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Fisheries Centre, University of British Columbia, Canada

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Edited by
Ussif Rashid Sumaila

A Research Report from the
Sea Around Us Project and the Fisheries Economics Research Unit
Sponsored by the Pew Charitable Trusts,
Philadelphia, USA

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DIRECTOR'S FOREWORD

As Acting Director, I don't really have to write a full 'Director's Foreword,' so this will be short and to the point. And this is appropriate, as this collection of three essays is also short and to the point.

The 'point,' evidently, is that economics drive fisheries. Moreover, economics often acts through subsidies and high discount rates, both devastating to fish stocks.

The first of these essays elaborates on the surprising insight that buyback (=decommissioning) schemes, meant to reduce fishing effort, have, in many cases, exactly the opposite effect, a fascinating example of what economists call 'perverse incentives.'

The other two papers elaborate on an earlier discovery, by the editor (and co-author) of these essays, of a method for explicit consideration of future generations when discounting the value of natural resources. This method accepts that, to a certain extent, we all must discount the future: otherwise, we would barely dare to act on opportunities that present themselves. However, the generations that will follow ours should also be able to exploit opportunities and thus to discount *their* future. The original solution to this quandary, originally presented by U.R. Sumaila in *Fisheries Centre Research Report* 9(5), in 2001, is generalized here by U.R. Sumaila and C. Walters, and applied to cod in Eastern Canada by C. Ainsworth and U.R. Sumaila.

This novel approach to looking at the discount issue has, I believe, a great future, and I hope this slim volume will serve as its launching pad.

The Fisheries Centre Research Reports series publishes results of research work carried out, or workshops held, at the UBC Fisheries Centre. The series focusses on the multidisciplinary problems of fisheries management, and aims to provide a synoptic overview of the foundations, themes and prospects for current research. Fisheries Centre Research Reports are recorded in the Aquatic Sciences and Fisheries Abstracts and are distributed to appropriate workshop participants or project partners. A full list of the reports is published at end of this issue. All papers are available as free PDF downloads from the Fisheries Centre's Web site *www.fisheries.ubc.ca*, while paper copies of a report are available on request.

Daniel Pauly
Acting Director,
UBC Fisheries Centre,
August 2003

SUBSIDIES, BUYBACKS AND SUSTAINABLE FISHERIES

Colin W. Clark
Professor Emeritus, Department of Mathematics, University of British Columbia
Gordon R. Munro
Professor Emeritus, Department of Economics, and Fisheries Centre, University of British Columbia
Ussif Rashid Sumaila
Director, Fisheries Economics Research Unit, Fisheries Centre, University of British Columbia. Corresponding author. Fax: 604 822 8934, email: r.sumaila@fisheries.ubc.ca

ABSTRACT

There is general agreement that many, if not most, fisheries subsidies are detrimental to effective resource management. There is not, however, general agreement about subsidies used for decommissioning/buyback purposes. One school of thought argues that such subsidies can have a positive impact upon resource management, by removing excess fleet capacity from the fisheries. An opposing school of thought criticizes the use of these subsidies on the grounds that the subsidies are, by and in the large, ineffective. This paper argues that decommissioning/buyback subsidies can have a positive impact upon resource management, but only if they are wholly unanticipated by the fishing industry. If, on the other hand, the subsidies are anticipated by the industry, the subsidies can have a decidedly negative impact, intensifying both economic waste in the fisheries, and overexploitation of the fishery resources.

Key words: Fleet capacity; Malleable and non-malleable capital; Human capital; Buyback subsidies; Regulated open access

INTRODUCTION

Two of the more intensely discussed and debated issues, pertaining to the management of world capture fishery resources, consist of fisheries subsidies and fleet capacity. The issues come together in the question of subsidies used for the purpose of reducing fleet capacity, through buyback/decommissioning schemes.

With reference to the North Atlantic alone, Munro and Sumaila estimate that approximately one third of the estimated total fisheries subsidies of U.S. $2.5 billion per annum are accounted for by buyback/decommissioning subsidies or the equivalent thereof (Munro and Sumaila, 2002). Since the lion's share of these North Atlantic buyback/subsidies is accounted for by the EU, it is worth noting, in passing, that the EU Common Fisheries Policy proposed reform package calls for an additional **€**272 million to be put aside as subsidies for vessel decommissioning purposes (Megapesea, 2002).

There is general agreement, based upon many studies at both the national and international level, that world fisheries subsidies are immense. There is further agreement that many of these subsidies are seriously detrimental to effective resource management and conservation (see, for example: FAO, 2001; Milazzo, 1998; Munro and Sumaila, 2002; OECD, 2000; United States Congressional Research Services, 1995).

There is not, however, general agreement about the impact of fisheries subsidies for buyback purposes. The FAO, in the preamble to its International Plan of Action for the Management of Capacity, states the widely held, and accepted, view that "… excessive fishing capacity is a problem … that contributes substantially to overfishing … and significant economic waste" (FAO, 1999). With this view in mind, the argument has been put forward that subsidies used for buyback purposes, will, by removing capacity, ease the exploitation pressure on the resources (and hopefully mitigate economic waste), and should, therefore, be regarded as positive, i.e. beneficial to resource management.[1]

The chief counterargument to the claim that buyback subsidies are beneficial has been that such subsidies, more often than not, prove to be ineffective. Capacity, once removed from a fishery, tends to seep back in (see, for example, Holland, Gudmundsson and Gates, 1999). There is another round of economic waste as yet more investment in excess capacity occurs, and the threat to conservation reappears (Weninger and

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1 See, for example, the detailed World Bank study, Subsidies and World Fisheries: A Re-examination, by Matteo Milazzo (1998). While recognizing that many fisheries subsidies do indeed lead to economic waste, and foster resource overexploitation, Milazzo maintains that there is a significant class of fisheries subsidies, which have a positive impact upon resource management and conservation. He cites, as his prime example, subsidies used for decommissioning/buyback purposes (Milazzo, 1998, pp. 64-72).

In the spirit of the Milazzo position, the European Commission has submitted a proposal to the World Trade Organization, which calls for the elimination of subsidies used to increase fishing capacity, but which also calls for the retention of subsidies used for decommissioning/ buyback purposes (Megapesca, 2003).

McConnell, 2000). Cunningham and Gréboval, in a recent study prepared for the FAO, warn that, while buyback/decommissioning schemes appear, at first sight, to offer an ideal way to reduce capacity, fisheries authorities must, before introducing such schemes, ensure that the conditions necessary for the long term effectiveness of the schemes are met (Cunningham and Gréboval, 2001).

This counterargument implies that, if the post buyback seepage of capacity back into the fishery can be blocked, the buyback subsides could have a positive impact upon resource management, or at least would do no harm. It is the contention of this paper that, under by no means unreasonable circumstances, these subsidies can readily both intensify long-run economic inefficiency in the fishery, and serve to undermine the conservation of the resource, even if the post buyback seepage of capacity of capacity back into the fishery can be fully and effectively eliminated.

We commence with a review of the significance, or lack thereof, of fleet capacity to resource management.

THE SIGNIFICANCE OF FLEET CAPACITY TO RESOURCE MANAGEMENT – A REVIEW

While capacity in fisheries, and problems of excess capacity, are commonly thought of in terms of physical capital, fishing capacity does, of course, include human capital, as well, which can readily contribute to the excess capacity problem (Mace, 1997). We shall, nonetheless, restrict the discussion in the heart of this paper to physical capital, and indeed to one class of physical capital, namely fleet capital. Having said this, however, we shall close the paper by speculating on whether the analysis developed is applicable, in all or in part, to human capital in fisheries.

In passing, we should also comment on measures of capacity. We shall not, in this paper, discuss precise measures of capacity. Rather, we shall refer the reader to the several current detailed studies on the subject (see, for example: Kirkley, Paul and Squires, 2002).

In any event, Gréboval and Munro (1999), and Clark and Munro (2002) assert that the concepts of malleability, and non-malleability, of fleet capital are central to the problem of excess capacity and the perceived need for decommissioning/buyback programs. To provide support for this assertion, we turn to the article of Clark, Clarke and Munro (1979), which was the first to address the issues of non-malleability of fleet capital, and the consequences arising therefrom, head on.

The now familiar Clark et al. (1979) model equations, to which we shall turn at several points in the paper, are:

$$\frac{dx}{dt} = F(x) - qEx \tag{1}$$

$$0 \le E(t) \le K \tag{2}$$

$$\frac{dK}{dt} = I - \gamma K \tag{3}$$

$$\pi = (pqx - c)E - c_f(I) \tag{4}$$

where x denotes the biomass, F(x) the natural growth rate of biomass, E the fishing effort, q the catchability coefficient, K the stock of fleet capital, I the rate of investment in fleet capital, γ the rate of depreciation of such capital. The price of harvested fish is denoted by p, while c denotes unit operating costs, both of which are assumed to be constant.

Net revenue flow $\pi(t)$ consists of net operating revenue $(pqx - c)E(t)$ minus investment costs $c_f(I)$. It is assumed that:

$$c_f(I) = \begin{cases} c_1 I & \text{if } I > 0 \\ c_s I & \text{if } I < 0 \end{cases} \tag{5}$$

(and $c_f(0) = 0$). Here c_1 is the unit purchase cost of capital, i.e. the cost of one vessel, and c_s is the scrap, or resale value, of one vessel.

Optimal management of the resource is characterized by the maximization of the present value of $\pi(t)$ (which we can thus refer to as the Net Present Value of revenue flows from the fishery) over an infinite time horizon. The resource rent maximization problem involves two state variables, these being: x(t) and K(t).

In the Clark et al. analysis, fleet capital is deemed to be perfectly malleable if: $c_1 = c_s$. The implication is that perfectly malleable fleet capital can be costlessly removed from the fishery. Thus perfectly malleable fleet capital is analogous to perfectly liquid assets, in the world of finance. Conversely, fleet capital is deemed to be perfectly non-malleable if $c_s = 0$ and $\gamma = 0$, which is to say that vessels have no resale value and never depreciate. In intermediate cases ($\gamma > 0$, or $0 < c_s < c_1$) fleet capital is described as being quasi-malleable (Clark et al., 1979).

Clark et al. (1979) make the point, en passant, that what we might term the standard dynamic bioeconomic model, as exemplified by Clark and Munro (1975), assumes implicitly that fleet capital is perfectly malleable, i.e., $c_1 = c_s$. Let us consider the implications of fleet capacity for the management of a fishery, appropriately modeled by the standard model. We shall use the Clark and Munro (1975) model, as an example.

In this model, the resource rent maximization problem is, because fleet capital is assumed to be perfectly malleable, reduced to a single state variable (x(t)) optimal control problem. The equally familiar model equations are

$$dx/dt = F(x) - qEx \tag{6}$$

$$0 \le E(t) \le E_{max}$$

$$\pi = (pqx - c_{total})E \tag{7}$$

where p is the price of harvested fish, as before and

$$c_{total} = c + (\delta + \gamma)c_1$$

Thus c_{total} is the sum of c, which we had previously referred to as unit operating costs, and the unit rental cost of fleet capital, where δ is the appropriate rate of discount (see: Clark et al., 1979).

The optimal resource management objective can be expressed simply as:

$$\max PV(E) = \int_0^\infty e^{-\delta t}\pi(t)\,dt \tag{8}$$

where $\pi(t)$ is given by Eq. (7).

The optimal strategy $E = E^*(t)$ maximizes this value:

$$E^*(t) \text{ maximizes } PV(E) \text{ subject to } 0 \le E(t) \le E_{max} \tag{9}$$

The solution to this linear control problem, which can be deduced by elementary methods (see Clark, 1990), is:

$$E^*(t) = \begin{cases} E_{max} & \text{if } x(t) > x_\delta^* \\ F(x_\delta^*)/qx_\delta^* & \text{if } x(t) = x_\delta^* \\ 0 & \text{if } x(t) < x_\delta^* \end{cases} \tag{10}$$

Here x_δ^*, the equilibrium equation is determined by the well known equation:

$$F'(x_\delta^*) + \frac{C_{total}F(x_\delta^*)}{x_\delta^*(pqx_\delta^* - c_{total})} = \delta \tag{11}$$

Under conditions of pure open access, by way of contrast, we have

$$E_{OA}(t) = \begin{cases} E_{max} & \text{if } pqx(t) - c_{total} > 0 \\ 0 & \text{if } pqx(t) - c_{total} < 0 \end{cases} \tag{12}$$

where E_{OA} is the open access rate of fishing effort. The Bionomic Equilibrium level of x, x_{OA}, as defined by Gordon (1954), is given by

$$pqx_{OA} - c_{total} = 0 \tag{13}$$

We shall, throughout the discussion to follow, make use of the distinctions between pure open access and regulated open access (Homans and Wilen, 1997). We assume that, under pure open access, there is complete absence of regulation and that the resource is subject to overexploitation, for the usual reasons. Under regulated open access, the fisheries managers, or authorities, maintain iron control over the harvests and stabilize the resource, but do not exercise effective control over the fleet size.

We regard these two situations as being, in fact, two ends of an open access continuum. One also has no difficulty in finding examples in the developed, let alone developing, world of fisheries subject to extensive regulations, in which the management authorities prove to be markedly less than successful in stabilizing the resource. We might refer to these many intermediate cases as imperfectly regulated open access.[2] Nonetheless, we shall, for ease of

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2 A good example is provided by the groundfish fisheries of New England, following the American introduction of Extended Fisheries Jurisdiction (EFJ) in 1977. These fisheries, which were within the U.S. 200 mile zone, were certainly subject to regulation, following the U.S. declaration of EFJ.

A combined index for the eight primary New England groundfish resources shows some recovery in the late 1970s, as a consequence of the removal of foreign fleets from the newly established U.S. 200 mile zone. From thereon in, until the late 1980s-early 1990s, when the authorities took what they hoped was vigorous action (United States, 1989), the resources declined inexorably. By 1991, the abundance level was but 25 per cent of what it had been at the end of the 1970s (Overholtz, Edwards and Brodziak, 1993). Overholtz, Edwards and Brodziak remarked in 1993 that “depletion of groundfish resources in the region [New England] has followed the classic pattern for open access” (Overholtz et al., exposition, confine our attention largely to the two extreme situations, assuming that the reader will be continually aware of the many intermediate cases in the real world.

With all of this in mind, let us commence with the relatively easy case of regulated open access. Crowding externalities can presumably arise, even if fleet capital is highly malleable. Beyond that, however, as demonstrated by Munro and Scott (1985), if fleet capital is perfectly malleable on an intra, as well as inter, seasonal basis, there will be no emergence of redundant fleet capacity, and of the associated economic waste and dissipation of resource rent.

With regards to pure open access, if fleet capital is perfectly malleable, the resource overexploitation associated with Bionomic Equilibrium, x_{OA}, is due to excessive (from society's point of view) fishing effort. If the fishery should, after achieving Bionomic Equilibrium, become subject to rigorous resource management, the task of the resource manager becomes that of reducing E(t).

This should cause no difficulty because, after all, $c_1 = c_s$, which, it will be recalled, implies that vessels can be shifted out of the fishery without difficulty, and without cost. Vessel owners, being faced with reduced harvesting opportunities in the fishery, can simply move elsewhere.[3] Thus we can conclude that, if fleet capital is perfectly malleable, as is assumed in the standard dynamic bioeconomic model, then fleet capacity, per se, matters little, if at all, in the management of the resource. Decommissioning/buyback programs are largely beside the point.

If, on the other hand, fleet capital is non-malleable (and thus the standard model is inapplicable), then fleet capacity does, in fact, matter. In the case of regulated open access, we get the well known outcome of the emergence of truly redundant fleet capacity, and the consequent economic waste (Munro and Scott, 1985; Wilen, 1987).

With regard to pure open access, we must first concede that, with respect to overexploitation of the resource under pure open access, the differences between the perfectly malleable, and non-malleable, fleet capital cases are not striking. Robert McKelvey has, for example, demonstrated that, if the fleet capital is quasi-malleable, Bionomic Equilibrium, as given by Eq. (13), will be the long run equilibrium (McKelvey, 1987).

It is when the resource becomes subject to rigorous management, after a history of pure open access exploitation that differences emerge. Once again, E(t) must be reduced, but this is now no easy matter. Having few, if any, alternatives, vessel owners can be expected to resist with vigor reductions in fishing effort/harvesting that may confront many of them with the spectre of bankruptcy (see: National Research Council, 1999; Sissenwine and Rosenberg, 1995).

Furthermore, if the resource managers do succeed in establishing harvest regulation, the existence of excessive non-malleable fleet capital can stand as a threat, a barrier, to effective resource management. As has been observed by fisheries resource managers countless times, vessel owners will actively resist any further TAC reductions called for by adverse environmental shocks, or by past management errors (National Research Council ibid.; Sissenwine and Rosenberg, ibid.)[4]. It should come as no surprise that, in the real world, there are innumerable cases of what we have termed imperfectly regulated open access, in which the resource managers' ability to stabilize the resource is decidedly less than perfect.

Thus, when fleet capital is non-malleable, excess fleet capacity can indeed lead to economic waste, and can stand as a formidable barrier to effective resource management. The case for buybacks, as

1993, p. 508). Rosenberg, Fogarty, Sissenwine, Beddington and Shepherd (1993), among others, have noted that the New England experience is by no means unique.

3 A real world example is provided by the Norwegian Spring Spawning (Atlanto-Scandian) Herring fishery. Historically, the Norwegian Spring Spawning Herring stock was one of the largest fishery resources in the North Atlantic. Due to overexploitation, under pure open access conditions, the resource crashed in the late 1960s – early 1970s. The remnants of the resource were confined to Norwegian waters. The Norwegian government declared a harvest moratorium lasting for over twenty years, and did so without encountering serious resistance from the industry. The fleet could be readily diverted to other fisheries, such as North Sea herring, mackerel and capelin. Hence, with respect to he Norwegian Spring Spawning Herring fishery, the fleet capital was highly malleable (Gréboval and Munro, 1999).

4 An example is provided by the lucrative snow crab fishery in the Gulf of St. Lawrence, in early May of 2003. An announcement by the Canadian Department of Fisheries and Oceans on May 2nd that the TAC for the coming season would have to be set approximately 23 per cent below that of the previous season led to more than just protests by affected New Brunswick crab fishermen. It led, as well, to widespread rioting and arson (The Globe and Mail, May 5, 2003).

a means of dismantling the barrier, appears to be, not merely plausible, but compelling. To quote Matteo Milazzo, from the extensive and detailed study on world fisheries subsidies, which he undertook for the Work Bank:

> … many commentators have noted how difficult it is to induce the exit of capital from fishing because these assets … have little other practical use. For that reason … disinvestment in fisheries has to be actively promoted with economic incentives, i.e. subsidies (Milazzo, 1998, p. 65).

BUYBACKS AND SUBSIDIES – REGULATED OPEN ACCESS

It has now been conceded that, if fleet capital is non-malleable, there exists, at the very least, a prima facie case for the decommissioning/buyback programs, and their accompanying subsidies. We consider first the use of buyback subsidies in the relatively simple and straightforward case of regulated open access. The resource is stabilized at the target level and the resource managers exercise iron control over the harvests. We shall then follow with the more complex situation, in which a fishery that had been a pure open access one, is subject to a resource management program, calling for resource restoration.

To begin, we offer a general observation. When fleet capital is perfectly malleable, the investor in such capital can afford to be myopic. Errors of over or under investment can be readily and quickly corrected. When fleet capital is non-malleable, on the other hand, the investor cannot afford the luxury of myopia, and must perforce be forward looking.

Now consider the case of regulated open access.[5] We shall suppose that, if decommissioning/buyback programs are introduced, the resource managers respond to the Cunningham and Gréboval (2001) admonitions, and ensure that the conditions necessary for the long term effectiveness of the schemes are met. There is no seepage of capital back into the fishery, once the buyback scheme has been introduced.

We shall continue to assume that both unit variable cost and the price of vessel capital are constant, as is the price of harvested fish. Next we assume that fishing vessels (and crews) are identical in nature and ability, and that technology is frozen. Finally, we assume, for ease of exposition, that fleet capital is perfectly non-malleable, i.e. $c_s = \gamma = 0$.

It is assumed that, under regulated open access, the resource managers specify an annual Total Allowable Catch (TAC), or the equivalent thereof, which remains fixed for all future time. Let Q denote this fixed annual TAC in tonnes. Entry into the fishery is initially unrestricted; the variable K denotes actual entry of vessels into the fishery. The catch rate of fishing is q tonnes/day/vessel. Thus if K vessels fish for D days during the year, the fleet's total annual catch, or harvest, is equal to qKD tonnes.

Let D_{max} denote the maximum possible length of the annual fishing season (days). If the fleet size is such that $qKD_{max} \le Q$, then the fishing season will be at its maximum length. If

$qKD_{max} > Q$, then the season must be reduced below its maximum length in order to ensure that the TAC is not exceeded. Thus:

$$TAC = \begin{cases} qKD_{max} & \text{if } K \le Q/qD_{max} \\ Q & \text{otherwise} \end{cases} \qquad (14)$$

The fleet's annual operating profits (FAOP) are given by:

$$FAOP = \begin{cases} (pq - c)KD_{max} & \text{if } K \le Q/qD_{max} \\ (p - c/q)Q & \text{otherwise} \end{cases} \qquad (15)$$

Since vessel capital is, by assumption, perfectly non-malleable, a vessel, once purchased, lasts forever and has no resale value. Consequently, the rational would-be investor must compare the cost of the vessel with the share of the present value of fleet operating profits the acquisition of the vessel promises him/her. Since the vessels (and crews) are assumed to be identical, an owner of a single vessel can be assumed to enjoy an average share of the aforementioned present value, i.e., total present value of operating profits divided by the number of vessels, K.

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5 The discussion to follow draws heavily upon Clark and Munro (1999), and Munro and Sumaila (2002).

Resource rent will obviously be maximized, if the minimum number of vessels required to take the restricted harvest are employed. Let us denote this minimum as K_{opt}. From Eq. (14) we have:

$$K_{opt} = Q/qD_{max} \tag{16}$$

If the total annual harvest Q is taken, then the present value of fleet operating profits will be equal to: [(p-c/q)Q](1+r)/r, where r denotes the relevant annual rate of interest. The present value of fleet operating profits, on a per vessel basis, is simply $[(p-c/q)Q]\bullet\left(\frac{1+r}{r}\right)\frac{1}{K}$. If we denote $[(p-c/q)Q]\bullet\left(\frac{1+r}{r}\right)$ as Γ, we can observe that the maximum present value of operating profits, per vessel, is simply

$$\omega = \Gamma/K_{opt} \tag{17}$$

From this it follows that no investment in fleet capacity will take place unless $c_1 \leq \omega$. If it is in fact the case that $c_1 \leq \omega$, then investment in fleet capacity will continue up to the point that

$$c_1K_{ROA} = \Gamma \tag{18}$$

where K_{ROA} denotes the regulated open access equilibrium level of fleet capital.

If $c_1 = \omega$, i.e. we have a breakeven fishery, then $K_{ROA} = K_{opt}$. If, on the other hand, $c_1 < \omega$, we shall be assured that $K_{ROA} > K_{opt}$. Excess capacity, when $c_1 < \omega$, is simply: $K_{ROA} - K_{opt}$, and the economic loss imposed upon society by this excess capacity can be expressed equally simply as:

$$c_1(K_{ROA} - K_{opt}) = \Gamma - c_1K_{opt} \tag{19}$$

We can refer to the L.H.S. of Eq. (19) as the Redundancy Deadweight Loss of regulated open access. Let it be noted that the Redundancy Deadweight Loss is incurred the instant that the excess capital is acquired. Once incurred, the Loss cannot be reversed by a buyback scheme, or anything else.

Now let us consider the effect of a buyback/decommission scheme, introduced after the regulated open access equilibrium is achieved. Existing vessel owners are licensed, and entry is strictly limited. The resource managers then persuade vessel owners to sell their vessels (and licenses) to the managers, and go on doing so, until the fleet is reduced to the optimal level K_{opt}. The accompanying limited entry program is carefully and effectively designed to prevent the fleet from once again exceeding its optimal size.

The impact of the combined buyback/limited entry program will depend critically, we shall argue, upon whether the program is, or is not, anticipated by the vessel owners. If this assertion seems to carry with it some of the flavour of the Rational Expectations School of macro-economic theory (see, for example, Turnovsky, 2000), it does so for a very good reason.

Let us illustrate with the aid of a simple numerical example (Clark and Munro, 1999). Let it be supposed that D_{max} = 200 days. We assume, in addition that:

Q = 10,000 tonnes

q = 1 tonne per vessel per day

p = $1,000 per tonne

c = $500 per vessel per day

c_1 = $500,000 per vessel

r = 0.10 – i.e., 10% per annum

The present value of total annual fleet operating profits will be:

$$\Gamma = (p - c/q)Q\frac{(1+r)}{r} \tag{20}$$
$$= \$55 \text{ million}$$

Also
$$K_{opt} = \frac{Q}{qD_{max}} = \frac{10{,}000}{200} = 50 \text{ vessels} \tag{21}$$

which implies that ω = $1.1 million. Since c_1 = $0.5 million, maximum resource rent is

$(1.1-0.5) million × 50 = $30 million

Now let it be supposed that, if excess capacity emerges, the fisheries authorities will, by t = 10, introduce a buyback program with the objective of reducing K to 50 vessels. Let us commence by also assuming that at t = 0 the fisheries authorities' future plans are wholly unanticipated by vessel owners. They assume, incorrectly, that regulated open access will continue forever. We can thus anticipate that at t = 0, investment in capital capacity will be given by:

$$K_{ROA} = (p - c/q)\frac{Q(1+r)}{c_1 r} = 110 \text{ vessels} \quad (22)$$

Thus there is excess capacity of 60 vessels, representing a Redundancy Deadweight Loss of \$30 million, and resource rent (in present value terms) of \$0 million. At t = 10, the resource managers introduce a "sudden death" buyback program to the complete surprise of the vessel owners. The vessel owners are, however, convinced (correctly) that the authorities will do whatever is necessary to reduce the fleet to 50 vessels and are further convinced (also correctly) that the accompanying limited entry program will be effective forever.

The present value of the operating profits of each of the remaining 50 vessels, discounted back to t = 10 will be \$1.1 million, i.e. ω. Thus, we can be assured that the resource managers cannot offer less than \$1.1 million per vessel. We shall assume, somewhat unrealistically, that the authorities are able to achieve their goal by offering a purchase price of

\$1.1 million and the accompanying limited entry program is indeed fully effective. The fleet remains at $K = K_{opt}$ from henceforth.

Let us suppose that the buyback scheme is financed by the government drawing upon its general revenues. If one can assume that the resultant increase in taxes and/or increased government borrowing and/or reduced government expenditures on other activities causes no perceptible loss to the economy, we can say that each vessel owner will enjoy a windfall gain of \$600,000, and that the Redundancy Deadweight Loss to the economy remains at \$30 million. The initial loss to the economy cannot be undone by the buyback program, but at least no further damage is done.

Now let us change the example by supposing that, at t = 0, the vessel owners have perfect foresight. They are certain that the resource managers will react to the emergence of any excess capacity by introducing a "sudden death" buyback program at t = 10, and that the managers will offer a price of \$1.1 million per vessel. The vessel owners also know that the fleet will be stabilized at 50 vessels and that the accompanying limited entry program will be entirely successful.

We shall also assume that vessel owners are aware that at t = 10, the resource managers will declare that only vessels operating in the fishery since t = 0, or before, will be deemed to be bona fide participants in the fishery. Any vessels entering the fishery after that time will be denied licences and forced out of the fishery without compensation. The reason for this seemingly artificial assumption will become apparent in due course.

We can now calculate the level of investment in vessels at t = 0, which we shall denote by K'_{ROA}. Equilibrium will then be achieved when:

$$c_1 K'_{ROA} = \sum_{i=0}^{10} (p - c/q) \bullet \frac{Q}{(1+r)^i} + \frac{c_2}{(1+r)^{10}} \bullet K'_{ROA} \quad (23)$$

where c_2 denotes the resource managers' offer price at t = 10. Observe that it is a matter of indifference whether an individual vessel owner sells his/her vessel at t = 10, or whether his/her vessel continues on as one of the remaining 50. Also observe that Eq. (23) can be rewritten as:

$$c_3 = \left[\sum_{i=0}^{10} (p - c/q) \frac{Q}{(1+r)^i} \right] \Big/ K'_{ROA} \quad (23a)$$

where

$$c_3 = c_1 - c_2/(1+r)^{10} \quad (24)$$

where $c_2 = \omega$ is the buyback price. In our example, we have:

$$K'_{ROA} = \frac{\$35,722,836}{\$75,093} = 476 \text{ vessels} \quad (25)$$

The implication is that the eminently "successful" buyback program will lead to a Redundancy Deadweight Loss of \$500,000 (476 – 50) = \$213 million. Recall that, if the authorities had done nothing, i.e., had forgone a buyback program, net resource rent from the fishery (in present value terms) would have been \$0 million (as the standard theory would predict). In our example of the anticipated buyback program, the resource rents (net economic benefits) from the fishery are:

\$55 million - \$213 million = - \$158 million

In terms of the goal of increased economic efficiency, the buyback/decommissioning scheme, when fully anticipated, is an unmitigated disaster.

The reason that the anticipated buyback program induces a large investment in fleet capacity is made transparent by Eq. (24). The effective supply price of fleet capital is no longer c_1, but is rather $c_3 = c_1 - c_2/(1+r)^{10}$. Thus, would be vessel owners are effectively being subsidized in their purchase of vessels. Indeed, as the reader can verify in our example, exactly the same outcome could have been produced under a "do nothing" policy (i.e., $K_{ROA} = 476$) by having the government offer the vessel owners at t = 0 a subsidy per vessel equal to 77 per cent of the purchase price c_1.[6]

Now note the following. Our choice of t = 10, as the initiation time of the buyback program, is entirely arbitrary. If the buyback program is anticipated α years in the future, we now have:

$$c_3 = c_1 - c_2/(1+r)^{\alpha} \qquad (26)$$

Recall that $c_2 = \omega$, and recall further that, in order for any investment in fleet capacity to take place, we must find that $c_1 \leq \omega$

In our numerical example where $c_1 < \omega$, c_3 is negative for $\alpha \leq 8$ yr. In this case the prediction is that $K'_{ROA} = +\infty$; there is no limit to the Redundancy Deadweight Loss.

We have $c_2 = \omega$ because of a perfectly enforced limited entry/buyback program from t = 10, onwards. If, on the other hand, it is anticipated that the program will be less than perfect, the we would have $c_2 < \omega$. We conclude that the more successful is the buyback, limited-entry scheme, the greater is the potential for vast economic waste, in the event that the program can be anticipated in advance.[7]

If it is indeed the case that $c_1 < \omega$, and α is small enough, investors in fleet capital can achieve a positive return on their investment, even if they never actually catch any fish. This is perhaps the most perverse aspect of buyback subsidies. If anticipated, such subsidies may encourage a large scale increase in fleet capacity, unrelated to any prospect of actually participating in the fishery.

The reason for our seemingly artificial assumption should now become clear. If there was no such restriction, vessel owners, with perfect foresight, would wait until the last possible moment before t = 10 to invest in capacity. Then we would indeed have $K'_{ROA} = +\infty$.

The above examples are, of course, extreme in that we have assumed perfect non-malleability of vessel capital and have allowed for the possibility of perfect foresight. Yet the point remains. Even in a world of uncertainty and a world in which vessel capital is quasi-malleable, rather than perfectly non-malleable, buyback programs, if anticipated, can be expected to have a major impact upon vessel owner investment decisions.[8]

In the examples discussed, the issue of the relationship between buyback/ decommissioning schemes and resource conservation has not arisen, because of the assumption that fisheries authorities exercise iron control over harvests. To address the conservation consequences of buybacks, we relax this assumption entirely by turning to the pure open access case.

BUYBACKS AND SUBSIDIES, FOLLOWING A HISTORY OF PURE OPEN ACCESS

We now consider the following situation. A fishery resource, which hitherto had been unexploited, is now subject to harvesting. The new fishery may emerge because of the discovery of the resource, or because market conditions, which hitherto had rendered the resource uneconomic to exploit, shift. In any event, the new fishery is initially subject to no, or to totally ineffective, harvest regulations. After the pure

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[6] Thus, if the possibility exists that buybacks will be anticipated, it is inconsistent to call, as did the European Commission, for the elimination of subsidies designed to increase fleet capacity, while at the same time calling for the retention of buyback subsidies (see n. 1).

[7] If the buyback program is not successful, in that there is seepage of capacity back into the fishery, there will, of course, be further economic waste. Consider an extreme case, in which capacity, once removed, is promptly replaced by new investment. Allow this exercise in futility to be repeated over and over, and let the buybacks be anticipated. We first note that c_2 will be very low indeed, because operating profits per vessel will be kept to a minimum by the ever-restored capacity. Secondly, we note that the PV of fleet investment costs, while high, can never approach infinity, given that the discount rate is positive.

[8] It is appropriate to ask, at this point, whether there is any empirical evidence in support of the claim that buyback/decommissioning subsidies will stimulate the expansion of fleet capacity. The answer is that there is. A recent empirical study by two Danish economists, Jörgensen and Jensen (1999), on the impact of EU decommissioning subsidies, concludes that such subsidies do indeed act as a stimulus to investment in fleet capacity. These subsidies, not only influence EU investors in fleet capacity directly, but also influence the investors' bankers. The evidence shows that these subsidies lead to the bankers offering more generous credit terms to would be investors in fleet capacity, than would otherwise be the case. The authors of the study point out that their results confirm those arising from an earlier Danish-Dutch study (Frost et al., 1996).

open access fishery has achieved equilibrium, the fisheries authorities intervene and implement a vigorous and stringent management regime, with the objective of rebuilding the resource to an optimal level, and ensuring that the fishery will be free of excess fleet capacity. It is assumed, initially, that the vessel owners are taken by complete surprise by the implementation of the management regime.

We now employ the (Clark, et al., 1979) full two-state-variable model, which is repeated below:

$$\frac{dx}{dt} = F(x) - qEx \tag{1}$$

$$0 \le E(t) \le K \tag{2}$$

$$\frac{dK}{dt} = I - \gamma K \tag{3}$$

We will continue to suppose that vessel capital is perfectly non-malleable, $c_s = \gamma = 0$, i.e., the resale value of vessels is zero, as is the depreciation rate. Because of this assumption, we can assume that $I(t) \ge 0$:

$$0 \le I(t) \le +\infty \tag{27}$$

The case $I(t) = +\infty$ allows for an instantaneous jump in K.

We now express the flow of net operating profits, at each point in time, as:

$$\pi(t) = (pqx(t) - c)\,E(t) \tag{28}$$

where, as before, c, a constant, denotes unit operating costs, and p, a constant, the price of harvested fish. Alternatively, we can express Eq. (28) as:

$$\pi(t) = (p - c_{var}(x))\,qx(t)\,E(t) \tag{28a}$$

where $c_{var}(x)$ denotes unit variable cost of harvesting:

$$c_{var}(x) = \frac{c}{qx} \tag{29}$$

If $\pi(t) > 0$, we can assume that the existing fleet will be used to capacity, i.e. $E(t) = K(t)$. There will, however, be a biomass level at which $\pi(t) = 0$, which we shall denote as $x(t) = x_a^0$.

The biomass x_a^0 is given by

$$p - c_{var}(x_a^0) = 0 \tag{30}$$

(specifically, $x_a^0 = c/pq$; see Eq. (28)). We can be certain that the resource would not fall below that level, since at biomass levels below x_a^0, fleet operating profits would be negative. Hence we have:

$$E(t) = \begin{cases} K(t) & \text{if } x(t) > x_a^0 \\ 0 & \text{if } x(t) < x_a^0 \end{cases} \tag{31}$$

There exists another biomass level, which we shall denote as x_b^0. This is the biomass corresponding to Bionomic Equilibrium, which would be the pure open access equilibrium, if vessel capital were perfectly malleable, i.e. if $c_s = c_1$ (see Eq. (13)). It is given by:

$$p - c_{total}(X_b^o) = 0 \tag{32}$$

where $c_{total}(x)$ is the unit total cost of harvesting. If we continue to suppose that $\gamma = 0$, we have

$$c_{total}(x) = \frac{c_{total}}{qx} \tag{33}$$

where c_{total} is now: $c + \delta c_1$. It can be shown (and should come as no surprise) that vessel owners will have an incentive to invest in vessel capital so long as $x > x_b^0$, but will have no incentive to do so once $x < x_b^0$ (McKelvey, 1985).

With all of this in mind, we can state the following. At time t = 0, i.e. at the time that the new fishery commences, investment in vessel capital will occur, and will occur (by assumption) instantaneously. How the level of investment is determined is a matter to be discussed momentarily.

Given our assumption that $c_s = \gamma = 0$, the only costs relevant to the vessel owners, once the vessels have been acquired, are operating costs. Exploitation of the resource by the fleet will cause the biomass to decline. The biomass may be reduced to $x(t) = x_a^0$, but there is no assurance that this will, in fact, occur. Investment in fleet capacity may not be sufficient to reduce the biomass to x_a^0.

Consider now Figure 1, which has been adapted from Clark et al. (1979) and McKelvey (1985;

1987). We denote the initial biomass x(0) as x_0, and assume (otherwise the fishery is not economically viable) that $x_0 > x_b^0$.

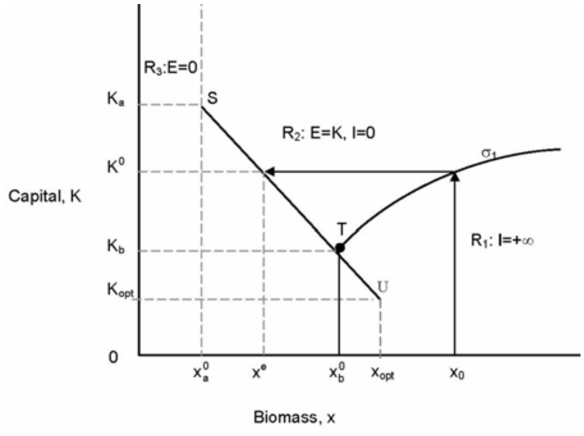

Figure 1 Buybacks: Unanticipated

Figure 1, an x – K state space diagram, can be viewed as a type of feedback prediction of both the level of investment in fleet capital, and the amount of fishing effort under pure open access. The curve σ_1 is a switching curve to be explained. There are three sub-regions: R_1 below the switching curve σ_1 and greater than x_b^0; R_2 above σ_1 and at biomass levels equal to x_a^0 and greater; R_3 at a biomass level less than x_a^0. The line S – U denotes the minimum amounts of fleet capital, K, required to harvest on a sustainable basis at all biomass levels between x_a^0 and a biomass level, which we have denoted as x_{opt} (but have not yet explained).

Once investment is made in fleet capital, K^0, at t = 0, E is set equal to K^0, so long as $x > x_a^0$. If x should be pushed below x_a^0, E will be set equal to 0, until x has increased to x_a^0. Hence, once the investment in fleet capital has been made at t = 0, x(t) will decline, but will never fall below x_a^0, except momentarily. There is no assurance, however, that x(t) will fall to x_a^0. Let K_a be the stock of fleet capital required to harvest x_a^0 on a sustainable basis, viz., $K_a = F(x_a^0)/qx_a^0$. Given x_0, p, c and c_1, we could well find that $K^0 < K_a$, and that an open access equilibrium biomass level will be achieved, lying between x_a^0 and x_b^0. This is the situation depicted in the figure.[9]

The switching curve, σ_1, determines the level of investment in K at t = 0, given that future buyback schemes (if any) are wholly unanticipated. The switching curve σ_1 (where I(t) is switched on and off) is determined as follows:

Once the vessels K^0 have been purchased, the operating profits from the vessels alone become relevant. The total present value of these operating profits is given by

$$PV(x_0, K^0) = \int_0^\infty e^{-\delta t}\{pqx(t) - c\}E(t)dt \qquad (34)$$

where x(t) and E(t) are as specified above, for all t > 0.

We continue to assume that vessels and crews are identical. Employing the same form of argument used in the previous section, we can argue that at t = 0, investment in capacity will proceed up to the point that

$$c_1 K^0 = PV(x_0, K^0) \qquad (35)$$

$$or \quad c_1 = PV(x_0, K^0)/K^0 \qquad (35a)$$

Thus, the switching curve σ_1 is determined by Eq. (35) (or Eq. (35a)).

In the example shown in Figure 1, $K^0 < K_a$. Hence, open access equilibrium is achieved at a biomass level, which we shall denote as x^e, which lies above x_a^0, $x_a^0 < x^e < x_b^0$.

We now suppose that, some time after x^e is achieved, the fisheries authorities intervene, with a vigorous management program, which, once again, takes the vessel owners by surprise. The authorities deem the present situation to be undesirable, and set a new target stock level $x_{opt} > x_b^0 > x^e$, and a corresponding optimal fleet capital stock K_{opt}, that would allow harvesting at x_{opt} to be undertaken on a sustainable basis, with no idle capacity. Harvesting has to be reduced,

[9] Region R^2 in Figure 1 (with E = K, I = 0) includes the entire area between x_a^0 and x_b^0, both above and below the equilibrium line SU. Points (x,K) in this region below SU would never be reached under the scenario considered here, but the feedback control rule E = K, I = 0 still applies to such points.

as does the amount of fleet capital devoted to harvesting. Vessel owners, having no alternative fisheries, and just breaking even, put up intense, and politically effective, resistance. The fisheries authorities respond by introducing a subsidized buyback program to remove $K^o - K_{opt}$ from the fleet, an action wholly unanticipated by the vessel owners. Subsequently, with $E = K_{opt}$, the resource rebuilds gradually to x_{opt}. Finally, the fisheries authorities respond to the Cunningham and Gréboval (2001) admonitions with great seriousness. There is no seepage of fleet capital back into the fishery. The stock of fleet capital remains at $K = K_{opt}$ forever.

The buyback subsidies are indeed conservationist in nature. The subsidies have had the effect of removing a critical barrier to resource stock recovery.

Now let us change the scenario and suppose that at t = 0 the vessel owners, based on their experience with other fisheries, anticipate fully the future intervention of the authorities, and the accompanying buyback program. We shall also assume that the vessel owners anticipate that the resource managers will, at the time of the inception of the program, declare that only those vessel owners who entered the fishery at t = 0, or earlier, will be bona fide participants in the fishery.

Finally, we shall, for simplicity, assume that the buyback program is introduced at $t = \theta > 0$, which is far enough in the future to ensure that the buyback occurs after the open access equilibrium has been achieved. We now wish to calculate the effect that such anticipation will have on the initial fleet capacity K^o.

Consider now the present value of the post buyback fleet operating profits, discounted back to $t = \theta$. This can be expressed as follows:

$$PV(x_1^e, K_{opt}) = \int_\theta^\infty e^{-\delta(t-\theta)}(pqx(t) - c)E(t)dt \qquad (36)$$

where $E(t) = K_{opt}$, and where x_1^e is to be explained. Using exactly the same arguments employed in the previous section, we can maintain that the buyback price of fleet capital at t = 0, c_2, will be given by:

$$c_2 = \left[\int_\theta^\infty e^{-\delta(t-\theta)}(pqx(t) - c)\,E(t)\,dt\right] \Big/ K_{opt} \qquad (37)$$

The buyback price, discounted back to t = 0 is $e^{-\delta\theta}c_2$.

Let us now denote investment in K at t = 0 as K_1^0. K_1^0 will be determined by:

$$c_1 K_1^0 = \int_0^\theta e^{-\delta t}(pqx(t) - c)E(t)dt + e^{-\delta\theta}c_2 K_1^0 \qquad (38)$$

where $E = K_1^0$ for $0 \le t \le \theta$.[10]

Equation (38) can be rewritten as

$$c_3 = \frac{\int_0^\theta e^{-\delta t}(pqx(t) - c)E(t)dt}{K_1^0} \qquad (39)$$

where

$$c_3 = c_1 - e^{-\delta\theta}c_2 \qquad (40)$$

Once again, when fully anticipated, buybacks constitute a subsidy to vessel owners at t = 0.

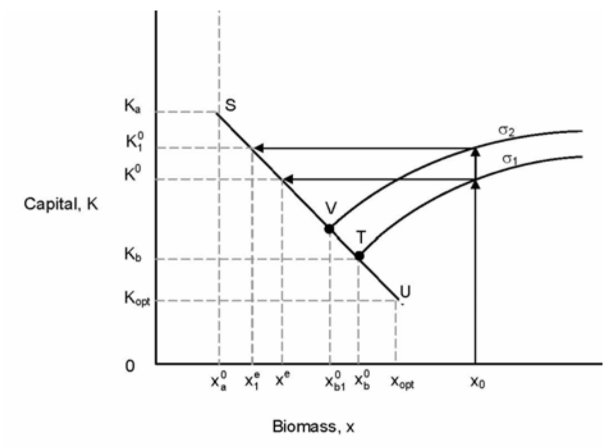

Figure 2 Buybacks : Anticipated

First, we consider the case in which $c_3 > 0$. Then the consequences of the subsidy are as illustrated in Figure 2. First note that the perceived Bionomic Equilibrium biomass, which we shall denote as x_{b1}^0, is now given by:

10 It may appear that with $E(t) = K_1^0$, the symbol K_1^0 cancels out and disappears from Eq. (38). This is not the case, however, because x(t) itself depends on K_1^0. In fact x(t) is a decreasing function of K_1^0, and this implies that Eq. (38) has a unique solution for K_1^0.

$$p - \frac{c + \delta c_3}{q x_{b1}^0} = 0 \qquad (41)$$

Because $c_3 < c_1$, we have $x_{b1}^0 < x_b^0$. Vessel owners will have an incentive to invest in fleet capacity if $x > x_{b1}^0$, but no incentive to do so if $x < x_{b1}^0$.

There is now a new switching curve, σ_2 and a new open access equilibrium x_1^e. We can refer to $K_1^0 - K^0$ as the anticipated buyback-induced extra investment in fleet capacity, and $x^e - x_1^e$ as the anticipated buyback-induced overexploitation of the resource. Thus, in our example, the buyback, if anticipated, has served to intensify economic waste through increased investment in fleet capacity, and has served to intensify the negative conservation consequences of open access.[11]

The question now is how much the intensification of economic waste and resource overexploitation does, in fact, really matter. It seems reasonable that a buyback, paving the way for the restoration of the resource, will still have a net positive impact, from the point of view of society, in spite of the consequences of the buyback being anticipated.

The answer is that the aforementioned intensification does indeed matter. If the buyback is fully anticipated, the outcome of an active resource management/buyback program will, in economic terms, be worse than, if resource managers had refrained from intervention, and had simply let the pure open access fishery run its course.

Return to Eq. (4), and the following discussion, in which the Net Present Value (Net PV) of revenue flows from the fishery, from t = 0 to t = ∞, was defined as the PV of operating profits, minus the PV of fleet investment costs, over that period . From Eq. (35), it can be seen that, given our assumptions, the Net PV of the revenue flows from a pure open access fishery, in the absence of intervention by the resource managers, will be zero, just as the received theory would predict. If the resource managers intervene in a hitherto pure open access fishery, with a resource management/buyback program, which is fully anticipated by the industry, the Net PV will not be equal to zero. Rather the Net PV will be negative.

Denote the PV of operating profits from the interventionist fishery as PV′. From Equations (36), (37) and (38), it can be seen that we can express PV′ as follows:

$$PV' = \int_0^{\theta} e^{-\delta t}(pqx(t) - c)E(t)dt + e^{-\delta\theta} c_2 K_{opt} \qquad (42)$$

where $E = K_1^0$ for $0 \le t \le \theta$.

Investment in K_1^0, at t = 0, is given by Eq. (38). A comparison of Equations (38) and (42), makes it transparently obvious that $c_1 K_1^o >$ PV′ (unless, of course, $K_1^0 = K_{opt}$, which can never occur, so long as the Bioeonomic Equilibrium level of x lies below x_{opt}). Hence, the Net PV of economic benefits derived from the fishery is negative. A policy of non-intervention in the fishery, bad as it is, is superior to the interventionist policy, if the buyback component of the interventionist policy is anticipated.

In the somewhat unlikely event that $c_3 < 0$, we see, as before, that the incentive for expanded capacity becomes unlimited. A new vessel obtained at cost c_1 later earns a discounted buyback payment $e^{-\delta\theta}c_2 > c_1$, with the consequence that there is no lower bound on the Net PV derived from the fishery.

We should note in passing, that, in contrast to the regulated open access case, we have no assurance that c_2 will equal the maximum present value of operating profits per vessel. Hence it is possible for $c_1 > c_2$. The reason is that, in the present model we have $x^e < x_{opt}$, so that a lengthy recovery phase, with low operating revenues, may occur. No such stock depletion effects occurred in the previous model.

To repeat our earlier comments, the assumptions of perfect foresight and perfectly non-malleable capital[12] are, of course, extreme. The point

11 One cannot be assured that the buyback program, when anticipated, will always lead to an intensification of resource overexploitation. Return to the case of buybacks unanticipated and suppose Ko was such that x was reduced to x_a^0. If buybacks become anticipated and the perceived cost of fleet capital is thereby reduced, the resource would not be reduced below x_a^0 (except possibly momentarily). What one can say is that buyback schemes, which are anticipated, create the distinct possibility that resource overexploitation will be intensified.

12 If the fleet capital is quasi-malleable, rather than perfectly malleable (e.g. suppose that $c_s = 0$, but that $\gamma > 0$), the results will be much the same, albeit more complex. This case can be safely left to the reader.

remains, nonetheless. Buybacks, if anticipated, if expected, can aggravate problems of both conservation and economic waste. In this sense, anticipated buybacks become a form of subsidy, with perverse implications similar to those pertaining to more direct subsidies.

Moreover, we should note, as well, that the assumption of perfect knowledge about the state of the resource is also extreme. The impact of buybacks, even if imperfectly anticipated, could easily lead to the resource being driven to levels, which after the fact, were seen to be dangerously low.

HUMAN CAPITAL IN FISHERIES AND SUBSIDIES: SOME CONJECTURES

We turn now to the promised speculation on the applicability of our analysis to capacity in fisheries in the form of human capital. It has been assumed, implicitly, up to this point, that human capital, unlike fleet capital, is perfectly malleable, with respect to the fishery. Human capital can flow easily into the fishery, and can exit with equal ease. We know, of course, that there are numerous cases in which human capital in fisheries is far from being perfectly malleable. The question of non-malleable human capital in fisheries, and our speculation, are of particular importance to developing country inshore fisheries, where capacity in the form of human capital is likely to be much more important than capital in the form of fleets, and where barriers to labour mobility are commonplace. The equivalent to buybacks with respect to human capital in the fishery, one can add, might take the form of retraining schemes, or simply payments not to fish, i.e. pensions.

There is one case, involving non-malleable human capital, in which the analysis in the preceding sections clearly does not apply. This case is what we shall term a "closed" fishery, in which the human capital in the fishery is non-malleable, due to barriers to labour mobility, but in which there is no flow of human capital into the fishery. An example is provided by the Maldives, where there is no perceptible movement of labour into the fishery, and where the human capital in the fishery appears to be immobile (Gosh and Siddique, 1998). In such a case, retraining schemes would make eminently good sense, if human capital in the fishery is deemed to be "excessive", since there is no risk that anticipation of the schemes would draw additional human capital into the fishery.

A case, in which the preceding analysis might apply, on the other hand, is one in which the flows of human capital to and from the fishery are asymmetric. The human capital can flow easily into the fishery, but once there it becomes trapped. This case is by no means uncommon in the developing world. A recent study commissioned by the FAO (Tietze, Groenewold and Marcoux, 2000: www.fao.org/sd/2001/PE0101a_en.htm) shows that there is still inter-generational occupational shift into fishing from other sectors of the rural economy in Tanzania, the Philippines, Bangladesh and India. Hence, in these countries (and most likely in many other developing countries) the flow of labor into fisheries is still a reality. In many, if not most, of these countries, once fishers enter a fishery, it is difficult for them to get out mainly due to the lack of access to alternative income sources (Tietze et al. 2000).

Retraining schemes become relevant in the case described, if there exists a non-rural sector in the economy, say a manufacturing and services sector, into which human capital can flow, given that it has been enhanced through training. In such a situation, the expectation of retraining in the fisheries sector, unaccompanied by retraining in the other sectors of the rural economy, could draw human capital into the fishery, in exactly the same way that anticipated buyback schemes will draw in fleet capital.

The solution in this case, however, is obvious and does not involve the abandonment of retraining schemes. Rather, it requires that there be simultaneous retraining schemes in the other sectors of the rural economy, as well.

In any event, it is our intention in this section to do no more than to offer some conjectures. The real research into the question of human capital in fisheries and the impact of the equivalent of buyback subsidies remains to be undertaken.

CONCLUSIONS

If buyback/decommission schemes can overcome the "seepage" problem, they can have a beneficial impact upon conservation – provided the schemes are unanticipated by the vessel owners. If the schemes are anticipated, however, then, even though the "seepage" problem has been eliminated, the subsidies can have a strong negative impact, both in terms of conservation of the resource, and in terms of economic efficiency. The conclusion is not particularly radical, and is really no more than an application of Rational Expectations to fisheries management, and recognition of the fact that it is folly to assume that vessel owners are myopic in their investment decision making.

We have no easy solutions to offer to the problems of capacity and conservation, other than to say that there appears to be no way out other than to adopt what the FAO refers to as an Incentive Adjusting (as opposed to an Incentive Blocking) approach to management (FAO, 1998). This would involve using taxes, and or, some form of rights based system, such as ITQs, cooperatives, or community based management[13]. How these are crafted together will certainly depend on the type of fishery being managed.

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INTERGENERATIONAL DISCOUNTING

Ussif R. Sumaila
and
Carl Walters
Fisheries Centre, University of British Columbia, Vancouver, Canada

ABSTRACT

This paper proposes a new intergenerational discounting approach for computing net benefits from the use of environmental resources. The approach explicitly incorporates the perspectives of both the current and future generations, as argued for by Pigou (1920) and Ramsey (1928), and required by most national and international laws related to the use of these resources. An equation for use in the calculation of net discounted benefits is developed, which provides a 'middle' position whereby both the 'reality' of 'personal' discounting and that of 'social' discounting are included in a social welfare function.

Keywords: current and future generations, discount factor, environmental resources

INTRODUCTION

This contribution is another attempt at grappling with the vexing problem of discounting flows of net benefits from natural and environmental resources. It is an attempt at answering the question: how should we discount flows of benefits in order to more adequately take into account the interests of future generations with respect to their needs from natural and environmental resources.

In comparing the present values of policy alternatives, it is standard to discount net benefits that will accrue in the future compared to net benefits that can be achieved today (Koopmans, 1960, Heal, 1997). Since cost benefit analysis (CBA) discounts streams of net benefits from a given project or policy alternative into a single number, namely, the net present value (NPV), discount rate assumptions used in these time stream comparisons can have a big impact on the apparent best policy or project (Nijkamp and Rouwendal, 1988, Burton, 1993, Fearnside, 2002). In particular, high discount rates favor myopic policies or projects that continue to exaggerate unsustainable resource use such as global overfishing (see for example, Pauly et al., 2002, Koopmans, 1974 and Clark, 1973).

Discounting as described above has attracted considerable attention from economists since Böhm-Bawerk (1889) and Fisher (1930) invented intertemporal preferences. There are many arguments for and against standard discounting in the literature (see for example, Baumol, 1952, Sen, 1961, Marglin, 1963, Arrow, 1979, Becker, 1980, Nijkamp and Rouwendal, 1988, Burton, 1993, Goulder and Stavins, 2002, Fearnside, 2002). A simple defense of discounting is that people have a positive time preference, which, it is argued, needs to be respected by the social planner (Bauer, 1957 and Eckstein, 1957). Goulder and Stavins (2002) provide a concise and typical defense of standard discounting. They argue that standard discounting is meant to ensure that the present value of net benefit calculations provide a meaningful indication of whether the efficiency criterion is satisfied or not. The authors suggest that adjustments of the discount rate to accommodate other legitimate policy questions such as intergenerational equity are problematic, as they blur the distinction between the efficiency criteria, and other legitimate policy-evaluation criteria. They therefore argue that in evaluating policies, it seems better to use the market interest rate while judging intergenerational fairness by direct examination. In other words, this should be done outside the cost benefit framework.

Many authors disagree with the arguments of Goulder and Stavins (see Schelling, 1995, Rabl, 1996, Lind 1995). For instance, Padilla (2002) state that intergenerational problems arise in standard discounting partly because of intergenerational externalities. This externality arises because future generations do not participate in decisions that will affect them. They cannot defend their interests in current decision making even though present decisions can have irreversible impacts on their welfare. In a situation where one party is absent, the 'Coasian' and 'Pigouvian' solution cannot help (Padilla, 2002). Schelling (1995) makes the point that a utility discount rate measures emphatic distance, and since future generations cannot be emphatically distinguished, discounting is inappropriate for intergenerational issues. Lind (1995) makes the interesting point that standard discounting makes the implicit assumption that designated capital transfers between generations are possible. An assumption Lind finds to be somewhat incorrect. Daly and Cobb (1989) declare that the idea of discounting losses of 'natural capital' is to be rejected in principle. They claim that irreversible losses such as these cannot be adequately adjusted for by lowering the discount rate. Rabl (1996), and also Schelling (1995), argue that discounting within a given generation is appropriate but not so between generations.

According to Chichilnisky (1996), sustainability means that the preferences of the current generation do not dominate the preferences of future generations in determining the intergenerational distributions of resources. She used this axiom to develop an intertemporal welfare, which is expressed as the weighted sum of standard net present welfare and the limiting properties of the system under consideration. The need for the interest of future generations to be included in our social welfare function (intergenerational equity), as required in many management jurisdictions via sustainability mandates, is more powerfully expressed in the case of natural and environmental resources, in particular, climatic change (see IPCC, 1996, 2001, Weitzman, 2001 Nordhaus, 1997, and UNEP, 1987). This is because it is believed by many that damages to these life support resources can be irreversible (Daly and Cobb, 1989).

The above criticisms have led to the development of a number of non-standard discounting approaches. Cline (1992) argues that the pure time preference component of the discount rate should be set to zero, thereby allowing for only the opportunity cost of capital component. The implication of this argument is to drive the discount rate below the market rate. Using empirical evidence from cognitive psychology, Heal (1997, 1998) concluded that stand discounting is inappropriate. He proposed a substitute, which depends on the length of time under consideration in a logarithmic fashion. Weitzman's gamma discounting (Weitzman, 2001) is an approach that exhibits similar behavior to Heal's logarithmic discounting. In developing his approach, Weitzman, based his argument on the fact that there are huge uncertainties about the magnitude of future discount rates (Weitzman, 2001). Other discounting approaches are the Chichilnisky criterion (Chichilnisky, 1996), Rabl discounting (Rabl, 1996), where the discount rate is set equal to zero at a certain point in the future, and the Fearnside unified index (Fearnside, 2002). Other interesting approaches are those of Collard (1981), Bellinguer (1991) and Nijkamp and Rouwendal (1988).

RATIONALE FOR THE NEW APPROACH

In contrast to Goulder and Stavins (2002), this paper makes the case that not only do economists need to provide decision makers analysis that reveal the standing of a planned environmental project or policy with regards to the economic efficiency criteria, they also need to develop evaluation approaches that explicitly include legitimate policy questions such as intergenerational equity. Alternative methods, like the one presented in this paper, will allow comparison and trade-off analysis between results from different approaches. They can be used to answer the question, how much in 'current generation discounted dollars' do we need to give up in order to ensure that future generations have the benefit of inheriting 'healthy' natural and environmental resources. In other words, this and similar approaches can be used to determine the 'price' in standard discounted dollars of ensuring the sustainable use of these resources.

According to Fearnside (2002), the decision as to the relative weight to be given to short versus long-term effects (in other words, current versus future generation interests) is a policy rather than a scientific question. For most nations in the world this policy question has already been answered via sustainability mandates. For example, the Magnuson-Stevens Fisheries Conservation and Management Act of the USA (Anon., 1996) specifically demand that the interests of future generations be taken into account in the management of the nation's fishery resources. Our approach provides an intuitive way to incorporate this requirement into the discounting approach.

A point made succinctly by Tol (1999) is that the choice of discount rate (and discounting approach) is both empirical and ethical. It is empirical because people do make trade-offs between present and future in their daily decisions. It is at the same time ethical because the discount rate determines the allocation of intertemporal goods and services between generations. Tol states that neither the empirical nor the ethical should overrule the other in the choice of discount rate or discounting approach. Tol's point relates to the discussion about 'personal tastes' and 'social tastes', which makes it possible to argue that people may really prefer the use of lower discount rates to evaluate societal goals and objectives, even while possessing a personal high time preference rate (see IPCC, 2001). People's political choices reflect their 'social tastes', but their personal economic choices reflect their ‘personal tastes’. One reason for this is simply that the ‘frame of reference’ is different in personal and social considerations (Marglin 1963). Thus, one may conclude that people’s social tastes are for lower rates than the market discount rate. This statement is reinforced by the fact that, at least, some members of the current generation actually care about benefits to generations yet unborn (see Popp, 2001). Our approach explicitly takes into account the ethical (social tastes) component of discounting while not neglecting the empirical (personal tastes).

Impatience of the individual is fundamental to financial decisions at all levels. It is an ingrained human attribute that allows us to instinctively account for uncertainty, lost opportunities, and other considerations relevant in resource acquisition. Standard discounting merely emulates our time preference on a larger scale; providing an analytical means to make value-based judgments.

Standard discounting though, fails to adequately capture human proclivity. Viewed as any other investment, the education of children generally yields a negative net present value at most practical rate of discount, making alternative investments more attractive. Yet parents and society seemingly disregard conventional financial wisdom, educating their children with little promise of return save the confidence that they have equipped them with the tools needed for survival. Indeed, “altruism” occurs at all levels of society without the concession that future benefits to our offspring carry significant value for us in the present. The discounting method we propose can more accurately model this critical behavior. Significantly, it can provide us with a responsible means to value the flow of benefits from long-term environmental policies when investors are separated in time from recipients. More practically, application of this new procedure may now offer incentive to rebuild depleted ecosystems such as the Grand Banks of Canada.

A final motivation for the current approach may be derived from Rawl’s (1972) veil of ignorance. It appears to us that if decisions by and for society are taken under the assumption that neither the current nor future generations know their position in terms of who comes first, they will all agree that our approach, which explicitly takes into account the interest of future generations, should be applied rather than the standard discounting approach. The approach aims to provide a basis for stewardship for future generations’ welfare as argued for by Brown (1992) and Coward et al. (2000).

DERIVING THE INTERGENERATIONAL DISCOUNTING EQUATION

The intergenerational discounting equation is a generalization of the original idea presented in Sumaila (2001). It is developed as follows. For each simulated future year, we treat the benefits as accruing to the current generation (at standard discount rates) plus to each of the annual 1/(generation time) increments of new stakeholders who will have entered the stakeholder population by that future year. Each incremental group of new stakeholders is assumed to discount future benefits at the standard or normal rate after entering the stakeholder population. In this manner we are able to include the interest of all generations as argued for earlier in this paper. We consider these assumptions axiomatic because we agree with Marglin (1963) that a democratic government should reflect only the preferences of the individuals who are presently members of the body politic, since these preferences have been shown to include the interests of future generations (for instance, Popp, 2001).

The discounting equation resulting from these assumptions contains two factors: the standard, normal annual discount rate that is assumed to apply to all stakeholders after entering the stakeholder “future population”, and a “future generation” discount rate that represents our willingness to forego benefits that we can obtain for ourselves now in favor of benefits that would accrue to future stakeholders.

The net present value of a flow of net benefits, NPV, is defined as

$$NPV = \sum_{t=0}^{T} V_t W_t \qquad (1)$$

where V_t is the net benefit in period t, and W_t is the weight used to discount V_t to the net present value. Let d denote the discount factor given the prevailing standard discount rate, r:

$$d = \frac{1}{(1+r)} \qquad (2a)$$

Then, the conventional weight or discount factor, $W_{c,t}$, in a given period or year, t, is given by

$$W_{c,t} = d^t \qquad (3a)$$

Let the annual future generation discount rate be r_{fg}, then the future generation discount factor, d_{fg}, is given by

$$d_{fg} = \frac{1}{(1 + r_{fg})} \qquad (2a)$$

To develop the modified equation (3a) for the proposed intergenerational discount factor, we expand our earlier assumptions as follows, (i) the present generation (stakeholders) discount flows of values at the standard rate, (ii) a new generation of size 1/G enters the population every year, where G is the generation time. This cohort of people discount values at the standard rate every year after entry, (iii) the current generation (as decision makers) discounts the interests (values) of these new entrants at a future generation rate, per generation (or rate/generation time per year). It should be noted that the within-generation discounting factor already includes some expectation of possible mortality for the existing generations, so there is no need to explicitly account for this.

Putting these assumptions together mathematically, we get the expression below for the intergenerational weight or discount factor in year t, $W_{i,t}$:

$$W_{i,t} = d^t + \frac{d_{fg} d^{t-1}}{G}\left[\frac{1-\Delta^t}{1-\Delta}\right] \qquad (3b)$$

where $\Delta = \frac{d_{fg}}{d}$, the ratio between the intergenerational and the standard discount factor. An examination of equation (3b) shows that the derived formula is valid for d_{fg} greater than or less that d. It reduces to the formula below in the case in which d_{fg}=d.

$$W_{i,t} = d^t + \frac{d_{fg} d^{t-1} t}{G} \qquad (3c)$$

The full derivation of equations (3b and c) is given in the appendix. Equations (3b and c) reduce to the standard discount factor when d_{fg} =0. By taking the derivative of equations (3b and c) with respect to G, we see that the intergenerational discount factor, $W_{i,t}$, decreases with increasing generation time. Note that equation (3b) avoids the comparability problem for all r_{fg}>0.

COMPARING INTERGENERATIONAL AND STANDARD DISCOUNTING

To compare and contrast the standard or the so-called Samuelson discounting and the proposed intergenerational discounting, Figure 1 is developed. It plots the present value of a constant annual flow of \$1 over a period of 100 years using these discounting approaches. A standard discount rate (r) of 5% is assumed for the calculations. Under the standard approach, the flow of \$1 is discounted using a rate of 5% in the usual manner. With respect to intergenerational discounting, we present three plots - when r_{fg}<r (r_{fg}=1%); r_{fg}=r=5%, and when r_{fg}>r (r_{fg}=20%). The generation time, G, is given a value of 20 years.

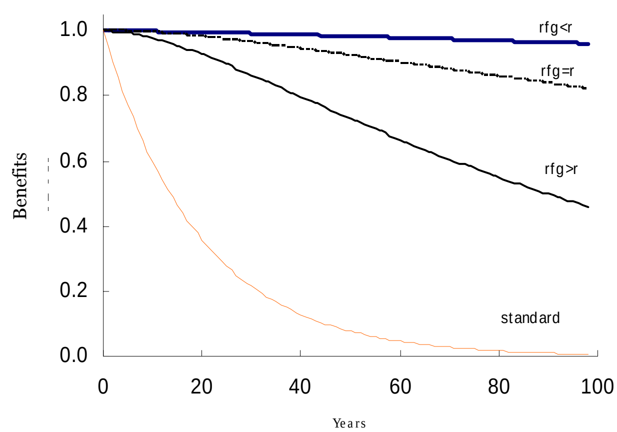

Figure 1: Present value of a constant annual flow of \$1 over a period of 100 years for the different approaches to discounting

From Figure 1, we see that intergenerational discounting results in less discounting of future flows compared to the standard approach in all the cases presented, with the degree of discounting depending on the level of future generation discount rate.

CONCLUSIONS

In addition to the standard discount rate, one will need to decide the future generation discount rate and the generation time in order to calculate the intergenerational discount factor developed herein. We deem a generation time of about 20-30 years to be appropriate. One could argue that most fishers and fisheries managers will not have more than this number of years to make decisions that would significantly impact the sustainability of fisheries and other natural resources. An easy way to fix a value for the future generation discount rate is to make it equal to the standard discount rate. One could also carry out a survey of fishing communities, regions of a country or the whole of a country to find out what people are willing to accept as the future generation discount rate in relation to the standard rate. Finally, one could use the internal rate of return for educating people to the PhD level in a given country.

Our new discounting formula achieves many of the results of other alternative approaches to discounting, it does so in an intuitive manner by partially resetting the discounting clock (Sumaila 2001), by taking into account the fact that a new cohort of people enter the population each year. The fact that our approach introduces two more parameters in the formula for calculating the discount factor may be seen as a disadvantage. But this also is the strength of the approach relative to other alternative approaches to discounting: It affords the approach invaluable flexibility, because the future generation discount rate can be chosen to reflect the particular situation at hand. For instance, the future generation discount rate can be fixed to capture the degree of irreversibility of the change to be brought about as a result of anthropogenic interventions. Another advantage of our approach compared to some of the alternative approaches available in the literature is that it successfully deals with the notorious comparability problem.

A potential disadvantage of our approach, like all the other alternative, is that its effect is to lower the discount rate as seen from the time perspective of the current generation, or what we call their discounting clock (Sumaila 2001). This, it is argued could serve as a double-edged sword with respect to conservation, because resource intensive projects that would otherwise not be profitable from the perspective of the private investor could turn out to be profitable with a lower discount rate (the so-called 'conservationist dilemma'). But, the discount factor we propose in this paper is supposed to be applied at the level of society. Private level decisions will still be made using the higher private discount rate, within the overarching policy framework made at the level of society.

We have proposed a new discounting approach that would take into account the interests of all generations with regard to the use of environmental and natural resources. The approach recognizes the need for discounting of flows of benefits by each generation because we agree that each generation would prefer to have their benefits now rather than tomorrow. The paper also recognizes the fact that capital has an opportunity cost and therefore discounting is necessary. At the same time the approach proposed builds in the need not to foreclose options to future generations when it comes to their future needs from the natural environment. In effect, we have produced a more balanced approach to discounting, which while recognizing the need for allowing for substitutability between natural and human made capital, does not allow for 100% substitutability. In this way, this approach can help policy makers design management solutions for the natural environment that would stop the kind of overexploitation of environmental and natural resources described in Koopmans (1974) and Clark (1973).

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APPENDIX:

Derivation of intergenerational discounting equation

The derivation of equations 3b-c can be most easily understood by examining a table of the present and future stakeholder value components that we propose should be included in $W_{i,t}$:

Year (t)	Present	Join yr 1	Join yr 2	...	Join year t
0	1				
1	d	$\frac{d_{fg}}{G}$			
2	d^2	$\frac{dd_{fg}}{G}$	$\frac{d_{fg}^2}{G}$		
.					
.					
.					
t	d^t	$\frac{d^{t-1}d_{fg}}{G}$	$\frac{d^{t-2}d_{fg}^2}{G}$	...	$\frac{d_{fg}^t}{G}$

That is, for each present stakeholder, we propose that new stakeholders numbering 1/G should be entered into the value weighting at each future year t, with initial discount weighting (or present concern to us) of d_{fg}^t. We assume that each of these incremental stakeholder groups will discount value at the normal rate d after recruitment to the stakeholder population.

$W_{i,t}$ is the sum of the elements of the t^{th} row of this table, i.e. $W_{i,t}=d^t+d^{t-1}\ d_{fg}/G+d^{t-2}d_{fg}^2/G+\ +d_{fg}^t/G$. Letting $\Delta=d_{fg}/d$ as above, this sum can be written simply as

$$W_{i,t} = d^t + \frac{d^t\Delta\left[1+\Delta+\Delta^2...\Delta^{t-1}\right]}{G}$$

Writing the Δ series component of this sum as $1/(1-\Delta)$ - $\Delta^t/(1-\Delta)$ (i.e. as the infinite sum less the t+1 and following terms, treating (as though it were always less than 1.0), we obtain equation 3b. Equation 3c is obtained by applying L'Hospital's rule to equation 3b, to obtain the limit of 3b as Δ approaches 1.0. We have checked these algebraic results against the full table above using spreadsheets, and have confirmed that 3b applies even when $\Delta>1.0$ so that the infinite series simplification does not apply.

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INTERGENERATIONAL DISCOUNTING AND THE CONSERVATION OF FISHERIES RESOURCES: A CASE STUDY IN CANADIAN ATLANTIC COD

Ainsworth, C.H.
and
U.R.Sumaila
Fisheries Centre, University of British Columbia, Vancouver, Canada

ABSTRACT

Where the conventional model of discounting advocates aggressive harvest policies, the intergenerational method of Sumaila and Walters (this vol.) could have been used to render the historic gross over-fishing of Atlantic cod economically unappealing compared to a more conservative long-term strategy. Their new approach considers the needs of future generations better than the conventional method by including (1/generation time) new stakeholders in the analysis each year; these entrants bring a renewed perspective on future earnings, partially resetting the discounting clock. Under conventional and intergenerational discounting approaches, we compare the net present value offered by a 40-year harvest profile of cod based on the actual harvest since 1985 with optimal scenarios suggested by a dynamic ecosystem model. Although optimal scenarios generate less initial harvest than the historic profile, their equilibrium yield is higher and so score proportionately better under the intergenerational valuation. The intergenerational discount rate represents the value that we in the present assign to benefits to be enjoyed by our children and their children, etc. Here, we test the ability of three intergenerational rates to preserve the resource: where the future generation discount rate is set less than, equal to and greater than the standard discount rate. A cost-benefit analysis of education provides the future generation discount rates (δ_{fg}). The lowest δ_{fg} represents the internal rate of return required to make an education to the PhD level at the University of British Columbia worthwhile (6.3%) and the highest represents the rate required to make education to the grade 10 level worthwhile (15.0%). We demonstrate that under a conventional discount rate of 9.3%, meant to represent an alternative rate of return, it was indeed more economic to harvest the stock close to collapse than it would have been to sustain the population. However, under intergenerational valuation the conservative, but sustainable optimal scenarios outperform the actual harvest profile.

INTRODUCTION

Through cost-benefit analysis the traditional method of discounting is often unable to sanction long-term environmental policies that fulfill the frequently stated, though nebulous mandate to provide for the needs of future generations (e.g. DFO, 2001; EC, 2002). Scaling down the value of future benefits exponentially through time ensures that immediate costs will outweigh any such project's far-off benefits at any practicable level of discounting, so that only myopic policies can result (Clark, 1973; Sumaila and Walters, this vol.). This results in 'front loading' of the benefits from our natural system, where profit taking occurs early at the expense of a sustained productive potential. This condition is further aggravated by the well-known problem of open access (Gordon, 1954). Evidence of front-loading is made clear in the harvest record of Canadian Atlantic cod in the years prior to the 1992 collapse. Assigning a social discount rate of zero, or well below the private discount rate observed in market transactions, may be an option to ensure environmental protection (e.g. Hasselmann et al., 1997; UN-FCCC, 1997), though others have cautioned against this (Fisher and Krutilla, 2002; Goulder and Stavins, 2002). Recently, alternatives to standard discounting have been proposed (e.g. Sumaila and Walters; Weitzman, 2001; Nielsen, 2001; Heal, 1998) that limit the devaluation of future benefits, making long-term projects appear economically sensible.

The time preference component of the social discount rate is affected by people's desire to have their benefits immediately (Brennan, 1997). This is partly due to impatience, a trait suggested to stem from our own mortality (Fearnside, 2002), and other factors that cause consumers to prefer immediate rather than postponed consumption. What time preference we choose to discount the flow of future benefits may act as a function of some distance measure that relates the investor to the recipient (Shelling, 1995; Azar and Sterner, 1996). Whether we are speaking of geographic, ethnic, cultural or temporal distance, investors would prefer to bestow benefits to those whom they consider more closely related, than to strangers. When speaking of temporal distance, Shelling (1995) goes on to suggest that as one's genes are spread thinner in future populations, one's relatedness to future recipients decreases. He sees this as an explanation of why we may prefer benefits to be received by our most immediate descendants. In this respect discounting emulates human behavior, providing investors with an analytical means to make a value-based decision.

However, the following cost-benefit analysis of education demonstrates that conventional discounting fails to fully emulate human behavior. If an alternative investment were to promise a greater return than a person's increased earning potential through education, we would expect that children would rarely be educated to the highest levels. Since parents and society choose to do so, future benefits from education to one's progeny must carry with it enough value in the present to make the immediate costs worthwhile. People are inherently applying some form of intergenerational consideration that is captured more fully by the discounting model of Sumaila and Waltersthan by the conventional method.

In a departure from what he called the 'standard economic argument for overexploitation', Clark (1973) proposed that depletion of the Grand Banks demersal fisheries, already evident by this time, could be blamed on the discounting practices of fishing consortiums, rather than open competition among impoverished fishermen. If true, then we would expect to find that at discount rates comparable to the rate of return available from alternate investments, conventional discounting would endorse overexploitation leading to the eventual collapse of the resource. We therefore compare cost-benefit analyses under intergenerational and conventional discounting of the actual history and projected future of the Canadian Atlantic cod fishery, with optimal scenarios offered by an Ecopath with Ecosim (EWE) ecosystem simulation model (Christensen and Pauly, 1992). Although the optimal scenarios generate less immediate benefit than the real-world harvest profile, they maintain higher resource abundance at equilibrium and permit greater sustained yields.

The intergenerational discount rate chosen affects the present value of future benefits (which are to be enjoyed by our children). Here we test the ability of three intergenerational rates to preserve the resource. We assume that the cost-benefit analysis of education provides the relative rates of discounting for benefits to be received by future generations. We presume that the conventional rate of discounting required to render education to the PhD level worthwhile represents the lower limit that society would be prepared to apply. Similarly, the discount rate required to make education to the grade 10 level worthwhile is taken as our upper limit.

METHODS

VALUATION

Conventional discounting

The flow of net benefits from the conventional model of discounting is expressed by the following equation,

$$NPV = \sum_{t=0}^{T}\left(d^{t} \times NB_{t}\right) \text{ where } d = \frac{1}{(1+\delta)} \qquad (1)$$

In the above equation, NPV is net present value; NB is net benefit accruing in year t; d is discount factor and δ is discount rate.

Intergenerational discounting

Sumaila and Walters introduce a form of intergenerational discounting in which the NPV consists of benefits accrued to the current generation at a standard discount rate, plus the benefits received by an annual influx of 1/(generation time) new stakeholders. New stakeholders bring with them a renewed perspective on future earnings, partially resetting the discounting clock. The equation therefore requires a standard annual discount factor and a discount factor used to discount benefits received by future generations when they join the population such that,

$$NPV = \begin{cases} \sum_{t=0}^{T} NB_t \left(d^t + \frac{d_{fg} \cdot d^{t-1}}{G} \cdot \left[\frac{1-\Delta^t}{1-\Delta} \right] \right) & \text{if } \delta \neq \delta_{fg} \\ \sum_{t=0}^{T} \frac{NB_t}{(1+\delta)^t} \cdot \left(1 + \frac{t}{G}\right) & \text{otherwise} \end{cases} \qquad (2)$$

where $\Delta = \frac{d_{fg}}{d}$.

G is generation time (assumed to be 20 years in this equation); *d* is standard discount factor and d_{fg} is the discount factor used to value benefits received by future generations in the year they join the population.

CALCULATING PROFITS

Optimal policies calculated under high discount rates result in greater overall landings than more conservative plans (until the point where future productivity is compromised). However, since greater harvests leave less standing stock biomass, which in turn increases harvesting cost, we introduce the following linear cost-abundance relationship to capture this effect:

$$NB_t = GB_t \cdot \left\{1 - C \cdot \left(1 + \left[\frac{B_{PhD} - B_t}{B_{PhD}}\right]\right)\right\} \quad (3)$$

Where GB is gross benefit (i.e. landed value[14]) in year t; C is base cost of fishing (assumed 60% of landed value[15]); B_{phd} is equilibrium biomass resulting from our optimum solution when $\delta > \delta_{fg}$, and B is biomass in year t. Net benefit is therefore standardized so that costs equal 60% of gross benefit at the stock density left by our most conservative strategy, with cost of fishing increasing linearly as standing biomass is reduced from this level.

For all projections we have assumed a steadily increasing price for cod that represents the trend from 1971-1992[16]. We did not consider prices after 1992 in calculating the trend since the collapse of the cod fishery may have contributed to the jump in price after this year, whereas optimal solutions would have averted the collapse.

SELECTION OF DISCOUNT RATE

As an estimate of the highest and lowest discount rate the public may be prepared to accept in valuing the benefits bestowed on future generations (δ_{fg}), we have chosen to use the internal rate of return needed to make a grade 10, and a PhD education economically worthwhile, respectively. Therefore, the following cost-benefit analysis may be what a taxpayer in 1981 would have used to compare the expected benefits from a child's education with that of an alternative investment. The value used to represent the rate of return for an alternate investment (δ = 9.3%) corresponds to the average annual rate of return for Bank of Canada long-term (10+ years) marketable bonds between 1981-2001 (GOC, 2002).

A child enters grade 1 at a BC public school in 1981. He or she graduates high school in 1992 at a total cost of $54,307 paid for by the provincial government (BC, 1989; BC, 1990). His four-year arts or science undergraduate degree at the University of British Columbia costs $50,192[17] (PAIR, 2002; UBC, 2002), which is paid for by tuition and government grants. Masters and PhD take six more years and costs $80,430[18] (PAIR, 2002; UBC, 2002). After 22 years he has completed his education at a total cost of $184,931 and begins earning income. As a national average, someone with a PhD level of training may expect to make $59,000 per year[19] (HRDC, 2002a), while a high-school dropout earns only $21,000 (HRDC, 2002b).

In figure 1, black shows the discounted costs of 22 years of primary, secondary and post secondary education; grey shows the discounted benefit of projected income for a 30-year career at the PhD level. Each year's cost has been deflated to the 1981-dollar equivalent and discounted to reveal the time preference for payment far from the 1981 perspective. We see that at δ = 9.3%, a PhD will not be worthwhile. However, figure 2 reveals that education to the grade 10 level is worthwhile compared to the alternate investment.

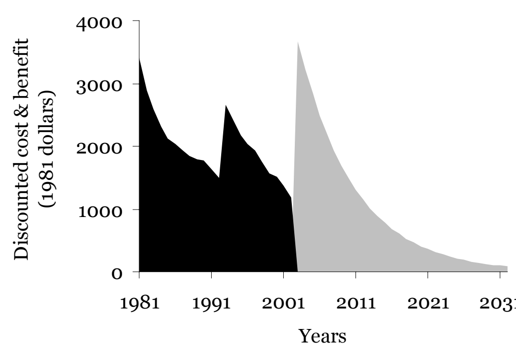

Figure 1. Discounted costs of education to PhD level (black) compared to discounted benefit from projected income for a 30-year career (grey). Discount rate used (δ = 9.3%) represents an alternate rate of return.

[14] Landed value per year is the product of landings and price.

[15] Based on DFO, 1994.

[16] Price measured in 1985 constant dollars (prices adjusted using the consumer price index: BOC, 2002).

[17] General purpose operating expenses divided by full-time enrolment equivalents.

[18] Additional technical costs estimated for grad school.

[19] PhD assumed to earn 25% more than Masters.

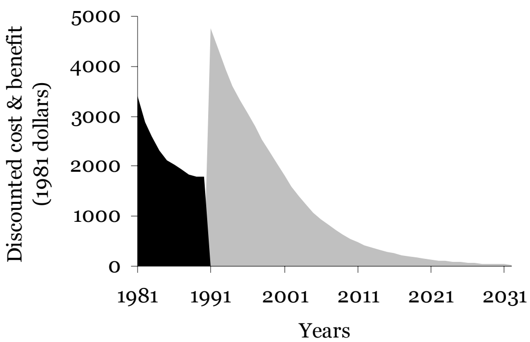

Figure 2. Discounted costs of education to grade 10 (black) compared to discounted benefit from projected income for a 43-year career (grey). Discount rate used (δ = 9.3%) represents an alternate rate of return.

Table 1 shows discount rates where varying levels of education become worthwhile. A PhD becomes uneconomic at all discount rates greater than δ = 6.3%, but an incomplete high school education (grade 10) is worthwhile at δ = 15.0%. Although average annual income of the high school drop-out is only 36% that of the PhD, this lower level of education is more advisable from a conventional cost-benefit perspective at the alternative investment discount rate because of a shorter education period and the time preference for early income.

In addition, total career length is also longer for a high school drop-out (the individual retires in 2032 in both cases).

This example represents a conservative estimate of the costs of education. Were this analysis repeated for private grade school the increased cost would weigh heavily in the evaluation because of its immediacy from the 1981 vantage point. Moreover, the early eighties saw very high yields in long-term marketable bonds (15.2% in 1981). If we had used this rate to represent an alternative investment rather than 9.3%, the average rate between 1981-2001, the returns from even the most modest education level would become less attractive than returns from the alternative investment rate.

In this analysis we have disregarded non-monetary benefits to education. However, even if we increase the benefit of education by 50%, to approximate these considerations, the discount rate required to make a PhD worthwhile is still 8.6% - less than the alternate rate of return. Further, we likewise ignore other incidental benefits in the following analysis of the Atlantic cod fishery (e.g. increased ecotourism and other enterprises that would accompany high cod abundance). Ultimately though, we argue that commercial considerations center foremost when deciding fishing policy.

Table 1. Effects of discount rate on educational attainment

Educational level	**Years of education**	**δ where education is worthwhile (IRR in %)[a]**	**Discounted constant 1981 dollars (in '000s)**		
			Cost	**Benefit**	**NPV**
High School Drop-out	10	15.0	22.2	42.0	19.9
High School Graduate	12	10.3	25.1	28.5	3.4
Trade/vocational School	13	11.4	27.5	36.3	8.7
College	14	8.6	29.8	26.8	-3.0
Undergrad	16	7.5	33.6	25.0	-8.6
Masters	18	7.4	36.9	26.5	-10.4
PhD	22	6.3	41.8	24.6	-17.3

(a) Internal rate of return

DETERMINING MAXIMUM POSSIBLE YIELD FROM SYSTEM

The trophic, mass-balance Ecopath[20] model described by Heymans (2003) represents the marine ecosystem of the Grand Banks off Newfoundland as it appeared in 1985[21], prior to the 1992 cod collapse. The optimal exploitation rate for each gear type that would maximize the sustainable cod yield over a 16-year time horizon was then determined using the policy search interface in Ecosim (Walters and Christensen, 2001). To have the optimization routine return a harvest strategy that would maximize cod catch, the search criterion was restricted to an economic optimization, and cod were described in the static model with a very high price compared to the other target groups. This configuration will cause the policy search to improve the cod harvest at the expense of other sectors. Cod catch in this policy scenario therefore represents an extreme maximum. Under this scheme predators and competitors of cod are eliminated, while other groups are preserved only in so much as they may support the cod population. The suggested Fs from the optimization procedure are then applied to a 16-year dynamic Ecosim simulation using the 1985 model as a starting point. The final end-state equilibrium is maintained for an additional 29 years, totaling 40 years or 2 generations (policy search time horizons greater than 16 years resulted in unstable model dynamics).

RESULTS

OPTIMAL POLICIES

The optimal policy search routine maximizes the NPV of all future earnings. If we apply a large discount rate, the optimal fishing mortalities are high and the population is aggressively harvested. Under intergenerational valuation the recommended level of exploitation is lower than under the conventional (F=0.137 yr^{-1} [$\delta>\delta_{fg}$]; F=0.147 yr^{-1} [$\delta=\delta_{fg}$]; F=0.179 yr^{-1} [$\delta<\delta_{fg}$]; F=0.312 yr^{-1} [conv.]) and so these policies will maintain the stock at greater abundance (Figure 4). Note that the baseline value of the model represents the average of years 1985-1987 and so initial biomass does not match the cod data set exactly (the model represents a composite of these years in other ecosystem values as well). The real-world estimate of biomass comes from VPA stock assessment (see Heymans, 2003 for data sources). The quantitative difference in end biomass between the real-world profile and the conventional optimum (denoted by A in figure 3) may be blamed on ineffective management. The difference in end biomass denoted by B represents the depletion that may be blamed on the application of conventional discounting. End state biomasses are shown in Figure 4.

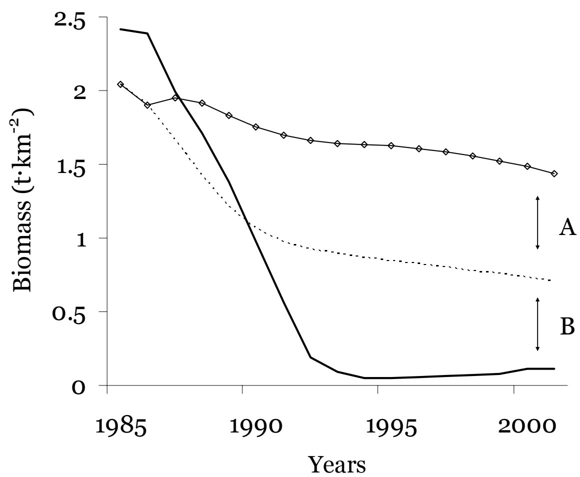

Figure 3. Biomass profiles of actual cod fishery (solid line), intergenerational optimum ($\delta=\delta_{fg}$; diamonds), and conventional optimum (δ=9.3; dotted line). Difference between end biomasses (B) represents depletion that may be blamed on ineffective management; (A) represents what may be blamed on the application of conventional discounting.

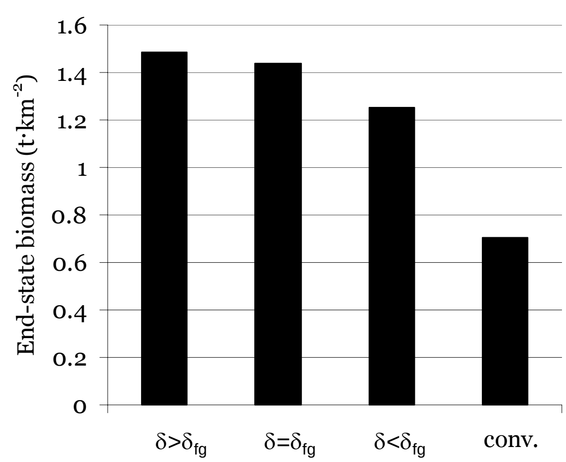

Figure 4. End state biomass for each optimal policy. Real world equilibrium (not shown) is maintained at 2001 level, 0.116t/km^2.

At the levels of discount rate chosen to represent δ_{fg}, (6.3%, 9.3% and 15.0%), the optimum strategy will not deplete the standing stock to a point where productivity is compromised according to the model. Therefore, total (and end-state) catch is improved with each increase in fishing mortality under the intergenerational schemes

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[20] The Ecopath and Ecosim suite of ecosystem simulation tools was developed at the UBC Fisheries Centre (Walters et al., 1997), based on earlier work by Christensen and Pauly (1992);

[21] The model is a synthesis of 1985-1987 data.

(Figure 5). The greater harvests recommended by the conventional optimum, however, do deplete the system leaving a reduced end-state catch (right bar in Figure 6). Not shown, the actual end-state cod catch (0.013 t/km²) is based on 2000 landings[22].

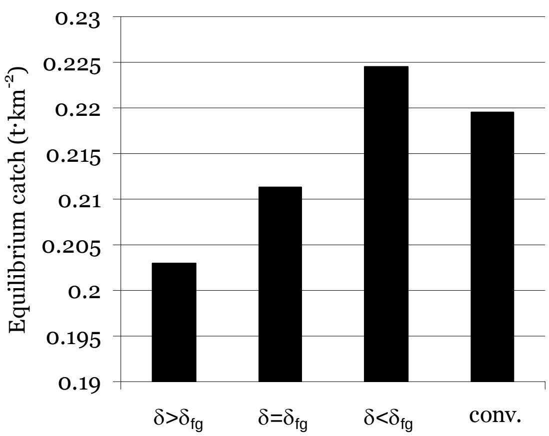

Figure 5. Equilibrium (end-state) catch for each optimal policy. Real-world equilibrium (not shown) is 0.013 t/km².

Under high levels of discounting we expect the actual harvest profile, which took most benefit early, to out-perform these theoretical maxima. Under low levels of discounting, or the described intergenerational approach, we expect the optimal harvest profiles to score a higher NPV than the actual profile since they maintain the resource better, thereby reducing the cost of fishing, and more benefit is allotted to future generations.

Economic results

Figure 6 shows the NPV of the 40-year harvest profiles based on the real-world cod dataset (dark bars) and the optimum solutions (light bars) under intergenerational and conventional valuation. The results indicate that at a conventional discount rate of 9.3%, depleting the stock through intense harvests (actual harvest) yields a greater NPV than preserving the stock (right-most set of bars). This supports Clark's (1973) assertion that fishing consortiums may desire over-exploitation under practicable levels of discounting. All optimum harvest profiles determined under intergenerational valuation out-perform the real harvest profile.

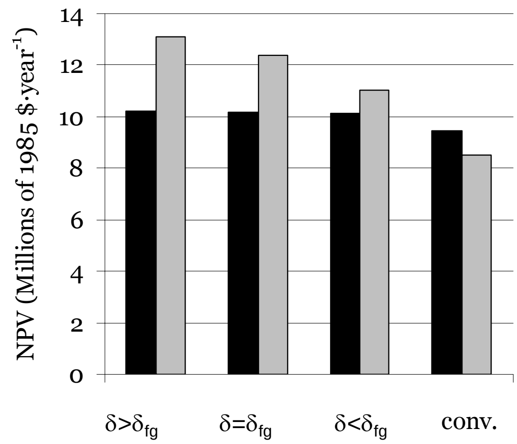

Figure 6. Annual net present value of 40-year harvest profile from 2J3KLNO based on real-world dataset (dark bars) and optimum solutions (light bars) under four discounting schemes.

Figure 7 shows the share of NPV enjoyed by the first and second generation under intergenerational and conventional optimal solutions (generation time = 20 years). The conventional optimum (far right) shows the full effect of time preference (i.e. valuing future benefits from the perspective of the first generation), while the intergenerational solutions combat this effect by partially renewing the discounting clock each year. Not shown, the real-world harvest profile in fact leaves a negative NPV for the second generation, indicating that the high cost of fishing such a depleted system out-weighs the potential benefits (i.e. requires subsidies). As for the absolute quantity of catch received, the most equitable strategy ($\delta > \delta_{fg}$) affords a 53%: 47% split to first and second generations, respectively; the conventional optimum yields a ratio of 59%: 41%, while the real-world harvest profile provides an inequitable ratio of 82%: 18%.

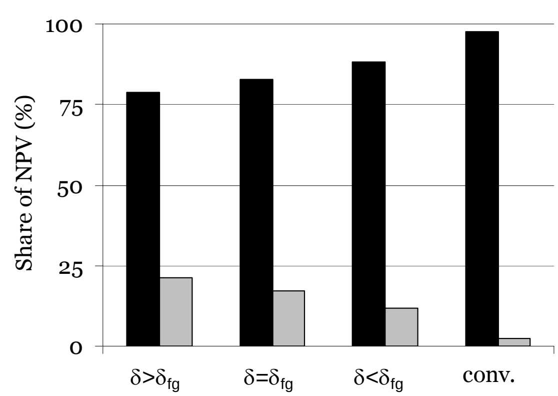

Figure 7. Share of NPV for first (dark bars) and second generation (light bars). Generation time = 20 years. Not shown, the costs of fishing outweigh benefits in the second generation under the real-world harvest profile (i.e. negative NPV, subsidies required).

[22] The real-world estimate of 2J3KLNO cod catch includes reported landings and estimated unreported discards from unpublished DFO[22] and NAFO[22] records, described in Watson et al., (2000).

SENSITIVITY ANALYSIS

Figure 8 shows the relationship between the discount rate and the equilibrium biomass for conventional (grey) and intergenerational ($\delta=\delta_{fg}$) valuation (black). At all levels of discounting, intergenerational valuation of benefits results in a larger equilibrium biomass, with differences becoming more pronounced at high levels of discount.

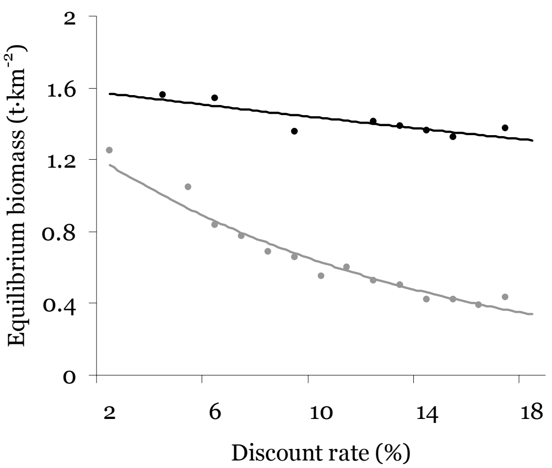

Figure 8. Sensitivity analysis of discount rate showing equilibrium biomass for intergenerational ($\delta=\delta_{fg}$; black) and conventional discounting (grey).

Some policy searches caused the model to become unstable, particularly when optimized at a low discount rate or under intergenerational valuation. The instability resulted in an explosion of cod biomass (among other unreasonable dynamics), due to a positive feedback effect as explained in the following section. The unstable solutions occurred more often at low discount rates because of the search routine's preference to leave a high end-state harvest. The routine had identified a too-good-to-be-true peak on the response surface that was the result of dynamic instability. The points shown in Figure 8[1] represent a more realistic peak on the response surface; one that describes a combination of fishing mortalities per gear sector that does not cause instability under simulation.

MODEL CONSTRAINTS

In conducting optimal policy searches it was necessary to reduce Heymans' (2003) estimate of cod production/biomass from 0.4 yr^{-1} to 0.35 yr^{-1}. The model in its original form was prone to dynamic instability under some manipulations, where an increase in fishing pressure on cod would result in an increased cod biomass, propagating a positive feedback effect that lead to unreasonably high harvest and biomass predictions. The reason for this effect may be rooted in the diet matrix of the model, where adult cod and other groundfish feed heavily on juvenile cod. As fishing removed adult cod (and other groundfish as bycatch), the relieved predation on the juveniles caused recruitment to increase at a rate that more than compensated for the removal of adults, resulting in a run-away population (Walters, pers. comm.). Resolution of this modeling problem will require re-examination of the diet matrix, and possibly the addition of depensatory effects in the form of forcing functions. However, under the constraints of this paper, we found that slightly reducing the productivity of adult cod prevented the feedback effect and resulted in more reasonable predictions.

CONCLUSION

Impatience of the individual is fundamental to financial decisions at all levels. It is an ingrained human attribute that allows us to instinctively account for uncertainty, lost opportunity costs, and other considerations relevant in resource acquisition. The economist's practice of discounting merely emulates our time preference on a larger scale; providing an analytical means to make value-based judgments.

The conventional model of discounting though, fails to capture human proclivity. Viewed as any other investment, higher education yields a negative net present value at any practical rate of discount, making alternatives more attractive. Yet parents and society seemingly disregard conventional financial wisdom, educating their children with little promise of return save the confidence that they have equipped them with the tools needed for survival. Indeed, "altruism" occurs at all levels of society without the concession that future benefits to offspring carry significant value for us in the present. As impatience has installed in us the capacity to improve our chances for personal survival, so too, care for one's children maximizes reproductive success.

The discounting method of Sumaila and Walters can more accurately model this critical behaviour. Significantly, it can provide us with a responsible means to value the flow of benefits from long-term environmental policies when investors are separated in time from recipients, or when the criteria of Pareto improvement cannot be met by conventional valuation. Should the subsequent generation prefer high-turnover species to cod, the opportunity to continue our depletion work will still remain. As managers though, we may wish to afford them the choice to decline that option. More practically, application of this new procedure may now offer incentive to rebuild depleted ecosystems like the Grand Banks.

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