The Economics of Extinction

How Much Is That Species Worth?

Jeremy Garwood looks at the key economic models of the last half-century that have redefined how humans view living organisms as economic resources that can be driven to extinction.

The last decades have seen a huge increase in the general awareness of threats to the stability of the Earth's environment and the continued maintenance of its most complex ecosystems. Life science researchers play an important role in describing the vulnerability of living organisms to multiple pressures that destroy natural habitats and drive many species to extinction. However, as scientists from all domains know only too well, it can be very difficult to communicate scientific data in a form that policy-makers can understand, let alone act upon. In order to formulate national and international government responses, the scientific observations have to be translated into a language that politicians, industrialists and bankers can understand alike – economics! This has resulted in international meetings such as the "2007 G8 + G5 Potsdam Initiative (The economics of ecosystems and biodiversity)", which considered how accounting principles, already used in government and business, could be applied "to calculate the physical flows of ecosystem services and their economic value". The current reasoning is that until we know how much Nature is worth to us in monetary terms, we cannot accurately estimate how much money we are prepared to invest in saving it, nor which bits are the most valuable when choosing what to conserve.

The economics of overexploitation

Little is known about many of the species that are currently disappearing – they may not even have been named and classified. Although such biodiversity loss is the current emphasis of conservation biology, economic concerns about extinction began with species that we recognise and exploit commercially – fish and whales.

The economics of species extinction was first modelled by Colin Clark, a professor of mathematics at the University of British Colombia. In 1973, Clark published an article in *Science* magazine entitled "The Economics of Overexploitation – severe depletion of renewable resources may result from high discount rates used by private exploiters". The model Clark presented provided the framework for most of the analysis and policymaking ever since; it became the basis for all currently existing policies for remedying species extinction.

Whales, fish and the Clark model

Clark's model modified the existing standard economic argument for overexploitation of resources. As he explained, Clark was concerned that this standard argument did not reflect the very real possibility that overfishing could result in resource extinction. During the 1960s, an accelerating decline had been observed in the productivity of many important fisheries, particularly the great whale fisheries and the famous Grand Banks fisheries of the western Atlantic. But the example he focused on was that of the Antarctic Blue Whale Fishery. In 1964, the International Whaling Commission (IWC) estimated the net reproductive capacity, in terms of net recruitment of five-year-old blue whales, as a function of this species' breeding stock. Their graph, which "was little more than an educated guess", appeared to indicate a maximum sustainable yield of about 6,000 blue whales per annum. The annual blue whale catch had expanded rapidly from 1926, when the first modern stern-slipway factory ships were introduced. In 1931, it reached 30,000 and then began tailing off. In 1965, in extremis, the IWC agreed to protect the species – their latest scientific observations had found the total remaining population to be less than 200 whales!

Clark wanted to show how this had happened. At the time, economists were advocating the use of 'maximization of economic rent' as a management policy, where the term 'economic rent' refers to the regular income derived from an endurable resource – it is the net income, or excess of revenue overcosts. However, since there is a variety of management possibilities for most resources, "it is worthwhile to enquire, which policy will produce the maximum rent".

A mathematical problem?

The existing model for overexploitation of resources was based on a "simple mathematical model". A quadratic equation, $y = f(x)$, represented the net recruitment to a particular resource stock of size 'x'. Net recruitment was assumed to be the same as the sustainable yield from a population of size 'x'. Changes were modelled over time using a differential equation. The economic components of this model consisted of a constant price, $p>0$ per unit of harvested stock and a unit harvesting cost, $C(x)$ that depends on the population size 'x'. "The simplest assumption is that this unit harvesting cost is proportional to the density of the population: in the case of pelagic fish, uniformly distributed over their range, this assumption would simply mean that C(x) varies inversely with x, meaning that the total cost of harvesting the sustainable yield, y = f(x) would be C = By/x where B is the unit cost coefficient." Okay, said Clark, so what level of sustainable yield for a population size 'x' will give rise to the maximum rent? Since rent is the difference between revenue and cost, the problem is how to maximise this difference. Surely, maximising rent is the same as maximising profits, so why, he asks, do fisheries and other natural resource industries never seem to attain this result?

A question of rent

The existing answer blamed "dissipation of rent" due to "open access" – in sea fisheries, the natural resource is not private property. This means that individual fisherman are free to fish where they like (or were, prior to Clark's model), resulting in a pattern of competition that dissipated their potential rent/profits. This is because when a working fisherman makes a profit, new individual fishermen will be attracted to the industry, increasing the intensity of fishing – the fish population will decrease and so will the total rent (or profit). As long as any rent remains, the process continues. The

fishery expands until, in the end, the fish population falls to a level of zero economic rent and fishermen are forced to find alternative employment.

Overexploitation according to this standard model was a result of "open competition, particularly among the impoverished and powerless". This was complete nonsense! "The worst problems of overfishing are, in fact, due to large, high-powered ships and factory fleets from the wealthiest nations."

To take account of what was really happening, Clark modified the model as follows. Instead of rent dissipation, he noted that:

1. Biological populations take time to respond to harvesting pressures and will only approach equilibrium after several breeding seasons.

2. The value of monetary payments also possesses a time component due to the discounting of future payments: the maximisation of rent/profit and maximisation of present value are not equivalent.

He was the first to show that the possibility of species extinction could be modelled.

"The fact that populations can be driven to extinction by commercial hunting hardly needs to be emphasised."

Previously, it was assumed that harvesting costs varied inversely with the population size, 'x'. This meant that costs became infinite as 'x' approached zero, i.e. for values of x=0.1, 0.01, 0.001, etc. However incredible it may seem, living organisms are counted in whole numbers – in fact, 'x' is always a whole number! This now meant that the cost of extinction was simply the cost of a harvest when x=1 or, more realistically, when x falls below the minimum viable population level and the species is functionally extinct.

What about the 'maximisation of present value'? In economic rent, Clark explains that the future potential monetary value that remains in the unharvested resource can be either above the present liquidation value (that is, the value of harvesting the whole population straightaway) – what he calls 'conservable flow'; or it can be below the liquidation value, referred to as 'expendable surplus'. The problem then becomes "Under what conditions will it be preferable to maximise profits by liquidating the whole population?"

Let's look at the price-cost ratio. If p, the price per unit of the harvested stock, is less than B, the unit cost coefficient, and this is equal to C(0), the harvesting cost to liquidate the population, i.e. $p<B=C(0)$, then extinction is not feasible. However, if the price per unit of the harvested stock is greater than the unit cost coefficient ($p>B$) then extinction will occur as a result of the maximisation of present value.

Based on his model, Clark argued that overexploitation, perhaps even to the point of actual extinction, is a definite possibility under private management of renewable resources.

"The implications of this argument for successful international regulation would seem to be that, if it is assumed that society wishes to preserve the productivity of the oceans and to prevent the extermination of valuable commercial species, control of the physical aspects of exploitation is essential."

An influential model

His conclusion was that the conservation of renewable resources would appear to require continual public surveillance and control of the physical yield and the condition of the stocks.

Needless to say, Clark's model has been the basis ever since for international agreements on fishing quotas and the cessation of commercial whaling. It was also adopted by CITES (the Convention on International Trade in Endangered Species) to define its policies on protecting endangered species through criminalisation of hunting/harvesting and total bans on trade in the resulting products – for example, hunting the African elephant for its ivory, or rhinoceroses for their horns. Currently, 175 states have signed up for CITES and it covers around 5,000 animal species and 28,000 species of plants.

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"There are probably few economic models that have had so global an impact as this one," said Timothy Swanson, before he went on to revise it.

Extinction comes ashore – the African elephant

During the 1970s and 1980s, the perception of species extinctions began to alter from well-focussed concerns about individual, well-recognised species to a broader concern for the potential loss of millions of virtually unknown species – Biodiversity Loss. Despite its ground-breaking influence, Clark's economic model was restricted to questions of commercially exploitable biological resources – it didn't really explain or propose policy solutions to biodiversity loss. In fact, as a fishery-based model, it didn't even consider the terrestrial resources required for endangered species survival.

In his 1994 paper, "The Economics of Extinction Revisited and Revised" (Oxford Economic Papers, 46, 800-821), Timothy Swanson, currently Professor of Law and Economics at University College, London, proposed to bring the economics of extinction "on shore".

Swanson argued that it was important to overhaul Clark's model since it had generated some domestic and international policies, which themselves represented important threats to many species.

As an example, he considered the African elephant. A rapid decline in African elephant populations was observed in the 1980s, falling from 1,343,340 in 1979 to 609,000 in 1989. Meanwhile, the annual volume of the ivory trade had nearly doubled to 1,000 tonnes. At this rate, species extinction was predicted within 20 years.

The Clark model, as applied to elephants, explained this as follows: there is open access to the resource, so the price of the resource is high relative to its cost of harvest (i.e. $p>C$) and it is a slow-growing resource. This means there are incentives to continue harvesting elephants even to an extent that is incompatible with the capacity of the resource (total elephant population) to regenerate itself.

In response, CITES simply moved the African elephant from its Appendix II to Appendix I, effectively prohibiting all international trade in ivory. Its "quick fix policy" was derived from Clark's model – it enforced criminalisation of the production process (killing elephants) and a ban on international trade of its outputs (ivory). Both of these measures shift the price-cost ratio down: the ban on trade lowers the price and criminalising hunting increases the cost. Therefore, from $p>C$, we moved towards $p<C$ and (theoretically) people stop hunting elephants.

End of story? No, says Swanson, because such a dependence on the cost/price ratio means that positive sustainable trade in elephants is not an option. Nobody can make money from harvesting elephants – no maximum sustainable yields or quotas are allowed. And this creates a problem that will lead to "the slower, but equally certain, decline of elephants – in fact, of all endangered species – due to unsuccessful competition for the limited land resources controlled by humans".

The general bioeconomic problem

Clark's model had been incorporated into Bioeconomics, an off-shoot of Natural Resource Economics. Here, the general economic problem facing living organisms had been formulated as follows:

1. Humans have a whole range of productive assets/resources to choose from. Human societies must select a portfolio of these assets from which they then derive a flow of benefits. Biological resources are one important part of this portfolio and these resources are assets (i.e. investments which generate flows) simply by virtue of their biological nature.

2. Not all assets will be maintained at their present stock levels. It is sometimes

optimal to disinvest in one asset, receive a one-time benefit from it, then invest this receipt in another asset. It is possible to engage in 'conversions' between assets and this will occur until the returns between assets are equilibrated, at the marginal return on capital.

3. Such conversions also occur with respect to biological assets – sometimes they will be converted to a man-made asset. This means that human society will disinvest in the biological resource in order to invest in human-made capital items, like machinery. A biological asset can also be converted to a different biological asset, for example, when clearing a forest to create a cattle ranch.

A matter of disinvestment...

4. Any asset that yields a non-competitive return will, in the process of equilibration, experience disinvestment in order to provide resources for investment in the preferred assets, even though the replacement asset may be very different (man-made) or very distant. Actually, it is this very process of disinvestment that lies at the base of the decline of all diverse biological assets.

Therefore, says Swanson, the fundamental force determining species decline is, in fact, the relative rate of investment by the human species. It is the human choice of another asset, in preference to the biological asset, that results in the inevitable decline of species. This means that extinctions, whether of specific species or of general biodiversity, result from their non-inclusion in the human asset portfolio.

"The general nature of the extinction threat is that a species will be seen as an inferior asset and thus will be excluded from the human portfolio. Exclusion from the human portfolio of biological assets is a sufficient condition for biological extinction."

Okay, Swanson says, the fundamental force driving species into decline is human disinvestment in a species and its consequences but this doesn't explain either the elephant problem or biodiversity loss. This is because non-competitive biological assets can be disinvested in less direct ways than harvesting and marketing. All living organisms depend upon biological necessities – food, light, air, water, etc. Human societies now control these basic natural resources (by virtue of their control over land-use decisions). In reality, to thrive or survive, biological resources must also compete for an allocation of these resources.

... and "undercutting"

The implicit assumption in pre-existing bioeconomic models had been that biological resources were naturally 'free goods' that did not require investment. It was believed that biological product resulted from natural processes of growth deriving from the biosphere's capture of photosynthetic energy. But Swanson argues that the form of this biosphere is critically dependent upon relative investment rates – the rate at which basic resources are allocated to individual species. Life forms must now compete for their "place in the sun" subject to human decisions concerning land use. Decisions concerning how many base resources to allocate to a species will shift the growth function for that species, determining its rate of productivity.

"Most of the extinctions and endangerments are occurring today without notice or knowledge." Even well-publicised cases, like elephants, usually occur without "appropriation of many rents" – they don't yield much revenue. In fact, Swanson showed human-sourced extinctions are not necessarily working through the medium of active, exploitable activities. In most cases, extinctions are just the direct result of passive "undercutting". That is, for most threatened life forms, the extinction problem is unwillingness by humans to invest in the required ancillary resources, such as terrestrial resources, essential for biological survival. He argues that it is this passive "undercutting" of species through base resource allocation that threatens most life forms today.

Nevertheless, there is still a subset, made up of the well-recognised species – elephants, rhinos, birds, that fits neither the active "optimal extinction model" nor the passive "base resource allocation" paradigm. These are precisely the endangered species that are meant to benefit from human management. But what kind of management? Swanson argues that they are subjected to an open access management regime and that, in a reverse on the idea of open access harvesting, species decline is being caused by open access forms of resource management because "a resource will only receive an allocation of management services if it is able to afford a competitive return to these".

Swanson's revised bioeconomic model implies a species conservation policy that seeks to create basic incentives for investment in diverse species and diverse habitats. The objective is to maximise the difference between the price and harvest cost, not to minimise it, i.e. p < C.

How to create incentives?

Hence, there are three alternative routes to extinction under Swanson's model:

1. Stock disinvestment: this covers biological resources with high price/cost ratios but low growth. There are strong incentives to harvest the entirety of the resource for its high value and to invest these gains in other assets. For example, the deforestation of tropical hardwood forests. These hardwood trees have substantial economic value but very low growth potential. It is "economically rational" to 'cash in' the hardwoods and invest the returns in other, more productive assets.

The example of cattle ranching

2. Management resource diversion: here, the biological resources possess 'medium' value but low growth rates. It is because they're slow growing that they make little sense as an asset – society has no incentive to invest in their growth capacity. Furthermore, due to their relatively low value, they do not justify a commitment of substantial amounts of national resources for the management of the exploitation process. Hence, the national government will allow these resources to be depleted through unmanaged exploitation. This is the case with the large land mammals, such as the African elephant. Half the elephant population disappeared during the 1980s but almost all of the hunting occurred in just four countries – Sudan, the Central African Republic, Tanzania and Zambia. All four countries were at the bottom of spending on African park and protection (around $15 per sq km); the decline of the African elephant was due to these "tacit" open access regimes.

3. Base resource conversion: this concerns all of those biological resources of little or no value to humans – the 'biodiversity problem'. These species are not overexploited, they are simply undercut. They are lost because humans find alternative uses for the lands on which they rely. For example, the depletion of unknown life forms when land is deforested and converted to other uses, such as cattle ranching.

"Even biological resources are now economic resources, in the sense that human societies have control over the terrestrial biosphere and human decisions on resource allocations determine (directly or indirectly), which life forms will continue to exist."

All forms of extinction policy – endangered species conservation, biodiversity losses and/or deforestation and land conversion – must deal with the fundamental cause of decline – perceived investment-unworthiness. They must be based on the idea of supporting institutions and incentives for enhanced investments in diverse resources. "This implies that diverse resources must be accorded very substantial values, including market values, if they are to receive the investments that they require for survival. This is the only means by which fundamental resources driving extinctions and diversity losses might be faced."

How much is the knowledge of existence worth?

Of course, that's not the end of the story. How much is a species worth? In their 1999 paper, "Bioeconomic modelling of endangered species conservation" (Discussion paper in Natural Resource and Environmental Economics no. 19, Massey University), Robert Alexander and David Shields pointed out that Clark and Swanson had only considered "consumptive values" in their models – economic value is realised by consuming the resource, e.g. fishing, harvesting, hunting, etc. However, there are in fact "non-consumptive use values" that should be introduced into equations for calculating the overall economic value of a species.

For example, some of the largest potential and realised benefits of the African elephant are non-consumptive – in Kenya alone, tourism generates more than $400 million per year, mostly related to wildlife and wilderness experiences. Great idea; tourists from wealthy countries come to spend their money in Africa. Unfortunately, tourism alone is insufficient to support increased investments in elephant conservation – only 3% of Kenya's tourism revenues were appropriated by the Kenyan Wildlife Service, with the consequent problems of open access management.

Furthermore, in these poor African countries, rising populations and climate change are increasing pressures on alternative land use to produce food. Unable to harvest elephants due to the CITES ban on ivory trade, local people see elephants as competitors for limited resources.

Alexander and Shields explain that we need to tap into an alternative source of elephant value. Even without going on safari, the elephants have an "existence value" that people are prepared to pay for. Just the knowledge that elephants exist and that they will continue to go on existing has a value. This, they say, is already one of the key reasons why people become members of conservation societies.

Those have the value, others the costs

But how can we convert existence value into an economically meaningful quantity? There are many structural reasons why existence values are not appropriated and they are not easy to overcome. "Existence values are non-rival in consumption and non-excludable, and thus are classified economically as public goods." By 'non-rival in consumption', they mean that the enjoyment one person receives from the existence of elephants does nothing to diminish the enjoyment of another – the good is not used up through consumption. By 'non-excludable', they mean the level of an endangered species' existence at any given time is the same for all people, meaning you cannot exclude a non-paying person from experiencing the knowledge that elephants exist. "As with all public goods, there is no incentive for any given individual to pay the value they receive and such a good is typically under-supplied without government intervention."

Yet, if the government decided to, it could use taxes to pay for providing the good – as already happens with traditional public goods, like police protection, national defence and road signs.

However, the problem of species extinction is complicated by its global nature – most of the world's biodiversity is concentrated in a small number of states, that are generally poor and "in dire need of appropriable income", while the bulk of the non-consumptive values of endangered species is to be found in the relatively wealthy developed nations. "There is no mechanism in place to transfer income from those who benefit to those who are asked to bear the costs." Nevertheless, based on their model, "it is clear that the continued survival of the African elephant, and of many other endangered species, depends upon the ability of our global society to develop a mechanism for the transfer of value from those who desire the benefits of continuing existarence to those who bear the cost of maintaining the species".

Ecopolitics

Converting scientific observations of biological extinctions into economic models is influencing policy change. The 2008 EU report on "The economics of ecosystems and biodiversity" talks of "a defective economic compass". "We are still struggling to find the 'value of nature'. Nature is the source of much value to us every day, and yet it mostly bypasses markets, escapes pricing and defies valuation. This lack of valuation is, we are discovering, an underlying cause for the observed degradation of ecosystems and the loss of biodiversity."

Read more about the issue in our Online Editorials "From Origins to Extinction" (parts 1-4) at *www.labtimes.org*.