysis of such fisheries

In developing analytical models of capture fisheries, economists look to the second approach:

B. "General Production" models, in which key parameters are merged – what mathematicians call **"lumped parameter"** models.

Perhaps the most famous of such General Production models is the one developed by M.B .Schaefer, in the early 1950s. The Schaefer model provides the foundation for most of the economic models of the fishery that we will be examining, so let us take a close look at it.

The Schaefer Model

We have:

(1) $dx/dt = F(x, \mathbf{A})$, where x denotes the biomass, and **A** denotes the aquatic environment, assumed to be constant. Hence (1) can be re-written as:

(1a) $dx/dt = F(x)$

- it is assumed that F(x) corresponds to the "logistic" law of population growth (19^{th} century Verhulst model population growth)

(2) $dx/dt = F(x) = rx\,[1 - x/G]$,

where G, a constant, is the "carrying capacity", or natural equilibrium biomass level (biomass cannot grow forever), and where **r** is the "intrinsic growth" rate.

Let us note the following: The %, or proportional, growth rate of the biomass is – $F(x)/x = r[1 - x/G]$

$$\lim_{x \to 0} F(x)/x = r$$

thus **r** is the *maximum* % growth rate

Now introduce harvesting. We have:

(3) $dx/dt = F(x) – h(t)$

The harvest production function is given by:

(4) $h = qE^{\alpha}x^{\beta}$, where q, a constant, is the "catchability" coefficient, a constant, an index of the state of fishing technology, and where the exponents, α and β, are constants

Note that this production function looks a lot like the Cobb-Douglas production function that we are familiar from Ec. 201/301: $Q = AK^{\alpha}L^{\beta}$, where Q is the quantity of output, where A is a constant, and where $\alpha + \beta = 1$.

-a critical assumption in the Schaefer model is that the fish are uniformly spread throughout the relevant aquatic environment, regardless of density. This amounts to assuming that $\alpha = \beta = 1$ – unlike the Cobb-Douglas production function.

In any event, with $\alpha = \beta = 1$, by assumption, we rewrite (4) as:

(4a) $h = qEx$

This assumption has, as we will see, important policy implications

By the way, what is the rate of fishing mortality in the Schaefer model? It is, simply: $qE = h/x$

-a diagrammatic representation of the Schaefer model, and the concept of sustainable harvest, or yield, and Maximum Sustainable Yield (MSY).

We next have to consider the relationship between fishing effort (E) and sustainable yield (harvest). This we need for the first economic model of the fishery.

Consider the following diagrams.

The diagrams show the relationship between E and sustainable yield, or harvest for two possible rates of E, E_1 and E_2 . We could carry out the same procedure for every other possible rate of E.

Fortunately, we do not have to. From the Schaefer model, we can develop a functional relationship between E and sustainable harvest (yield), which we shall denote as: h_s.

We start off by returning to our harvest production function:

(I) $h = qEx$

We note that, if harvesting is taking place on a sustained yield basis, then it will be the case that:

(II) $h = F(x)$,

recalling that $F(x) = rx[1 – x/G]$,

we can (II) re-write as:

(IIa) $qEx \quad = rx[1 – x/G]$

Associated with any sustainable harvest there will be an equilibrium, steady state, level of the biomass, x.

From (IIa) we can derive an equation for x, representing the equilibrium, steady state, level of x, given a particular E:

(III) $x = G[1 - (q/r)E]$

Now substitute for x in Eq. (I) [the harvest production function], from (III), and we have an equation for sustainable harvest (yield), h_s:

(III) $h_s = qE\{ G[1 - (q/r)E]\}$

$= qGE – (q^2G/r)E^2$

(IIIa) $h_s = uE – vE^2$,

where $u = qG$, $v = q^2G/r$, and where u and v are obviously constants

-a diagrammatic representation

The concept of “Biological Overfishing”. $E > E_{MSY}$,

which will cause the biomass to fall below x_{MSY}

-more diagrams

The H. Scott Gordon Economic Model of the Fishery and Resource Rent Dissipation

This model, which appeared in 1954, marks the beginning of modern fisheries economics.

It is a “static” economic model, because this was the best that Gordon could do with the tools available to him at the time.

While it has drawbacks, because of its static nature, it has important lessons, and continues to have a major influence on policy makers. Moreover it provides the foundation for the dynamic economic model of the fishery that we will examine later.

Basically what Gordon does is to take the Schaefer based fishing effort (E) sustainable yield (harvest) relationship that we have discussed and add in prices and costs to make it an economic model.

-consider the following diagram

Key Assumptions Underlying the H. Scott Gordon Model

1. Demand for harvested fish is perfectly elastic. Hence, price for harvested fish, ***p***, is a constant.

2. ***p*** provides a perfectly adequate measure of marginal utility (MU) of harvested fish to society

3. Supply of E is also perfectly elastic. Hence, the unit (average) cost of E, ***b,*** is a constant. Moreover,
   $\boldsymbol{b} = MC_{E.}$ Also note that the total cost of E is simply:
   $TC_E = \boldsymbol{b}.E$

4. There is no discrepancy between private and social cost of E. ***b*** is exactly equal to the true unit opportunity cost of E.

5. The fishing industry is perfectly competitive.

6. Human and produced capital in the fishery are both "perfectly malleable", meaning that they can be easily and costlessly moved in and out of the fishery.

The implication of assumptions 2. and 4. combined is that we are living in a **First Best World**.

Some Further Definitions:

Value of the Marginal Product of E (VMP_E)

Total Revenue with respect to E:

TR_E = (Sus. Yield or Harvest).***p***

$$\frac{d(TR_E)}{dE} \equiv VMP_E$$

Value of the Average Product of E (VAP_E)

$$VAP_E = \frac{TR_E}{E}$$

Marginal Cost of E (MC_E)

TC_E = ***b***.E

$$MC_E = \frac{d(b.E)}{dE} = b$$

Average Cost of E (AC_E)

$$AC_E = \frac{b.E}{E} = b$$

Note that MC_E = AC_E

Next note it will always be the case that
VMP_E < VAP_E, except when E = 0.

TR_E = ***p***.h_s = ***p***[uE – vE^2]

Thus VMP_E = ***p***[u – 2vE] (do the differentiation)

$$VAP_E = \frac{TR_E}{E} = p[u - vE]$$

Resource Rent defined – Joan Robinson

"The essence of the conception of *rent* is the conception of a surplus earned by a particular --- factor of production over and above the minimum necessary to do its work. The conception of rent----is closely connected with the 'free gifts of nature'—the essential characteristic of which is that they do not owe their origins to human nature"
Joan Robinson, *The Economics of Imperfect Competition*

The rent associated with the "free gifts of nature" (natural resources) we term **Resource Rent**.

<u>The Gordon Argument</u>

Applying elementary Welfare Economics, Gordon maintains that in a First Best World, E (basically combined labour and produced capital services) should be allocated to the fishery up to the point that:

VMP_E = MC_E - reasons for

It so happens that at the point that $VMP_E = MC_E$ total Resource Rent will be maximized – economists refer to this as **MEY – Maximum Economic Yield**

Denote total Resource Rent as: RR

$RR(E) = TR_E - TC_E$

First order condition for a maximum is:

$$\frac{d(RR)}{dE} = 0$$

$$\frac{d(RR)}{dE} = \frac{d(TR_E)}{dE} - \frac{d(TC_E)}{dE} = 0$$

But:

$$\frac{d(TR_E)}{dE} \equiv VMP_E$$

$$\frac{d(TC_E)}{dE} \equiv MC_E$$

Hence, the first order condition implies that:

$\mathbf{VMP_E = MC_E}$

Denote the E corresponding to MEY as $\mathbf{E_{MEY}}$.

In the absence of property rights, private or public, the fishery will not be in equilibrium at $E = E_{MEY}$.

Suppose that we are at $E = E_{MEY}$. There is no landlord (sealord) to appropriate the Resource Rent. The rent does not disappear, but rather becomes incorporated into the fishing firms' economic profits.

Theory of Perfect Competition in the Long Run – the Zero Profit Theorem – the industry will expand or contract up to the point that the economic profits of the firms in the industry equal zero - a comment on economic profits.

At $E = E_{MEY,}$ the economic profits are definitely positive, hence the fishing industry is not in equilibrium.

The fishing industry will therefore expand (E will increase), and will go on expanding, until $\mathbf{TR_E = TC_E}$, $E = E_{\infty}$.

If $TR_E = TC_{E,}$ then $VAP_E = AC_E$ (why?)

But we know, given the Gordon assumptions, that $AC_E = MC_E$

It thus follows that, at $E = E_{\infty}$, we have: $VAP_E = MC_E$

BUT we know that $\mathbf{VMP_E < VAP_E}$ (except in the uninteresting case when E = 0).

HENCE, at $E = E_{\infty}$, $\mathbf{VMP_E < MC_E}$. The optimal allocation rule has been violated.

We end up with an overallocation of E to the fishery.

Furthermore, at $E = E_{\infty}$, the Resource Rent has been completely dissipated. RR = 0.

The resource, as a "natural" capital asset, is yielding zero!

Gordon referred to $E = E_{\infty}$, as:

BIONOMIC EQUILIBRIUM - reasons for

What is not shown clearly in the Gordon model, as we have presented it, is the fact that there is more going on than an overallocation of labour and produced capital service (E) to the fishery. The fishery resource is being overexploited from society's point of view – this form of natural capital is subject to excessive disinvestment from society's point of view, when we are at **BIONOMIC EQUILIBRIUM**. This will become clear later on.

The World Bank/FAO publication: *The Sunken Billions: The Economic Justification for Fisheries Reform* (2009), estimates that world capture fisheries are losing potential resource rent in the order of US$50 billion per year – root cause – ongoing "common pool" characteristics of many of the world's capture fisheries.

Suppose now that the fishing industry was not perfectly competitive, but was rather under the control of a single firm – "sole owner"

What then would the profit maximizing "sole owner's" policy be? It would be to stabilize the fishery at $E=E_{MEY}$. Thus "sole ownership" leads to a socially desirable outcome - a seemingly perverse result from the "common pool" conditions of the fishery.

The Gordon economic model of the fishery provides a classic example of **Market Failure**.

The market sends out incorrect signals (from society's point of view)

This provides a case for government intervention (management)

As we shall see, most government management of the fishery is designed to counter the negative consequences of the "common pool" nature of the fishery.

<u>Gordon's Secondary Conclusion</u>

A secondary conclusion arising from the Gordon model is that the marine biologist's management criterion of MSY is incorrect.

We have: $TR_E = \boldsymbol{p}.\ h_s$
Maximizing h_s implies maximizing TR_E
First order condition for a TR_E maximum is that :

$\frac{d(TR_E)}{dE} = 0$, i.e. $VMP_E = 0$

In order for our allocation rule to be satisfied at E = E_{MSY}, we would have to find that ***b*** = MC_E = 0 – completely unreasonable, argues Gordon

In the Gordon model, we always have: $\mathbf{E_{MEY} < E_{MSY}}$

The marine biologists are not sufficiently conservationist, because they focus only on physical yields!

To drive the point home, consider the following diagram, in which $E\infty < E_{MSY}$

From Fishing Effort Costs to Harvesting Costs

We can much greater progress by looking at harvesting costs and revenues. This will allow us to relate the consequences of "common pool" fisheries to the biomass, x.

First harvesting costs:

We are doing the same sort of thing that we do in Ec. 201/301 in going from costs and revenues with respect to inputs to costs and revenues with respect to output. The output in this case consists of harvests of fish.

So far we have:

TC_E = ***b***.E

But

h = qEx

$$\therefore\ E = \frac{h}{qx}; \quad b.E = b.\left(\frac{h}{qx}\right)$$

We now have an expression for Total Harvesting Costs:

$$C(h,x) = \frac{bh}{qx}$$

To get Average (unit) Harvesting Costs divide through by h, and we have:

$$c(x) = \frac{b}{qx}$$

Marine biologists refer to qx as the Catch Per Unit of Effort (CPUE) – it is like the average product of E

The consequences for c(x) of decreasing biomass size:

The smaller is x the larger is c(x). Note the following:

$$\lim_{x \to 0} c(x) = \infty$$

<u>Total Sustainable Revenue from fish harvests (TR_S)</u>:

We have, from the Schaefer model: $h_s = F(x)$

So $TR_S = \boldsymbol{p}.F(x)$

<u>Total Cost of Harvesting the Sustainable Harvest (Yield)</u>

We have: $C(h,x) = \dfrac{bh}{qx}$

We also have: $h_s = F(x)$

But $F(x) = rx[1 - x/G]$

Hence:

$$C(F(x),x) = \frac{brx[1 - x/G]}{qx},$$

$$C(F(x), x) = \frac{br[1 - x/G]}{q}$$

Thus: C(F(x), x) is:

1. a linear function of x

2. decreasing in x {when x = G, C(F(x), x) = 0}

see diagram

This shows clearly the resource consequences of a "common pool" fishery.

Corresponding to E_{MEY} there is x_{MEY}; and corresponding to E_{∞} there is x_{∞}

Obviously $x_{\infty} < x_{MEY}$

Hence, we can now see that, if MEY is optimal from society's point of view, then a "common pool" fishery leads to overexploitation of the resource.

Note that this would be true, EVEN IF $\mathbf{x_{\infty} > x_{MSY}}$.

Looking forward. Suppose that we have $x = x_\infty$. The goal is to be at MEY. It is not simply a matter of reducing E from E_∞ to E_{MEY}. The resource has to be rebuilt from x_∞ to x_{MEY}. If the resource is slow growing, this could take years and years.

- the case of Southern bluefin tuna, off Australia and New Zealand.

The Perspective of the Individual Fisher

For the individual fisher we have, in terms of harvest revenue and costs:

$$TR = p.h$$

$$TC = h.\frac{b}{q\bar{\bar{x}}}$$

$\bar{\bar{x}}$. The individual fisher regards the biomass as virtually fixed – reasons for.

Assume that the individual fisher is a profit maximizer. Then the fisher will attempt to produce up to the point that MC = MR.

$$MR = \frac{d(ph)}{dh} = p$$

$$MC = \frac{d(h\{b / q\bar{\bar{x}}\})}{dh} = \frac{b}{q\bar{\bar{x}}}$$

If $p > \frac{b}{q\bar{\bar{x}}}$, then the fisher will attempt to increase h.

Expansion of the fishery will continue until: $p = \frac{b}{q\bar{\bar{x}}}$

The individual fisher will have only a very small impact on x, the consequences of which he/she will share with all other fishers – **Resource Externality.**

When ALL fishers attempt to increase their exploitation of the resource, x will decline.

The overexploitation of the resource does not come about because of irrational behaviour on the fishers. On the contrary, they are acting like rational profit maximizing competitive firms.

The Consequences of Reduced Harvesting Costs in a "Common Pool" Fishery

The decline in costs may come about through falling ***b***, because of technological improvements, reflected in ***q***, or because of government subsidies (e.g. fuel subsidies).

See diagram. The falling harvesting costs will make a bad situation worse – another perverse outcome of "common pool" fisheries.

We can also see from this diagram why no one worried much about "common pool" fisheries 150 years ago, and why it took time for the problem to emerge and become recognized - which it was by the time of World War II.

We can also see why, upon recognizing the problem, the resource managers were, and have been, in a constant race against advances in fishing technology.

A Comment on International Fisheries

The Gordon-Schaefer model of a completely unregulated fishery is still very applicable to international fisheries – High Seas fisheries.

-the case of the Bering Seas pollock fishery

Both Americans and Russians have established EEZs in the region. There is a High Seas region in the middle not covered by the EEZs – the "Donut Hole"

In the 1980s and early '90s, pollock resources in the "Donut Hole" were plundered.

A Significant Limitation to the Gordon-Schaefer Model

The model predicts that a true open access fishery is never in danger of being driven to extinction.

We have from the model:

$h = qE^{\alpha}x^{\beta}; \alpha = \beta = 1$

consequence:

$$c(x) = \frac{b}{qx}$$

$$\lim_{x \to 0} c(x) = \infty$$

There is an effective economic brake on resource exploitation.

Recall that an underlying assumption of the model is that the fish are always uniformly distributed in the relevant body of water.

Some fish species, however, are characterized by intense schooling, e.g. herring, anchovies.

In such cases, $\beta \neq 1$. Rather $\beta < 1$, or even $\beta << 1$.

Take the extreme case in which $\beta = 0$. Then:

$c(x) = \frac{b}{qx^0}$; which we should properly re-express as:

$$c = \frac{b}{qx^0}$$

unit harvesting costs cease to be a function of x (so long as x>0).

The harvesting costs do not increase as **x** declines. The economic brake does not work.

The example of Norwegian Spring Spawning Herring.

From Pure Open Access to Regulated Open Access

The Gordon-Schaefer model is a model of what we shall now refer to as **Pure Open Access**. There are no property rights to the resource, whatsoever, there are no regulations on the fishery, national or international –the perfect “common pool” fishery case.

Regulated Open Access is the case in which there is intervention by government – at the national or international level (implying in turn that there maybe public property rights to the resource) – in the form of global controls over the season to season harvests. An example is provided by Total Allowable Catches (TACs). There are, however, no limits on the fleet size. The vessel owners have open access to the TAC.

The limited season to season harvest (TAC) now becomes the “common pool”. If human capital and produced capital used in the fishery were perfectly “malleable”, there might not be a serious problem. This is almost never the case .We do find in virtually all fisheries seasonal fixed costs – costs that cannot be escaped, once the vessels are committed to the fishery.

The consequence then of the TAC as a “common pool” is economic waste primarily, but not entirely, through the build up of redundant produced (and human) capital in the fishery.

A simple example:

In a given fishery the annual TAC = 1,000 tonnes

The TAC can be taken by **1** vessel operating over a 200 day season.

Ex-vessel price of the fish - $200 per tonne

We start off with the fleet consisting of **1** vessel – the minimum fleet size
Vessel annual costs, all reflecting true opportunity costs:

Fixed costs $20,000

Variable costs $500 per fishing day

Vessel costs for a 200 day season

Fixed costs	$20,000
Variable costs	100,000
Total Costs	$120,000

Gross Revenue $200 x 1,000 tonnes = $200,000

Therefore the vessel's economic profits are:

$200,000 - $120,000 = $80,000

Now a second identical vessel is attracted to the fishery by the positive economic profits.

The seasonal costs and revenue are as follows:
With two vessels in the fleet, rather than one, the season length is reduced from 200 to 100 days.

Annual Fleet Costs
Vessel 1

Fixed costs	$20,000
Operating costs	50,000

Vessel 2

Fixed costs	20,000
Operating costs	50,000

Total Fleet Costs $140,000

Fleet economic profits = $200,000 – 140,000 = $60,000

Economic profits reduced by the second and redundant vessel into the fleet

If we continue to assume that the fishing industry is perfectly competitive, we can say that, under Regulated Open Access, the fleet will expand up to the point that economic profits are reduced to zero. The Zero Profit Theorem once again.

As under Pure Open Access, this will result in resource rent dissipation.

The difference between the minimum costs of harvesting the sustainable yield, and the actual costs of harvesting the sustainable yield.

-see diagram.

In fact the dissipation of resource rent can be worse than under Pure Open Access. Under Pure Open Access there are no government administrative costs – by definition. Under Regulated Open Access, there are government administrative costs. When the industry is in equilibrium, the true resource rent could be *negative*. There are examples of national fisheries that are almost certainly making a negative contribution to the country's GDP.

This type of fishery is often referred to as an ***"Olympics style"*** fishery. He/she who wins the race gets the fish – the race for the fish.

The 1982 Pearse Royal Commission report on B.C. fisheries. The problems identified by Pearse have not yet been fully eliminated.

Other Sources of Economic Waste in Regulated Open Access Fisheries

1. "Crowding" – leading to destruction of gear

2. Excessive investment in vessels and gear, e.g. super powerful engines – "capital stuffing"

3. Short seasons – e.g. B.C. Pacific halibut fishery: maximum season length – 250 days per year. At one point, season down to 6 days per year. Leads to:

    a. poor handling of fish on the vessels
    b. risk to fishers
    c. processing sector inefficiencies due to glut/famine cycle.

Link Between Regulated Open Access(ROA) and Pure Open Access (POA)

In our discussion of ROA, we have assumed that the resource managers exercise complete and effective control over the season by season harvests through TACs, or equivalent. **BUT**:

1. Large fleet size makes control of harvests difficult – chronic TAC "overages"

2. Resource managers operate in a world of uncertainty. Difficult to determine optimal TAC accurately. Chronically unsatisfied vessel owners will pressure resource managers to implement liberal TACs – often use political influence. If the vessel owners succeed, the liberal TACs may prove in retrospect to have been dangerously high.

Valid Conclusions Arising from the Static Economic Model of the Fishery

A. MSY management criterion not defensible on economic grounds. It is based solely on physical yields.

B. Pure “common pool” Open Access fisheries lead to labour/produced capital services misallocation and to overexploitation of the resources, from society’s point of view.

C. Attempts to regulate capture fisheries by global harvest quotas alone (Regulated Open Access) lead invariably to economic waste, particularly through build up of excess fleet capacity.

Limitations of the Static Economic Model of the Fishery

I. Can create the illusion that restoration of the fishery resource from x_∞ (Bionomic Equilibrium) to x_{MEY} is a swift and costless undertaking.

II. Pushes the underlying biology into the background –this can be dangerous.

III. Ignores uncertainty. Uncertainty is the hallmark of real world capture fisheries management.

Introduction to the Dynamic Capital-Theoretic Economic Model of the Fishery

Why do we need it?

Review the key H. Scott Gordon diagram – with fishing effort, E.

The creates the impression that, to move from Bionomic Equilibrium to MEY, all we need to do is to reduce E from $E = E_\infty$ to $E = E_{MEY}$ - this is wildly misleading.

Suppose that we are at Bionomic Equilibrium, and that the Schaefer model is the correct biological model. Hence: $h = qEx$.

Suppose further that $E_{MEY} = ½ E_{\infty}$. The initial effect of cutting E from E_{∞} to E_{MEY} would be reduce **h** by ½!

Consider the following diagram.

In reducing E, harvest will gradually increase as x grows from x_{∞} to x_{MEY}. – reasons for.

This could be a rapid process, or a slow one.

The example of Southern Bluefin tuna, exploited by Australia, New Zealand, Japan, South Korea and others. The resource is under ineffective cooperative management. It is agreed that the resource is overexploited.

Empirical studies show that a major rebuilding of the fish stock is required, if the fishery is ever to come anywhere close to yielding MEY.

These same studies show that, even if a TAC = 0 was to be declared throughout the stock rebuilding phase, it could take 20 years to reach the desired stock size.

The rebuilding of a fish stock means that costs must be incurred today, in the hope of an uncertain payoff in the future.

Obviously, we are being presented with a resource investment problem.

This fact was recognized by H. Scott Gordon - 1956 –quote.

The reason that he went no further than his static model was because this was the best he could do with the mathematical tools available to him at the time.

A Dynamic (Capital Theoretic) Version of the Gordon-Schaefer Model

We continue to accept all of the explicit assumptions of the Gordon-Schaefer model that we have discussed up to this point, e.g. we assume that the demand for harvested fish and the supply of E are both perfectly elastic.

-We shall also abstract from the costs of managing the fishery - assume that such costs are zero (if we dropped this extreme assumption, it would not change the final results, but it would make the analysis somewhat messier).

Question: to what extent is it worth society's while to invest (positively or negatively) in the fishery resource? This is our Theory of Capital question.

We will focus on positive investment in the resource.

The economic effect of building up **x** will (within limits) be to increase sustainable resource rent – SRR.

This addition is assumed to go on forever and ever.

This means that we will be able to use versions of the simple investment decision rules that we discussed earlier:

C = PV,

where $PV = \frac{R}{\delta}$

$y = \delta,$

where $y = \frac{R}{C}$

The above were derived from discrete time models. We will be turning to continuous time models, but the point remains. The complex resource investment decision rules that we come up with will basically just be complex versions of the above.

Obtaining a rigorous derivation of the fisheries investment rules requires some heavy duty mathematics, which we shall avoid.

If you are interested in the rigorous derivation, turn first to “Mathematical Bioeconomics and the Evolution of Modern Fisheries Economics” and Ola Flaaten. More detailed versions of the derivation are available upon request.

Now consider the following diagram.

Next consider an increase in **x** equal to 1. Roughly speaking, the Sustainable Resource Rent consequences of the increase in **x** are given by:

$$\frac{\Delta SRR}{\Delta x}.1$$

$$\lim_{\Delta x \to 0} \frac{\Delta SRR}{\Delta x} = \frac{d(SRR)}{dx}$$

Next note that: SRR = (p – c(x))F(x) $\{$h = F(x)$\}$
So we have:

$$\frac{d(SRR)}{dx} = \frac{d((p-c(x))F(x))}{dx} = (p-c(x))F'(x) - c'(x)F(x)$$

The addition to SRR comes from two sources:

1. Change in F(x) - (p-c(x))(F′(x))

2. Change in harvesting costs --- $c'(x)$
   but $c'(x) \leq 0$. If $c'(x) < 0$, then a minus times a minus is a positive, i.e.{ - $c'(x)F(x) > 0$}

The Present Value (PV) of an addition to SRR:

$$PV = \frac{\{(p - c(x))F'(x) - c'(x)F(x)\}}{\delta}$$

Next, the cost of an incremental investment in **x:**

In order for **x** to be increased, the harvest, **h**, must be reduced, thereby reducing current resource rent (in other than exceptional circumstances).

Denote resource rent at any point in time as: π

$\pi = [p - c(x)]h$

$$\frac{\partial \pi}{\partial h} = [p - c(x)]$$

The Net Present Value (NPV) of a marginal investment in x can be expressed as:

$$NPV = \frac{\{(p - c(x))F'(x) - c'(x)F(x)\}}{\delta} - [p - c(x)],$$

i.e. the PV of additional SRR minus the cost of the investment

If NPV > 0, then go ahead and continue investing. If NPV < 0, you have gone too far.

The investment rule is: invest (disinvest) up to the point that NPV = 0.

We can express the investment decision rule as:

$$[p-c(x^*)]=\frac{\{(p-c(x^*))F'(x^*)-c'(x^*)F(x^*)\}}{\delta}$$

where **x*** denotes the optimal biomass level

Compare this with our basic investment decision rule:

C = PV, where $PV=\frac{R}{\delta}$

We can also express our fisheries investment rule as:

$$\frac{\{(p-c(x^*))F'(x^*)-c'(x^*)F(x^*)\}}{[p-c(x^*)]}=\delta$$

Compare this with the other version of our basic investment decision rule:

$y = \delta$, where $y = \frac{R}{C}$

We can simplify the second version of our fisheries investment decision rule, so that we have:

$$F'(x^*) - \frac{c'(x^*)F(x^*)}{(p - c(x^*))} = \delta$$

This equation is often referred to as:

The Fundamental Rule (Equation) of Renewable Resource Exploitation

We can simplify further and re-write the Fundamental Equation as:

$$F'(x^*) + \frac{\partial\pi / \partial x^*}{\partial\pi / \partial h}\Big|_{h=F(x^*)} = \delta,$$

where, as before, π denotes resource rent. (The h = F(x*) indicates that harvesting is being done on a sustainable yield basis).

The second term on the L.H.S. (left hand side) of the Fundamental Equation is often referred to as the **Marginal Stock Effect**. If reflects the impact of an investment in **x** upon harvesting costs.

The L.H.S. of the Fundamental Equation is, overall, the yield on a marginal investment in the resource (**x)**, also know as the “own rate of interest”. The yield consists of two components, the impact of investment in **x** upon sustainable harvests, and the Marginal Stock Effect.

Note that, if harvesting costs were completely independent of **x** (given that **x** >0), the Fundamental Equation would reduce to:

$$F'(x^*) = \delta$$

The Fundamental Rule can also be seen as a version of the **Golden Rule of Capital Accumulation** from the economist’s Theory of Capital

Linking the Dynamic Model to the Static Model

Given our assumptions, the simplest way in which we can express the Fundamental Equation is as follows:

$$\frac{d(SRR)/dx^*}{[p - c(x^*)]} = \delta$$

According to the static Gordon-Schaefer model, the optimal biomass, x_{MEY}, is that associated with maximum sustainable resource rent (SRR).
The first order condition for maximum SRR is that:

$$\frac{d(SRR)}{dx} = 0$$

Go back to the above equation. If $\frac{d(SRR)}{dx} = 0$, then

the only way in which the equation can hold, i.e. $x^* = x_{MEY}$, is if $\delta = 0$.

We thus conclude that the static Gordon-Schaefer model assumes implicitly that δ **= 0!**

If $\delta > 0$, then it is not worth society's while to invest in **x** all the way up to x_{MEY}

Next Bionomic Equilibrium:

Go back to our simplest version of the Fundamental Equation and re-express it as:

$$\frac{d(SRR)/dx^*}{\delta} = [p - c(x^*)]$$

At Bionomic Equilibrium, we have:

$p = c(x); p – c(x) = 0$

The above equation can hold at Bionomic Equilibrium, i.e. $x^* = x_\infty$, if and only if, δ **= ∞!**

From this, we can draw two conclusions:

A. In a Pure Open Access fishery, the fishers are given the incentive to discount massively future economic returns from the fishery.

B. Even in dire circumstances, we will find that the true Social Rate of Discount, δ,is far below ∞. Hence, if we are at Bionomic Equilibrium, $x = x_\infty$, we can say, unequivocally, that the resource has been overexploited from society's point of view, i.e. $x^* >> x_\infty$.

By the way, this is the reason that we have denoted the biomass level, **x**, and the rate of fishing effort, **E**, associated with Bionomic Equilibrium as $\mathbf{x_\infty}$**,** and $\mathbf{E_\infty}$, respectively.

So where is x^* located? We cannot say, off hand, without further investigation. If: $0 < \delta < \infty$, as is reasonable, the only thing we can say immediately is that x^* lies somewhere between x_∞ and x_{MEY}.

Surely, we can at least be certain that $x^* > x_{MSY}$. Actually, we cannot. The assurance arising from the Gordon –Schaefer model that the optimal biomass level will always exceed x_{MSY} rests upon two assumptions: (i) the Marginal Stock Effect (MSE) is positive; (ii) $\delta = 0$.

Go back to the following version of our decision rule equation:

$$F'(x^*) + \frac{\partial\pi / \partial x^*}{\partial\pi / \partial h}\bigg|_{h=F(x^*)} = \delta$$

The social rate of discount and the Marginal Stock Effect can be seen as pulling in opposite directions. The larger is δ, other things being equal, the **less** you will wish to invest. The larger is $\frac{\partial\pi / \partial x^*}{\partial\pi / \partial h}$, other things being equal, the **more** you will wish to invest.

If the MSE >0, and $\delta = 0$, as in the Gordon-Schaefer model, then in order for the investment decision rule equation to hold, we must find that $F'(x^*) < 0$. This implies that $\mathbf{x^*} > \mathbf{x_{MSY}}$ – reasons for.

If $\delta > 0$, then “all bets are off”.

Note that, if the MSE = 0, then $\mathbf{x^*} \leq \mathbf{x_{MSY}}$.

Furthermore, and of far greater importance, is the fact that, if $\delta > 0$, it matter a great deal whether the fishery resource is a fast growing, or slow growing, one.

This, admittedly, is not at all obvious in the Fundamental Equation, as we have presented it so far. Some further investigation is required.

Marine biologists look to **r,** the intrinsic growth rate, as a measure of whether the species is fast growing, slow growing, or in between.

Now recall that we have in our model:

$F(x) = r[x-x^2/G]$,
and that hence: $F'(x) = r[1-2x/G]$.

Here is the key. For any given level of **x**, F(x) and F′(x) are *proportional* to **r**.

Consider the following example.

Suppose that G = 400,000 and that x = 200,000 (we are at MSY).

We have two cases:

A. fast growing species- **r** = 0.500

B. slow growing species – **r** = 0.025

Case A. we have F(x) = 50,000

Case B. we have F(x) = 2,500

Go back to the following one of the many versions of the Fundamental Equation:

$$\frac{\{(p-c(x^*))F'(x^*)-c'(x^*)F(x^*)\}}{\delta}=[p-c(x^*)]$$

We can, by substitution, re-write the equation as:

$$\frac{\{(p-c(x^*))r\left[1-\frac{2x^*}{G}\right]-c'(x^*)r\left[x^*-\frac{(x^*)^2}{G}\right]\}}{\delta}=[p-c(x^*)]$$

Now factor out the **r** in the numerator of the L.H.S. of the above equation and we have:

$$\frac{r\left|(p-c(x^*))\left[1-\frac{2x^*}{G}\right]-c'(x^*)\left[x^*-\frac{(x^*)^2}{G}\right]\right|}{\delta}=[p-c(x^*)]$$

So what now? The numerator of the L.H.S. of the above equation is just a complicated form of: $d(SRR)/dx^*$, i.e. the additional sustainable resource rent arising from a marginal investment in **x**.

This additional sustainable resource rent, we now see, no surprise, is *proportional* to **r.** The larger (smaller) is **r**, the larger (smaller) will be the additional sustainable resource rent.

We can, if we wish, re-order terms in the above equation to get:

$$r\left\{\left[1-\frac{2x^*}{G}\right]-\frac{c'(x^*)\left[1-\frac{x^*}{G}\right]}{(p-c(x^*))}\right\}=\delta$$

which we can re-express simply as:

$$r\left\{\theta(x^*)\right\}=\delta$$

Expressed in this form, the L.H.S. of each of the two above equations is, as we have seen, the "own rate of interest" of the resource. Hence, we can also say the "own rate of interest" of the resource, for any given level of **x**, is proportional to **r**.

Does this really matter?

It matters not at all, if $\delta = 0$ (why so?).

It does matter, and matters a great deal, if $\delta > 0$**.**

If **r** is low, then the chances are very good that we will have: $\mathbf{x^* < x_{MSY}}$**,** even, if the Marginal Stock Effect is positive, and even if δ is not all that large.

Some example, including the case of Antarctic baleen whales – modeled by Colin Clark and R. Lamberson.

Go back to the observation that the size of **r** matters not at all, if $\delta = 0$.

One implication of this is that, if we start off at $\mathbf{x = x_\infty}$, with thoughts of building up x to $\mathbf{x = x_{MEY}}$, it makes no difference whatsoever, whether it will take 2 years or 25 years to build the resource up to $\mathbf{x_{MEY}}$. If this strikes one as being absurd, it does so for very good reason – another reason why the assumption that $\delta = 0$ is unacceptable.

<u>Existence Value</u>

Existence Value refers to the benefits that society enjoys by knowing that the resource is safe from extinction. This has become a major political issue.

In Canada, we have the **Species at Risk Act** – implications of a listing under the Act.

The US has **The Endangered Species Act .**

Many other countries have similar pieces of legislation.

Also – **CITES** – Convention on International Trade in Endangered Species (ratified by 180 states).

The case of the B.C. groundfish trawl fishery and affected sponge and coral species with negligible commercial value.

We can incorporate Existence Value into our model. Denote such value, with regards to a fishery resource, as: $\phi(x)$ – which, in fact, can be measured in monetary terms.

Diagram - $\phi'(x)$

$\lim_{x \to 0} \phi'(x) = \infty$ (or at least some very big number)

It can be shown that our Fundamental Equation now changes from:

$$F'(x^*) - \frac{c'(x^*)F(x^*)}{(p - c(x^*))} = \delta$$

to

$$F'(x^*)+\frac{\phi'\left(x^*\right)-c'(x^*)F(x^*)}{(p-c(x^*))}=\delta$$

What has happened, in effect, is that we have an additional component to the Marginal Stock Effect.

The consequences:

Suppose that harvesting costs were completely independent of the size of **x** (given that **x** >0), so that c′(x) = 0. Suppose further that Existence Value was zero, or not recognized.

We have seen that the Fundamental Equation would then reduce to:

$$F'(x^*)=\delta$$

Recall that:

$$F'(x)=r\left[1-\frac{2x}{G}\right]$$

From this it is clear that:

$$\lim_{x\to 0}F'(x)=r$$

Now suppose that **r < δ,** e. g. suppose that δ =0.035 – 3.5%, but that r = 0.025 – 2.5%

The resource manager could then rationally decide that the resource, as natural capital, should be liquidated, with the proceeds being invested elsewhere in the economy.

Now continue to assume that c′(x) = 0, but suppose that there is a positive Existence Value. Our Fundamental Equation would then be:

$$F'(x^*) + \frac{\phi'\left(x^*\right)}{(p-c)} = \delta$$

It would never pay to liquidate the resource, because:

$$\lim_{x \to 0} \phi'(x) = \infty$$

Long before **x** reaches zero, the "own rate of interest of the resource" would exceed δ**.**

Regulated Open Access and the Dynamic Model: A Comment

We have seen that the payoff to an investment in the fishery resource takes the form of additions to the ***sustainable*** resource rent.

Consider now a marginal investment in the fishery resource.

The net present value of the investment, NPV can be expressed as follows:

$$NPV = \frac{d(SRR)/dx}{\delta} - [p - c(x)]$$

Following the marginal resource investment, there is, however, no control over fleet size so that the resource rent is ultimately fully dissipated, implying that:

$$d(SRR)/dx = 0$$

which in turn implies that:

$$NPV < 0$$

(given that [p-c(x)]>0)

The resource investment would thus, in economic terms, be a very bad one indeed.

This may *understate* how bad the investment is in economic terms - reasons for.

Resource Investment Programs

Should we invest as rapidly as possible in the resource, or invest at a slower rate?

It all depends!

-an example

Uncertainty in Fisheries Management

Our dynamic models to this point have been "deterministic" – act as if the future is known for certain – of course it is not!

Return on marginal investment in resource stock should properly be seen as the ***Expected*** return on the investment.

-impact on resource management

The Precautionary Approach to Resource Management

-Application of the dynamic economic model of the fishery.

-while there is evidence that the model is having fairly widespread influence on policy makers, the first fishing state to apply the model explicitly is Australia.
- Australians, in turn, have done full scale modeling for one fishery – Northern Prawn fishery in the Gulf of Carpentaria. Other fisheries are certain to follow.

<u>Management of Domestic Fisheries (fisheries within the EEZ)</u>

The core of the problem that we have discussed lies in fisher incentives.

Incentives – a general comment.

In “common pool” fisheries, fishers are given no incentive to invest in the resource. On the contrary, they are given a powerful incentive to engage in resource disinvestment – mining the resource.

Approaches to Fisheries Management (FAO)

A. INCENTIVE BLOCKING APPROACHES

B. INCENTIVE ADJUSTING APPROACHES

INCENTIVE BLOCKING APPROACHES:

These are the obvious approaches. If you do not like peoples' incentives, block them from responding to these incentives, e.g. traffic control

Pure Open Access – block the fishers' incentives to overexploit the resource by imposing harvest controls – e.g. TACs

This approach leads to the Regulated Open Access problem -overcapacity

First attempt to deal with the overcapacity problem involved another Incentive Blocking Approach:

Limited Entry, also known as Licence Limitation, programs

If too many vessels are coming into the fishery, then restrict entry to the fishery.

- decree that every vessel entering the fishery must carry a licence. Then limit the number of licences issued.

Coefficient of Excess Capacity –a digression (from the FAO)

-measure fleet capacity as follows. Given a fish resource of certain size and age structure – capacity of fleet deemed to be equal to the amount of fish the fleet would take during a certain period – e.g. fishing season - if the fleet were to be fully utilized.

Denote **Actual** capacity by:

Y_C.

Denote the **Target** capacity, the capacity that the resource managers want, as: Y_T Suppose that the TAC = 10,000 tonnes. Then Y_T = 10,000 tonnes. The resource managers want a fleet, which, if fully utilized, would catch 10,000 tonnes per season, and no more.

The Coefficient of Excess Capacity is given by:

$$\theta = \frac{Y_C - Y_T}{Y_T}$$

If Y_T = 10,000 tonnes and Y_C = 15,000 tonnes, then $\theta > 0,$ and fleet overcapacity is seen to exist.

In this example, $\theta = 0.5,$ which we interpret as: the actual capacity is 50% greater that the target capacity.

The objective of the Limited Entry program is quite simply to ensure that: $\theta = 0.0$

Since fisheries, to which the Limited Entry program has been applied, commonly start out with: $\theta \square\ 0,$ the program has typically been accompanied by a "buyback" (decommissioning) scheme.

- "buybacks" explained

The original Limited Entry programs allowed, indeed encouraged, the limited number of vessels to compete for shares of the TAC. If the fleet was just sufficient in size to take the TAC, where was the harm in allowing the vessels to compete?

We will refer to this (for reasons to be seen) as a **Type I** Limited Entry Program – Limited Entry with an "Olympics style" TAC- he/she who wins the race, gets the fish

The pioneering Type I Limited Entry Program was established for the B.C. salmon fishery in 1970.

- it was initially greeted with enthusiasm by economists, and was to be copied in many other fisheries throughout the world- certainly in many other Canadian fisheries

- the B.C. salmon fishery – an example

- another example, the B.C. Pacific halibut fishery. Limited Entry Type I program introduced in 1979. No "buybacks", but number of licenced vessels strictly limited.

-an aggravating factor, if number of vessels becomes "small". Strategic interaction among the fishers emerges.

Type I Limited Entry program becomes a competitive game. Even if each fisher realizes that by competing and expanding capacity all will lose, each fisher has no choice but to compete. If the fisher does not compete – making sure that he/she has the best technology – the fisher will lose part or all of his/her share of the TAC – perfect “Prisoner’s Dilemma”.

INCENTIVE ADJUSTING APPROACHES

Disappointment with Incentive Blocking Approaches has led to more and more emphasis being given to Incentive Adjusting Approaches – rather than block fishers from responding to perverse incentives, design management scheme so as to adjust fisher incentives, and bring those incentives into line with the goals of society.

The economist’s classic incentive adjustment approach consists of taxes - positive or negative.

Taxes

Very seldom used, but can in theory do all that is needed.

Example of a tax on harvest.

-in essence, the state, as resource owner will absorb all of the resource rent. The resource would then cease to be a “common pool” resource – the Gordon problem would vanish

-see diagram

Taxes have seldom been used –politically difficult to implement, and have obvious disadvantages. Very difficult for governments to get an accurate estimate of industry costs. Conditions constantly changing, so that the taxes would have to be constantly adjusted.

Having said this, there is still an important role for taxes, if not alone, then with other management instruments.

-an example of successful use of taxes, partly explicit, partly implicit – Mauritania in Northwest Africa mid-1980s to mid- 1990s.

Fisheries very important to Mauritanian economy. Major fisheries have very few landing points – easy to monitor.

In 1984 the government established the Société Mauritanienne de Commercialiasation de Poissons (SMCP). Vessels in the major fisheries forced to sell to the SMCP. The SMCP then marketed the fish, virtually all of which went into export market.

The SMCP was thus a monopsonist.

The SMCP imposed export and other minor taxes – explicit taxes. In addition, however, it set the price to the vessel owners, thus allowing for implicit taxes.

-consider the following

If taxes are not to be used, alternative incentive adjusting schemes have to be implemented. The key alternative consists of harvesting rights based management schemes

<u>Harvesting Rights Based Management Schemes</u>

Limited Entry **Type II**:

-retain Limited Entry, but add in a harvesting rights scheme for the fishers that (hopefully) will turn a competitive fisher game into a cooperative game. The initial aim was to eliminate the “race for the fish”

-known officially in the US as Limited Access Privilege Programs (LAPPs)

–popularly referred to as **“catch share”** schemes, although this is probably a misnomer.

-do harvesting rights based management schemes lead to the creation of fisher property rights? – a controversial, and much debated, issue.

Types of Harvesting Rights Based Management Schemes:

A. Individual Harvest Quotas (IQs)

B. Community Based Fisheries Management Schemes (sometimes referred to as Territorial Use Rights Fisheries [“TURFs”])

C. Fisher Cooperatives

D. Sectoral TAC Allocation Schemes (very close to C.)

One can also find blends of A. and B.; A. and C.

Limited Entry schemes and fisher games – a comment.

Individual Harvest Quotas - IQs:

Also referred to in Canada as:

IFQs –individual fishing quotas

IVQs - individual vessel quotas

ITQs – Individual Transferable Quotas

EAs – Enterprise Allocations - for offshore fleets in Atlantic Canada

IQs – operate as follows:

1. Resource managers limit the number of vessels in the fishery and set the season by season TAC (or equivalent) – as usual

2. The TAC is divided up into individual harvest quotas - distributed (or sold) to individual fishers, vessel owners, or companies.

3. Hope that **2.** will lead to the removal of the “race for the fish”, and the consequent overinvestment in vessels and gear.

We have noted before that one sure sign of growing excess fleet capacity in a fishery subject to TACs is a steadily declining season length.

One indication that an IQ scheme is working effectively is that the season length will begin increasing.

Case of the B.C. sablefish and Pacific halibut fisheries. Both had been subject to a Type I Limited Entry scheme around 1979-1980. Both had the same experience of rapidly decreasing season lengths. By the end of the 1980s, resource rent in the two fisheries was, from a national standpoint, probably negative.

Department of Fisheries and Oceans (DFO) introduced an IQ scheme in the sablefish fishery in 1990, and an IQ scheme in the Pacific halibut fishery in 1991.

Immediate improvement in season lengths – see figures.

<u>Questions</u>

a. should the IQs be transferable (i.e. capable of being leased or being sold)?

b. should the IQs be short term or long term?

c. if the IQs are long term, should they be issued in terms of fixed quantities, or as percentages of the TAC?

Economists argue in favour of IQs that are

i. transferable

ii. long term in fact, if not in law

iii. expressed as a percentage of the TAC – NOT expressed in fixed quantities

IQs that are i., ii., and iii., become almost like (non-voting) shares in a corporation.

Argument on behalf of i. is that transferability improves efficiency. Inefficient fishers sell or lease to efficient fishers. We shall see that transferability is important for other reasons.

i., ii. and iii. together give the fishers an incentive to maintain, and indeed invest, in the resource.

If the resource is being mismanaged, the future TACs will be lower, which will mean that the amount that individual fishers can harvest in the future will be reduced – IQs expressed as percentages of the TAC.

If the IQs are transferable (ITQs), a market for ITQs will emerge. If the resource is being mismanaged, with the above consequences for future TACs, and, if the market participants are rational, these future consequences will be immediately reflected in the price of ITQs today – reasons for.

Example of the B.C. sablefish fishery. The vessel owners have established the Canadian Sablefish Association

- for the past several years the Association contributes around $800,000 a year to DFO for sablefish stock assessment and research. Why? – because the sablefish fishers have become “green”? – No, because it is in their selfish interest to do so.

The Association also makes contributions towards surveillance and enforcement.

Convergence among the four schemes (IQs, TURFs, fisher cooperatives and sectoral allocations)

Cancino, Uchida and Wilen (see Reading List) contrast ITQ schemes and TURFs as individual vs. collective decision making – this is misleading.

ITQ holders often shown as operating as individuals, in isolation from fellow fishers. BUT, we cannot assume that, under ITQ schemes, strategic interaction among the fishers disappears. Many cases in which most definitely does not happen.

If strategic interaction among the fishers remains after an ITQ scheme is implemented, then it can be argued that the ITQ scheme will succeed, if and only if, it manages to turn a competitive fisher game into a cooperative one.

An effective ITQ based fisher cooperative game means that the fishers coalesce, i.e. acting like a cooperative or community

Examples – B.C. sablefish fishery and B.C. groundfish trawl fishery:

Canadian Sablefish Association;

Canadian Groundfish Research and Conservation Society

–emergence of ITQ “companies”

-link to Nobel Laureate Elinor Ostrom and “governing the commons”

Problems with ITQ Schemes

I. <u>Multiple species fisheries</u>

It used to be believed by economists that multiple species fisheries presented ITQ schemes with hopeless complexities. ITQ schemes, they argued, would only work in single species fisheries.

Now, however, precisely the reverse argument is being made, namely that ITQ schemes come into their own in multiple species fisheries. The case of the B.C. groundfish trawl fishery.

In this fishery, there are up to 50 species being fished. When ITQs were introduced to the fishery in the mid-‘90s, DFO issued quota to all the relevant species to each vessel owner, and then hoped for the best. Quotas were transferable from the beginning.

Vessel owners became quota portfolio managers. For example, some vessel owners specialized in a few species, and so had a shortage of some quotas and a surplus of others. They would buy the quota they needed and sell off the quota, which was surplus to their needs. The quota market has become highly developed with quota brokers.

-it is obvious that transferability of quota is ESSENTIAL, if this multiple species fishery ITQ scheme is to work.

System has, in fact, worked very well.

DFO has moved a step forward.

Since 2006, the B.C. Pacific halibut, sablefish and groundfish trawl ITQ schemes have been integrated.

Prior to 2006, fishers in the three fisheries inevitably had bycatch of species not covered by their quotas. For example, a sablefish fisher might have some halibut bycatch. By law, the sablefish fisher would have to discard his/her halibut bycatch. Very good chance that the discarded halibut would not survive – horrible economics; horrible biology.

Under the post 2006 scheme, the aforementioned sablefish fisher would be required to keep his/her halibut bycatch, would also be required to obtain halibut quota to cover the halibut catch. How could this be done? – through the market.

II <u>Monitoring</u>

i. highgrading

ii. "quota busting"

iii. poaching by outsiders

- the terms explained

Effective monitoring is essential for ITQ schemes, if they are to have any chance of success

-put this in a game theoretic context. We have said that a successful ITQ scheme can be thought of as a stable cooperative game (unless there is no strategic interaction among the fishers). One condition that must be met, if a cooperative game is to be stable is that each and every player is convinced that the solution to the game will make him/her at least a well off as he/she would be under competition – Individual Rationality. If there is extensive and uncontrolled cheating by players, and/or if there is extensive poaching – free riding – by outsiders, an otherwise law abiding player will conclude the he/she might well be better off under competition – the cooperative game will break down.

Having said this, effective monitoring is a problem for ANY fisheries management scheme. The Type I Limited Entry schemes have often broken down because of ineffective monitoring – lack of control over fishing capacity expansion; "TAC busting".

Possibility of self-monitoring- self enforcement in ITQ schemes. The case of the B.C. sablefish fishery.

III Equity

Excessive returns to the lucky few fishers.

The issue of "armchair" fishers – those who rent out their quota.

Sale, or lease, of quota to non fishers – the "Toronto dentist"

Creation of fisher property rights – giving away of public property to private interests.

-the coming of fisheries royalties, and/or ITQ auctions.

Community Based Fisheries Management Schemes (“TURFs”)

Fisheries management powers granted in all ,or in part, to geographical based communities

-communities have to be cohesive and have effective leadership for this sort of scheme to work. Have to be able to work out fair rules for sharing the returns from the fishery – a cooperative game, once again. Cancino ,Uchida and Wilen – detailed examples of such communities from Japan and Chile – popular in many developing fishing states.

Fisher cooperatives – the case of the Alaska Pollock fishery.

Convergence of “catch share” schemes- the case of the B.C. groundfish fishery habitat agreement.

Marine Protected Areas (no take zones)

- take a selected area of the fishing ground and declare it to be off limits for fishing. Fish assumed to move between the "no take zone" and the area in which fishing is allowed.

-an ancillary fishery management instrument. No one really seriously considers using MPAs alone.

- first requirement – enforceability. If effective measure cannot be implemented to enforce the MPA, then the MPA will useless.

- key argument for implementing MPAs – irreducible uncertainty in fisheries management.

Ecosystem Approaches to Fisheries Management

Every respectable policy maker involved in fisheries management talks about the need to take an ecosystem approach to resource management. So what is an ecosystem?

A common dictionary definition is:

"A community of organisms together with their physical environment, viewed as a system of interacting and interdependent relationships."

In terms of capture fisheries, this means taking into account the interactions of species between and among themselves, and the interaction of the species with their aquatic environment, and humans.

This is much like the economist's concept of General Equilibrium – everything depends upon everything else.

In simplest terms, it means getting away from relying on single species models. The dynamic economic model of the fishery that we have examined has been extended to deal with multi-species fisheries. This creates no conceptual difficulties. Instead of thinking about managing a single "natural" capital asset, we think in terms of managing a portfolio of such assets.

What is then important is not the net economic returns from individual fish stocks, but rather the net economic returns from the fishery portfolio.

Two comments:

i. it is not possible to manage an entire ecosystem - we do not have the tools to do so.

ii. human beings are not separate from the relevant ecosystem; they are part of it.

The case of the B.C. groundfish fishery, once again.

The Management of International Fisheries

Since fish are mobile, most coastal states find that they have to share some of their fishery resources with other fishing states.

Internationally Shared Fish Stock – a fishery resource that is exploited by two or more states (or entities, e.g. the EU) – examples Pacific salmon and Pacific halibut, both shared by Canada and the US.

Classes of Internationally Shared Fish Stocks (FAO):

Transboundary stocks

Straddling stocks

Discrete high seas stocks

The management of internationally shared fish stocks- the Two Basic Questions:

Non-cooperation and the "Prisoner's Dilemma"

Normally cooperation DOES MATTER!

- example of Pacific salmon and "fish wars"

If cooperation does matter, then we have to look at the conditions that must be met for a cooperative resource management arrangement to be stable through time

-Theory of cooperative games – John Nash

The two fundamental conditions

Players bargain over division of economic returns from the fishery. May, or may not, have to bargain over the resource management regime – no guarantee that the players will have identical management goals.

Two Key Concepts

I Cooperative Surplus

- θ^* and β^* -solution payoffs to A and B respectively.

- θ_0 and β_0 – “Threat Point” payoffs to A and B respectively.

Then, the Cooperative Surplus (CS) is given by:

$CS = [\theta^* + \beta^*] - [\theta_0 + \beta_0]$

e.g. Barents Sea – cooperative resource management arrangement between Norway and Russia – groundfish, e.g. cod – 40 years old.

Estimated that $CS = 50 \times [\theta_0 + \beta_0]$

II Side Payments

Essentially transfers between players in either monetary or non-monetary form

Cooperative fishery game ***without*** side payments. Payoff to A determined by the A fleet harvest in A EEZ ALONE. What is true for A is true for B.

-particularly important, if A and B resource management goals differ.

A third fundamental condition - time consistency, or resiliency, through time.

-this means that the cooperative fishery resource management arrangement must be able to withstand unpredictable shocks. If it cannot, then the arrangement may break down at some point in the future, hence the arrangement is not “time consistent”

-the case of Pacific salmon, once again.

- while shocks cannot be predicted with accuracy, many can be anticipated – the analogy of earthquakes.

<u>Forestry</u>

Forests produce both commercial AND non-commercial products and services

- examples of the latter:

a. recreation

b. sustaining wildlife

c. absorbing CO_2 -**sequestering**
this is very important in dealing with global warming

Property Rights: - in Canada the property rights to forest lands are well established - 95 % are publicly owned. In Canada, there is nothing like the “common pool” problem encountered in capture fisheries - reasons. “Common pool” problems do arise internationally, however.

<u>Commercial Aspects of Forestry</u>

Classes of wood:

i. softwood

ii. hardwood

-essentially the difference between coniferous and deciduous trees
i. – examples: Douglas fir, cedar, hemlock, pine

ii. –examples: oak, maple, birch

B.C. forest industry overwhelmingly softwood based.

Commercial Activities:

a. logging

b. sawmilling

c. plywood and veneers

d. pulp and paper

b, c. and d. –processing activities

Forest industry is important for Quebec and Ontario and *very important* for B.C.

Phases of Commercial Exploitation

First phase – mining of old growth timber

Second phase – replanting for harvest in the future – a combined natural and human activity

We will refer to this Second phase as **plantation forestry**

The B.C. forest industry, which became significant by the last quarter of the 19^{th} century, was for a century basically a First phase industry. The industry is now entering the Second phase.

Forestry economics begins with the Second phase. At a later point, we will talk about the economics of First phase operations.

<u>Basic Concepts:</u>

"stand" of trees – trees on a given piece of land of uniform age.

forest - a set of "stands" . We will later talk about a "normal" forest.

ROTATION – let the trees on a stand grow to a certain age. Then cut the trees down, and replant for a future harvest.

Single rotation vs. multiple rotations

To develop the economic theory for plantation forestry, we need continuous time (as opposed to discrete time) models, and we have to talk explicitly about discounting on a continuous time basis.

(we were able to finesse the issue of discounting on a continuous time basis in our discussion of dynamic economic models of the fishery, we cannot do this here)

To do this, we have to review the concept of exponentials

Exponentials – a digression.

Biology of a stand of trees – very simple in comparison with fisheries biology

Volume of wood on the stand through time – V(t)

Current Annual Increment - CAI

Mean Annual Increment – MAI

Concept of **Stumpage Value** – the value of a stand of trees, upon harvesting - Stumpage Value will obviously vary through time

Price and cost assumptions

Concept of Net Stumpage Value after Planting

The Single Rotation Model

When the trees are cut down, the land will no longer be used for forestry purposes.

Choose the optimal harvesting time, **t,** which is the t that will maximize the PV of future value of the Net Stumpage Value after Planting

- if the max PV of the Net Stumpage Value after Planting is less than the planting costs at t = 0, then do not plant.

An Investment Decision Rule:

$$\frac{pV'(t)}{pV(t)-C}=\delta$$

Extreme cases:

(i) $\delta = 0$

(ii) $\delta = \infty$

The Multiple Rotation Model

The heart of forestry economics

<u>The Faustmann Model</u>

The land upon which the stand of trees is to be planted is to be used over and over to grow trees from period t = 0 to t = ∞.

Rotation periods to be of equal length – if the optimal first rotation period is 50 years, the second optimal rotation period will also be 50 years, and so on – reasons for.

Denote the common Rotation Period by **I** (notation used by the text).

We have:

$$PV = \frac{pV(I) - C}{e^{\delta I} - 1} - D$$

The R.H.S. of the above equation is referred to as: the “site” value of the land at t = 0 – the value of the land as a productive forest asset through time.

Choosing the optimal Rotation Period - I

The Faustmann Investment Decision Rule:

$$\frac{e^{\delta I}-1}{e^{\delta I}} \cdot \frac{pV'(I)}{pV(I)-C} = \delta$$

OR

$$\frac{pV'(I)}{pV(I)-C} = \frac{\delta}{1-e^{-\delta I}}$$

We can refer to $\frac{e^{\delta I}-1}{e^{\delta I}}$ as the “Faustmann Corrective”.

The impact of the “Faustmann Corrective” upon the optimal Rotation Period.

The Rotation Period will be shorter than it will be for the Single Rotation case – reasons for

Re-expressing the Faustmann Investment Decision Rule:

$$pV'(I) = [pV(I) - C].\frac{\delta}{1 - e^{-\delta I}}$$

But

$$[pV(I) - C].\frac{\delta}{1 - e^{-\delta I}} \equiv \delta[pV(I) - C] + \delta\left\{\frac{pV(I) - C}{e^{\delta I} - 1}\right\}$$

Hence:

$$pV'(I) = \delta[pV(I) - C] + \delta\left\{\frac{pV(I) - C}{e^{\delta I} - 1}\right\}$$

R.H.S. of the above equation – two components to the opportunity cost of a marginal investment in the stand of trees.

Extreme cases:

(i) $\delta = 0$

(ii) $\delta = \infty$

Case (ii) is easy; case (i) is much more difficult

The concept of the:

Average Economic Yield per Rotation

$$\frac{[pV(I)-C]}{I}$$

If we measure I in terms of years, e.g. I = 50, a 50 year rotation, then the Average Economic Yield per Rotation, gives us the average economic yield per year.

If $\delta = 0$, then the optimal **I** (Rotation Period) is the one that will maximize $\frac{[pV(I)-C]}{I}$

A simple example, using a finite time period:

- a 20 time period, with two alternative rotation strategies, 4 years and 5 years.

at the end of Year 4,we have $[pV(4)-C]=120$

at the end of Year 5, we have $[pV(5)-C]=125$

Strategy A. Set I = 4

We will then have:

$$\frac{[pV(I)-C]}{I} = \frac{120}{4} = 30$$

Strategy B. Set I = 5

We will then have:

$$\frac{[pV(I)-C]}{I}=\frac{125}{5}=25$$

Consider Strategy A. The yearly average of 30 for the first rotation will be the same for every following rotation. Therefore, the total return to be gained from following Strategy A over a 20 year period will be:

30 x 20 = 600,

If Strategy B is followed for 20 years, the total return will be:

25 x 20 = 500

It is true that $[pV(5)-C]>[pV(4)-C]$, but the per year return under Strategy A is greater than it is under Strategy B. It is the per year return that counts.

The Pearse B.C. Douglas Fir example

The Forester's view:

Optimal **I** is that the one that will maximize:

$$\frac{[V(I)]}{I}$$

Prices and costs ignored.

Assumed that $\delta = 0$

This policy is seen as leading to Maximum Sustainable Yield - MSY, once again.

The concept of **The Normal Forest**

(adopt Forester's assumptions)

Skimming off the growth of the Forest

- an example from South Africa -short rotation period, by Pacific North American standards

The First Phase of Exploitation - The Mature Forest Issue

"Mine" the virgin forest and then re-plant. The phasing in of the Normal Forest.

The Hanzlick Formula:

The Hanzlick Formula can be expressed as follows:

AAC – The Allowable Annual Cut

MAI – Mean Annual Increment

I_{opt} – Optimal Rotation Period

AAC = (Volume of Mature Timber)/ I_{opt} +

(MAI from Immature Stands)

The "Falldown Effect"

-high yields from the virgin forest not sustainable – result inevitable.

-a fisheries analogy

Forest Non-Market Values

Forests produce many non-market values, such as:

i. recreation

ii. maintenance of water systems

iii. support of wildlife

Of particular importance, in this era of the threat of global warming, is the absorption and holding of carbon dioxide CO_2. This is referred to as the "sequestering" of $CO_{2.}$

Properly, we should when doing our PV calculations incorporate all of the non-market forest values, along with the market, i.e. commercial, values.

The economics of non-market forest values is not well developed.

We do what we can within the context of Phase Two of forest exploitation – plantation forestry.

Consider the first three sets on non-market values. "Sequestering" of CO_2 requires special comment.

There is a fundamental difference between commercial/market values arising from a stand/forest and non-market values.

When a stand of trees is planted, we have to wait for a period of time before the commercial values are realized - e.g. stand of Douglas fir 60+ years.

The non-commercial values start being realized as soon as the trees are planted on the stand.

The Single Rotation Case

Given that $\delta > 0$, the PV of the commercial values from the stand, what we referred to as the NSV up to this point, will go to zero, if the age of harvesting is far enough off in the future.

The PV of the non-market values can NEVER go to zero – there will be some non-market values forthcoming from the stand, however small, at t=0.

We should also note that, with a single rotation, as soon as the trees are harvested the non-commercial values come to an abrupt halt.

Consider the following diagrams: PV_{CM} vs. PV_F, where PV_F denotes the PV of the flow of non-market values from the stand.

What we proceed to do is to add PV_{CM} and PV_F

$PV_{CM} + PV_F = PV_{tot}$
The optimal time of harvesting, T_{opt} ,is given by the maximum on the PV_{tot} curve.

It is possible that $T_{opt} = \infty$, i.e. it will pay never to harvest the stand. This could occur, if PV_F overwhelms PV_{CM}. Think of ecological reserves and of forest park land – the Stanley Park solution.

The “sequestering” of CO_2 is a special case. In the case of the other three sets of non-market values (i-iii), these values come to a halt when the trees on the stand are harvested. When the trees on the stand are harvested much of the “sequestered” CO_2 will be released!

In terms of the non-market values with respect to “sequestered” CO_2, they become **negative** at the time of harvesting. This, of course, will push T_{opt} farther out into the future than would be the case, if “sequestered” CO_2 was not seen as being worthy of consideration.

The Multiple Rotation Case

Now we are faced with the threat of indeterminacy.

Non-market values i - iii do not come to an abrupt end when the stand is harvested, since replanting will occur immediately, and the flows will start again.

Almost 40 years ago a study was done on Pacific Northwest Douglas fir stands, trying to estimate, the optimal rotation period when non-market values were included, I_{CM+F}, using a Faustmann type of model. Denote the optimal rotation period when commercial values alone are considered as I_{CM}. At the time, the "sequestering" of CO_2 was not considered.

The question that was then posed was whether:
$I_{CM+F} > I_{CM}$; $I_{CM+F} < I_{CM}$; $I_{CM+F} = I_{CM}$.

There was no definitive answer, because there really is not just one I_{CM+F} . For certain types of non-market values, one would certainly want an **I** that is greater than $I_{CM.}$ We can add that the non-market value arising from "sequestered" CO_2 would certainly serve to give us an $I_{CM+F} > I_{CM}$ outcome**,** due the release of CO_2 every time the stand is harvested.

On the other hand, it was found that some form of wildlife actually benefit from periodic harvesting of the trees. Looking at these non-market values alone, an **I** that is ***less*** than I_{CM} would be desirable.

Even though "sequestered" CO_2 has become very important, we are still left with an unclear outcome.

The planting, or enhancing, of stands/forests for the express purpose of "sequestering" CO_2 has been examined in a set of economic studies. This has become a big issue, because under the Kyoto Treaty, which Canada signed, countries can obtain carbon credits for undertaking such activities. Importance of sequestering enhanced by the Paris Conference.

The studies carry out an investment decision type of analysis – compare the costs of carrying out the forest planting and tending activities, including the opportunity cost of the forest land, with the PV of the "sequestered" CO_2 . General conclusion appears to be that it does not pay in many temperate zones, e.g. the EU, but that it would pay in many tropical countries, e.g. Brazil.

How are developing tropical countries to be persuaded to do this? The suggestion that has come up is that developed countries make payments to these developing countries to engage in "sequestering" of CO_2 activities. The benefits of "sequestered" CO_2 are, after all, shared.

- Side payments, once again.

Forest Tenure Arrangements in B.C. – Some Comments

In B.C. up to 90% of the forest land is crown land, i.e. owned by the state (province).

Forest companies are granted, under licence, what amount to harvesting quotas – referred to as tenure arrangements. Government sets equivalent to fisheries TAC – AAC.

Sounds like IQs in fisheries. But, there is no issue over property rights – clearly in the hands of the state.

Furthermore, there is no significant strategic interaction among the forest companies – they are not harvesting a common resource.

Forest companies, as well as being granted harvesting rights, are called upon to carry out various forest management functions.

Major licencing schemes:

Tree Farm Licences – for large companies
term of licence – 25 years

Forest Licences – for medium size companies
term of licence – 15 years

Both Tree Farm Licences and Forest Licences have "evergreen" provisions – licences can be renewed, before the end of term – say after 10 years.

Under both schemes, companies are required to engage in re-forestation – replant logged areas ,and then follow up the planting with silviculture – tending the crop. The companies are required to do all of this ***at their own expense.***

The companies are subject to various penalties, if they do not meet these re-forestation requirements in a satisfactory manner.

The big issue is whether the companies have the needed incentives to carry out the re-forestation, i.e. "investment".

Economic return from the forest "investment" may not be realized for 60 years, or more, after planting. The maximum licence term is 25 years.

Companies expect, *but are not guaranteed*, to have licences renewed. Hence, the companies will tend to discount returns from replanted forests at a high rate. There would be no problem, if the penalties for non-compliance were fully effective. If the penalties for non-compliance are not fully effective, risk that the companies will do the absolute minimum in engaging in forest "investment".

Consequences – a hint of the "common pool" problem.