Economics in Fisheries Management

LPWM2005 Fisheries Management

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Lecture 1. The bioeconomic model

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Contents

Fish are a renewable resource. If the harvest is at an appropriate level it can continue indefinitely. If the harvest is continually above the ability of the stock to grow then stock depletion will occur. Overfishing occurs when the harvest is greater than growth. A stock is overfished when it is reduced below a reference level, such as the stock level that would deliver maximum sustainable yield (MSY).

Logistical model of population growth

A bioeconomic model of a fishery enables us to consider aspects of management, both in physical and financial terms. We first consider the nature of the biological growth curve in a fishery.

A stock that is not harvested will be in equilibrium. It cannot grow more because of limitations of habitat, other ecological factors or food supply. After a stock is harvested the excess food supply will enable it to grow back to equilibrium. Any rate of yield can be sustainable if it is equal to the growth of the stock. If the yield exceeds the rate of growth, stock depletion will occur.

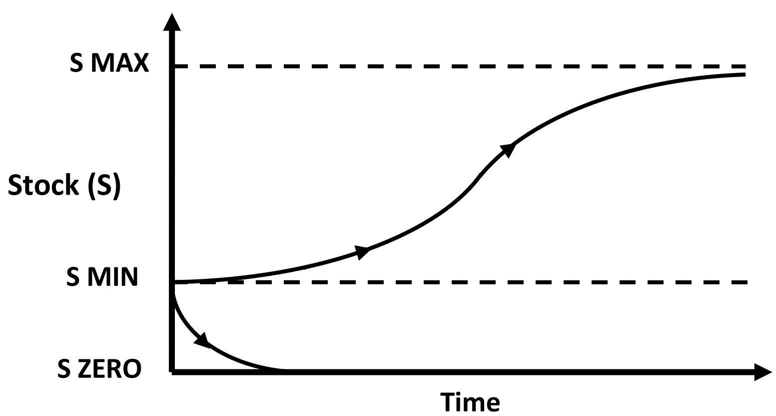

Fig 1. Biological growth curve of a fishery

The stock or biomass of a single fish species may exhibit growth through time as illustrated in Figure 1. The curve is a logistic function: at low levels fish multiply at an increasing rate but as they begin to compete for food supplies their rate of growth slows and eventually the stock reaches a maximum equilibrium level, which is the ecosystem's carrying capacity for that species. If the stock is reduced below the minimum the species is driven to extinction.

Figure 2 plots the same information as Figure 1, but shows growth of the fish resource on the vertical axis and stock level on the horizontal. The rate of growth is slow at low levels of stock, becomes more rapid as stock increases and then slows to eventually become zero as the stock reaches a natural equilibrium, where mortality equals recruitment. The growth function is the rate of change of the stock over time.

The figure allows us to identify a concept in widespread use. That is the maximum sustainable yield (MSY), which occurs when the growth rate of the stock reaches a maximum. If it takes one year to regenerate, MSY can be taken each year. But MSY is the most we can take from the resource on a sustainable basis without reducing the long-term stock.

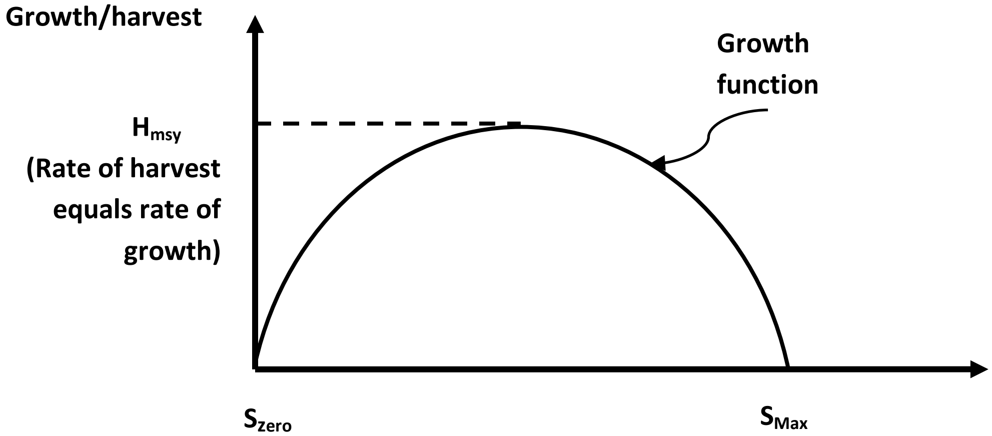

Fig 2. Growth in a fish stock

If the rate of harvest is greater than the sustainable yield indicated by the growth function i.e. if it is subject to overfishing, then the stock will fall (Figure 3). Conversely, a lower rate of harvest, as indicated by the growth function, will allow the stock to grow.

In Figure 4, continual overfishing has resulted in a reduced stock level, $S_{2,}$ i.e. it is overfished; while fishing harvest is sustainable at constant H_2, it is at a much lower level than possible at H_{msy}. To achieve MSY, the stock would need to recover to $S_{msy.}$

At H_3 and S_3 harvest could be increased to H_{msy} with a reduction in stocks to $S_{msy.}$

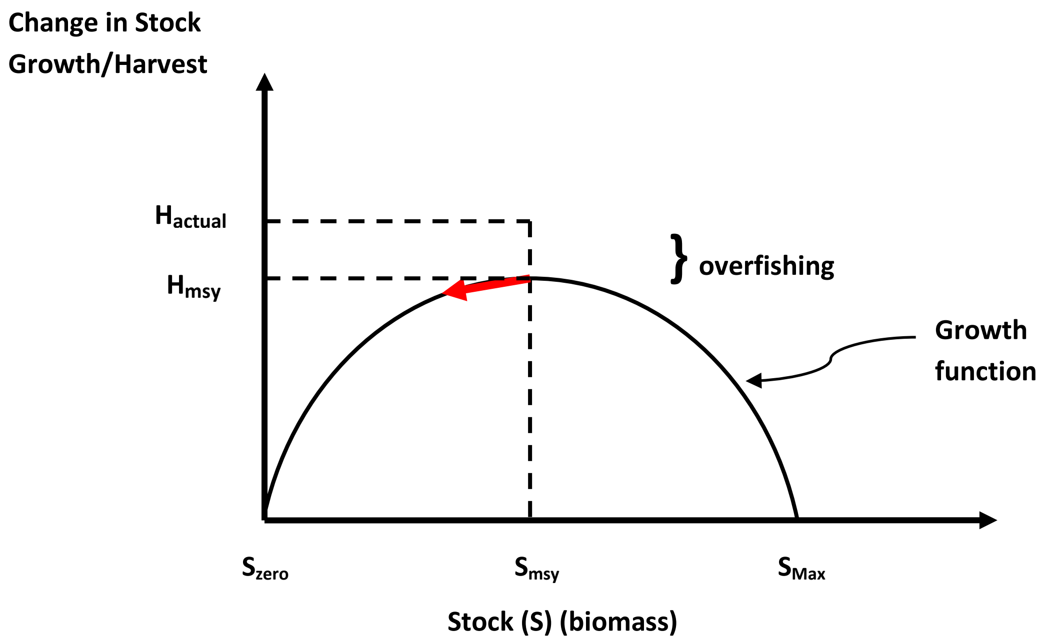

Fig 3. Overfishing and growth function

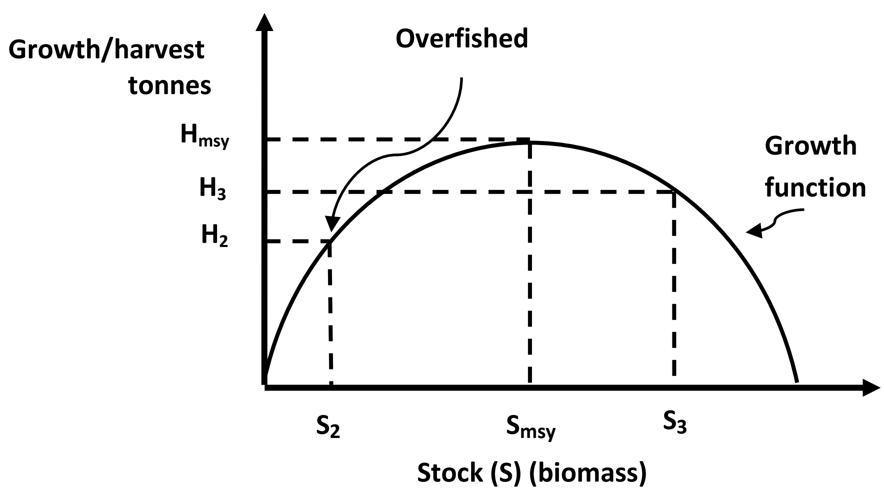

Fig 4. Yield curve for a fishery: harvest and growth rate of stock

Effort-harvest function

We now introduce effort into the consideration of sustainable harvests. In a fishery, particular levels of effort are each associated with a particular yield or harvest. An effort that is applied continuously will result in a sustained harvest. A level of effort that coincides with the maximum growth rate of the stock, and is maintained, yields the highest sustainable harvest, or MSY.

Effort is a term for the economic resources devoted to catching fish. This includes the costs of capital (boats and gear), labour and materials and energy. We can represent effort in a number of ways, such as number of boats fishing, or boat days fished, or number of hooks deployed. Different levels of effort are associated with different levels of cost.

Efficient level of effort

While any level of effort is associated with a sustainable yield (except for a level of effort that is so high that it reduces the stock to levels so low that it cannot sustain itself), we are most interested in knowing the level of effort that produces a maximum sustained yield (MSY).

The MSY is often the goal of fisheries managers, given that it is the maximum biological yield available in a fishery.

However, the aim is to find the most efficient effort level in economic terms. The most efficient level of effort, found after introducing the costs of effort into decision-making, is always less than what gives MSY.

Assuming that the price of fish and costs are constant allows the construction of a revenue and cost function. The total revenue curve is the yield from the growth function multiplied by the price of fish. The total cost curve rises from the origin in a straight line. As effort increases, so do total costs, as in Figure 5.

The net income is then the difference between total revenue and total cost.

The level of effort that maximises net income, maximum economic yield (MEY), is to the left of MSY, at E_{mey} in Figure 5. Note that although the total revenue is higher at MSY, the costs are even greater so net revenue is lower at MSY than at MEY and the stock larger. The net revenue is also referred to as the "resource rent" generated by the fishery.

Under open access rent is driven to zero as more and more fishing effort is applied seeking rents, until all rent is exhausted at $E_{oa,}$ and only "normal" profits are made ("normal" profit being wages plus interest on capital).

If the fishery is placed under single ownership or joint ownership in which the owners act collectively, it might be reasonable to suppose that resource will be managed to maximise resource rent.

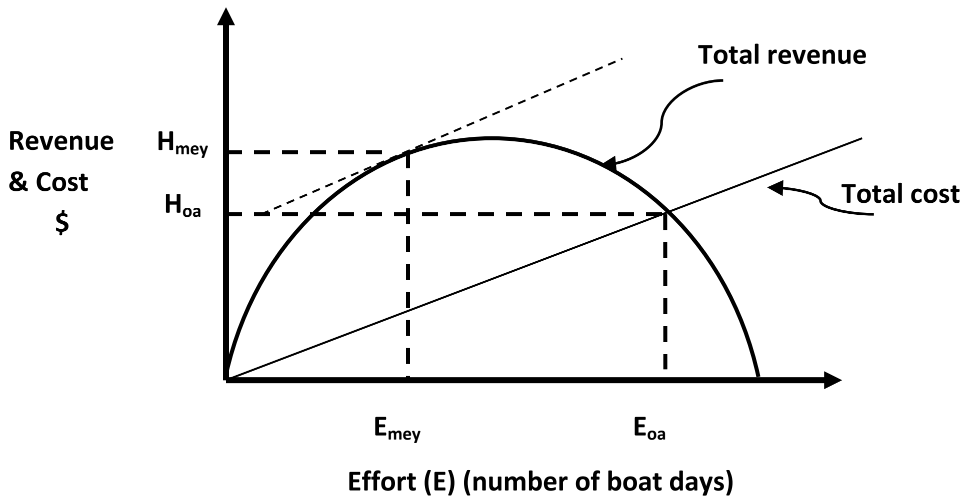

Fig. 5: Efficient harvest in a fishery

Another way of looking at this is to remember that profit or resource rent is maximised at marginal revenue = marginal cost (Figure 6).

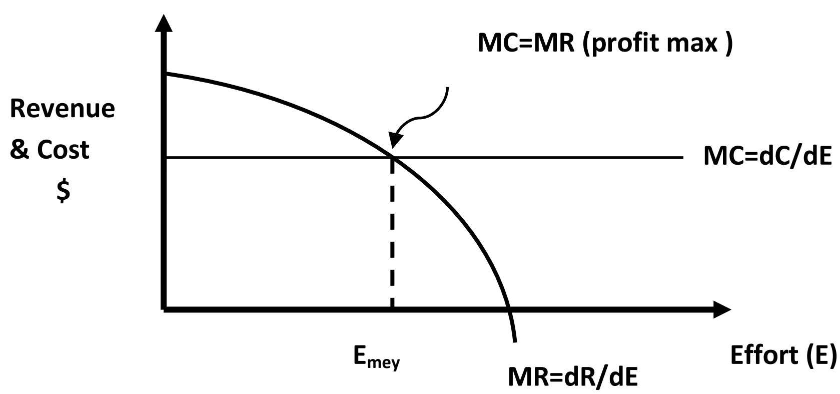

Fig 6: Marginal conditions and profit maximisation

Open access problems

In the real world, the property rights to ocean fisheries are not held by single individuals or even, until recently, defined groups acting cohesively. Rather, fisheries tend to be subject to open access with new entrants being attracted to fisheries by the resource rents available. However, the more new entrants there are the more likely it is that resource rent will be dissipated and only "normal" profit will be earned. This is the level of effort E_{oa} in Figure 5. At this "open access equilibrium" the stock and the harvest rate are lowered. Costs vary between fishers, however, and some will go out of business.

Where a community or group of nations fish on a common property resource there will always tend to be individuals or nations that will want to take or be permitted to take a catch that will be greater than at MEY. If such unregulated fishing exists, all members will suffer as the total resource rent available is reduced and the total catch falls.

If stocks are depleted and take time to recover then future generations could suffer.

If there is a critical size to the population then open access could lead to extinction of the fish being targeted.

The group may respond by developing rules that limit the use of any individual. However, the effectiveness of the rules depends on the methods used to limit individual effort.

Methods of management and their economic consequences

Property rights

Anthropologists and historians have found that for centuries localised groups of people have sought to define and defend territorial rights to fisheries by excluding outsiders. The group then makes rules aimed at sustaining the resource. Such an approach can work well when resources are localised in inshore fisheries.

Before the 200 nautical miles (nm) exclusive economic zones (EEZs) were introduced nations could only control fishing in their territorial waters, which extended for 3 or 12 nm from shore, while the high seas were open access. Countries can now claim and enforce their jurisdiction over their EEZs.

Where countries are composed of many islands, as is the case for Pacific island nations, the EEZs can cover vast areas. For these small countries administering effective management over their EEZs is difficult and costly.

Geographically-based groups or individuals are less effective in managing a fishery based on migratory species. For effective management all the members of the group in the migratory path of the fish need to be involved and to agree on rules to limit catch.

Command and control

The most common approach to fishery regulation has been command and control, for example by limiting fishing days, number and horsepower of vessels or types of gear. While these methods may reduce effort to levels that deliver MSY, they raise the costs of achieving that yield. In Figure 7 regulations reduce effort from E_{oa} to E_{msy} and E_{mey}. However, in so doing, costs are raised and resource rents are reduced.

Economic efficiency demands more than achieving optimal yields and stock. It also requires that the yield is achieved at minimum use of scarce resources.

Another disadvantage of command and control in fisheries management is that fishers will always attempt to increase aspects of their operation that are uncontrolled. If boat numbers are controlled, bigger boats are introduced. If vessel length is controlled, larger engines are installed. A limitation on horsepower increases the number of trips. And so on.

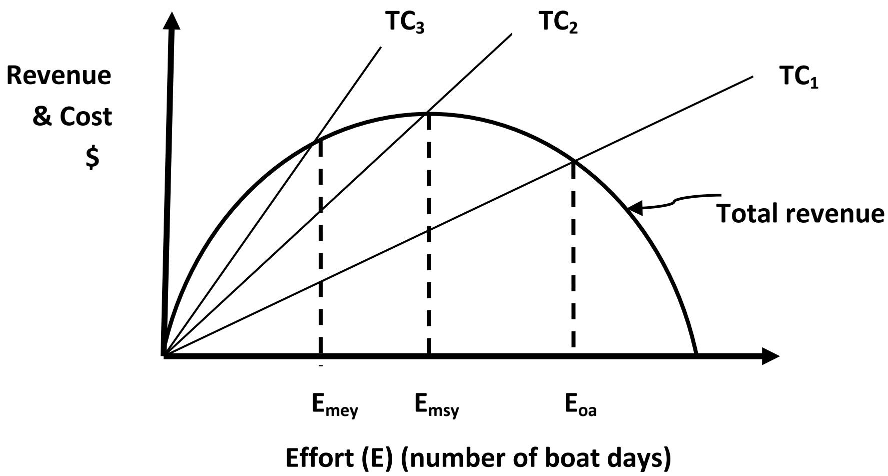

Fig 7: Effects of fishing regulations

TACs

A common regulatory approach by authorities responsible for fisheries management is to set and enforce a total allowable catch (TAC). Incoming catches are monitored and when the TAC is reached the fishery is closed. Monitoring is a difficult and costly procedure especially if landings are widely dispersed. The existence of resource rents created by limiting effort attracts more vessels into the fishery so that a "derby fishery" is a result. Larger vessels are built with greater fishing capacity and they race – as soon as the season opens – to maximise their share of the limited catch. The end result can be a dissipation of rents, as for an open access fishery.

ITQs

An advance on TACs is the allocation of the TAC between individual fishers. Vessels without a quota are barred. To maximise efficiency, individual quotas are transferrable between quota holders (ITQs). The most efficient fishers buy quota from less efficient or retiring fishers.

ITQs have a greater prospect of ensuring that the fishery attains MEY and rents are maximised. ITQs also improve the chances that economic efficiency is maximised because each fisher holding a quota will minimise costs. However, the management of an ITQ system is not without difficulties. The catches of each fisher must be monitored and accounted for to ensure compliance. It may be difficult to detect the unloading of 'hot fish' in remote locations or even at sea.

ITQs are a form of property and wealth can become concentrated in a few hands. This may be a bone of contention among those who regard fish as public resources rather than a private resource. On

social grounds it may be necessary to prevent quota ending up in just a few hands. The method of allocation of quotas in the first instance can also be controversial and is open to claims of inequity.

Other major problems emerge in multispecies fisheries, which are common. Where a quota species is caught along with other species the tendency is for the quota species to be discarded to stay within quota, while maximising the catch of the non-quota species. The discarded fish are not recorded and the TAC system is undermined.

Introducing time

Our discussion has tended to be couched in the context of static situation in a fishery. However, fisheries and fish management are dynamic; the price of fish and the costs of fishing change.

Economic theory suggest that if our discount rate is lower than the rate of natural increase in a stock times its price (or the marginal productivity of the resources) then it pays to consume the resource later rather than sooner. As long as the asset is growing faster than the discount rate, it pays to leave the asset in the sea. We wait for the natural growth of the assets plus price rises, which we expect to rise with an increasing scarcity of fish resources and rising demand.

A question to be asked is: if we increase the current harvest, will the value of this be equal to or greater than the present value of future losses in rental brought about by the reduction in stocks? If the answer is no, then harvesting should not increase, and vice versa.

Decision rules

Increase catch

When: Value of increased catch > value of reduced future catches

Decrease catch

When: Value of decreased catch < value of increased future catches

Uncertainty in fisheries management

Lack of biological and catch data, both current and historical, can plague the introduction of management. Moreover, natural and ecological variables such as ocean temperatures or predators make quantification of fish stocks and appropriate effort levels difficult. One way of coping with uncertainty is to take a precautionary approach to setting TACs. Continual monitoring of the fishery, for example of catch per unit of effort, will progressively provide more data on which to base future management decisions. But data is often deficient and there is uncertainty surrounding stock level and growth rates. Thus the precautionary principle should be applied to setting TACs.

In cases where the stocks have been reduced to very low levels due to continual overfishing, the fishery may be closed to allow recovery because future catch values will outweigh the loss in present catch. But note that it is not always certain that stocks that have been reduced to very low levels will actually recover. Their place in the marine ecosystem may have been taken by other less valuable species.

Preservation values

The discussion up to now has focused simply on ensuring that a fishery is sustainable and economically efficient. However there are many emerging issues that impinge upon these simple goals.

In some cases the preservation value of a resource is much greater than the commercial value. Whales are a good example. Other examples are species that may be crucial to the tourism industry, e.g. marlin. We can add this opportunity cost – the preservation value – to the costs of fishing, to achieve total social cost.

A concern that is gaining ground is the level of bycatch in fisheries. Bycatch is often of no value to the fishers and is discarded. The bycatch may include endangered marine species and non-marine species such as sea birds. Information on levels of bycatch is more often than not scarce, unless regulations require fishers to keep records. Bycatch species may be pushed to the brink of extinction before there is awareness of the risks involved.

Technical innovation may reduce the level of bycatch. However, unless there is a general awareness of the issue it is unlikely that bycatch issues will actually be rated important enough by authorities responsible for fisheries management to reduce or close a fishery.

In Figure 8, there is no risk of extinction because effort was delivering MEY which is less than MSY. Nevertheless, because of the high preservation value of the species the costs of harvest are increased by imposing a tax on fishing that reflects the total external cost, or preservation value. The level of effort that maximises rent is E_{soc} and the stocks increase, but at a cost of reduced rent (the difference between TSC and the revenue curve).

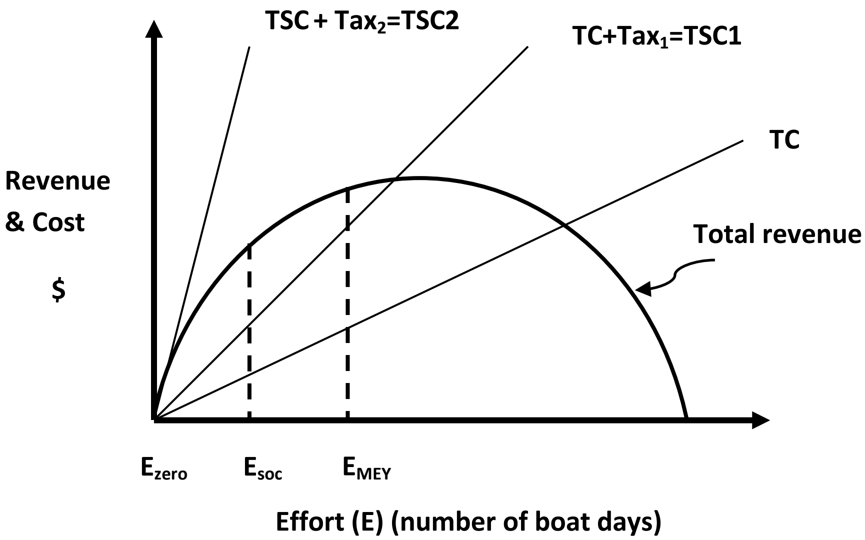

Fig. 8: Social optimum with preservation value

If it is decided that preservation value is so high as to warrant the discontinuation of fishing then the tax could be increased to TSC2, so that fishing becomes unprofitable and falls to zero.

Key terms

Bioeconomic model Maximum sustainable yield (MSY) Resource rent Open access/Rent dissipation Maximum economic yield (MEY) Overfishing Overfished	EEZ High seas TAC ITQs Precautionary principle Decision rules Bycatch

Glossary

dC=change in cost

dE=change in effort

dR=change in revenue

EEZ=exclusive economic zone

E=Effort

H=harvest

ITQ=individual transferrable quota

MEY=maximum economic yield

MC=marginal cost

MR=marginal revenue

MSY=maximum sustainable yield

OA=open access

S=stock

SC=Social cost

SOC=Society

TAC=total allowable catch

TC=Total cost