

Evaluating the Benefits from Restored Ecosystems: A Back to the Future Approach

Ussif R. Sumaila^{1,2}, Tony J. Pitcher¹, Nigel Haggan¹ and Russ Jones³

1. Fisheries Centre, University of British Columbia, Vancouver, Canada
2. Chr. Michelsen Institute, Bergen, Norway
3. Haida Fisheries Programme, Skidegate, Haida Gwaii, Canada

Abstract. We argue in this paper that the present fishery policy goal of sustaining current levels of ecosystem resources will foreclose future options for the generation of food, wealth and services from ocean resources. Hence, only a policy of rebuilding of ecosystems can reverse this trend. A novel methodology, termed Back To The Future, defines ecosystem policy goals with which to guide this rebuilding process. In the Back to the Future method, models of past ecosystems are reconstructed using information about the presence and abundance of species derived from historical documents, archaeology, local and traditional environmental knowledge (LEK and TEK). The reconstructed ecosystems are then subjected to economic evaluations to determine the potential market and non-market (that is, social and ecological) values that can be derived from each of them. A comparison of the different values under the different alternative ecosystems is carried out to assess the trade-offs involved in implementing different rebuilding scenarios. A novelty of the proposed approach is that, for almost the first time, the Back to the Future methodology provides the TEK of aboriginal and indigenous peoples with a valuable, direct role in resource management and science.

Keywords: Ecological, economic, social, benefits, rebuild, ecosystems, discounting

1. Introduction

Fisheries, the extraction of living aquatic organisms for food and profit by humans, are embedded in natural aquatic ecosystems that are imperfectly understood. Despite a long history of sophisticated numerical analysis, the management of fisheries presents a dismal series of collapse and dissipation of rent that calls for both explanation and remedy (Pitcher and Pauly 1998).

Overcapacity is a major world-wide bio-economic problem that no-one seems to be able to arrest (Mace 1997). Generating overcapacity has been termed “Ludwig’s Ratchet” (Pitcher 2000a; Ludwig et al. 1993). Unfortunately, human responses to these difficulties in terms of management actions and commercial fishing decisions tend to be maladaptive, (Haggan 1998; Hart and Pitcher 1998) despite the hope that co-management may alleviate some of these problems (Pinkerton and Weinstein 1995; Pinkerton 1989). Grounded in single species thinking and repeated by almost all mainstream fisheries economists since then, Beverton and Holt (see Pitcher 1998c) predicted that fishers

will cease fishing when a stock becomes depleted. But all that fishing capacity is likely to be used, and evidence suggests that fishers try to maintain their income by switching to lower value species lower down the food web when valuable higher trophic level fish become depleted (Pauly et al. 1998a; Sumaila 1999).

Another contributory reason underlying fishery disasters is that management has not been able to learn in the face of errors in data, uncertain assessment and imperfect control instruments, despite the long availability of quantitative methods for adaptive management (Bundy 1998; Hilborn and Liermann 1998).

But a more fundamental reason for fishery collapses is the long-term impact of fishing on the species composition of aquatic ecosystems. Through several direct and indirect effects, fishing alters niches towards generalist, k-selected species, leading to simpler ecosystems, higher volatility and, as noted above, lower value and trophic levels. The ecological processes leading to these changes, termed “Odum’s Ratchet” (Pitcher 2000a), are difficult to reverse and are, as yet, imperfectly understood. Through

this process, fisheries sequester ever higher proportions of primary production (Christensen and Pauly 1995) and large high-value species with specialized niches are rapidly lost (Christensen and Pauly 1997). A consequence is that 'trash' fish come to replace high-value table fish, a process which has reached disaster levels in the South China Sea, Gulf of Thailand and Black Sea, and is proceeding unchecked almost everywhere else. The emergence of new fisheries for cephalopods and jellyfish supports the notion of such a world-wide shift in the nature of exploited marine ecosystems (e.g. Caddy and Rodhouse 1998). This ecological mechanism suggests that future disasters will occur at an increasing rate (Pauly et al. 1998b).

Avoiding the profound changes in aquatic ecosystems that are wrought by fisheries requires a major change in the philosophy underlying fisheries management (Pitcher & Pauly 1998). Traditional single-species fish stock assessment, although necessary for computing the details of age structure and population biomass, is simply incapable of providing the information to remedy or reverse this process (Pitcher 2000b). What is needed is an evaluation of the impacts of fishing on aquatic ecosystems, and the adoption of policy goals that aim to maximize profits, or total benefits to society, by comparing the fisheries in alternative exploited ecosystems (Pitcher et al. 1999; Pitcher 2000b, 1998a, 1998b). This agenda requires multispecies, ecosystem-based assessment models.

The essential features of these techniques are, first, to model reconstructions of past and alternative ecosystems (see Pauly, Pitcher and Preikshot, 1998) and second, to evaluate their economic values if they were to be restored, including the costs and uncertainties of restoration. The policy goal for management then becomes the restoration of the ecosystem that maximises net benefits to society. We term this the "Back to the Future" (BTF) policy process. This is a fundamentally different process from the conventional use of sustainability as a policy goal, which, at worst, may serve only to sustain the present misery (Haggan 2000; Haggan and Beattie 1999; Pitcher and Pauly 1998). Adopting the BTF method counters the tendency to use as a baseline the state of things as they were at the start of our careers: a cognitive impediment to comprehending the full effects of fishing on aquatic abundance and biodiversity that has been termed "Pauly's ratchet" (Pitcher 2000b; Pauly

1995). BTF also effectively counters the two other ratchets, Odum's and Ludwig's, described above. Previous publications have described various aspects of the BTF method, and provide details of its rationale (e.g. Pitcher et al. 1999): In this paper we concentrate on the economic basis for the BTF process.

2. Economic valuation

We start off by asking the question: will 'markets' help us determine the 'true' value of any ecosystem restoration effort? Clearly, the answer to this question is NO! (see for instance, Baumol and Oates, 1988). We discuss three reasons why this is the case. First, the market captures 'value in exchange' and not 'value in use'. Adam Smith himself wrote in his classic book, the "Wealth of Nations" that these two values are not always equal. Sumaila (1999) illustrates how these two values may manifest themselves in a phenomenon described as "Pricing down marine food webs". Over time, more small finfishes are landed and supplied to the global fish market relative to large finfishes, the price of the former have been rising relatively faster than those of the latter, contrary to what one would have expected, *cet. paribus*. Second, non-market (that is, social and ecological) values are usually not captured by the market. Third, discounting makes long-range benefits insignificant. This is clearly problematic for the BTF framework, which argues for the need to rebuild present ecosystems to their past states so as to make ecosystem resources and services available to future generations too. These shortcomings of the market with respect to valuing ecosystem goods and services are taken into consideration in this paper.

2.1 The Ecosystem-Economic Valuation Approach

The approach consists of a number of stages: (i) constructing present and past ecosystems using ecosystem models; (ii) computing the market values of past and present ecosystems; (iii) valuing Ecological-Economic benefits of past and present ecosystems; (iv) determining the Ecological-Social-Economic value of past and present ecosystems; and (v) analyzing the outcomes of the evaluations in stages (i) to (iv).

2.1.1 Ecosystem modeling

To reconstruct past and present ecosystems, the Ecopath/Ecosim modeling approach is used. Details of the method are given in Pauly and Christensen (1993), and Walters et al. (1997), we give only a very brief description here. In a nutshell, Ecopath is a static version of Ecosim, a dynamic ecosystem model developed by Walters et al. (1997). It includes all trophic levels in the analysis (from primary producers to top predators). It emphasizes ecological relationships thus making it intuitively simple and transparent. Ecosim relies on a system of differential equations to generate dynamic biomass predictions of each ecosystem component i as affected directly by fishing and predation on i , changes in food available to i , and indirectly by fishing or predation on other groups with which i interacts (Walters *et al.*, 1997):

$$\frac{dB_i}{dt} = f(B_i) - M \cdot B_i - F_i \cdot B_i - \sum_{j=1}^n c_{ij}(B_i, B_j)$$

where $f(B_i)$ is a function used to predict production, which is dependent on biomass, B ; M is the natural mortality from causes other than predation; F is the fishing mortality and $c_{ij}(B_i, B_j)$ is the function used to predict consumption rates from B_i to predators, B_j .

2.1.2 Market values

We are concerned here with determining the value of ecosystem resources that are harvested and sold in the market. We therefore apply the conventional cost-benefit analysis technique to evaluate the present value of profits that can be derived from the alternative ecosystems constructed (see Angelsen and Sumaila, 1997 and the references therein). Benefits are determined by taking the product of price and catch for the landings from each alternative ecosystems. In general two main cost items need to be incorporated. First, the cost of “waiting”, captured by the process of discounting. Second, the actual cost of landing a given unit weight of marine resources from the ecosystem. Taking the costs and benefits together and discounting them to their present value, we determine the net present value of potential commercial benefits to be derived from the alternative ecosystems. It

should be noted that market prices and cost are applied here since we are interested only in the net commercial values. This valuation will be of interest to private users of ecosystem goods and services, since they are more likely to put more weight on their own private benefits. The next two valuations should be of more interest to policy makers.

2.1.3 Ecological-Economic Values

In addition to the above cost-benefit analyses, we also attempt to capture the fact that (at least from society’s point of view) ecosystems and the resources they contain have value above those bestowed on them by the market. We are therefore interested in getting hold of both intrinsic (or existence) and non-use values of the ecosystem.

The literature on the valuation of ecosystem resources and services gives wide and often controversial estimates of the value of ecosystem resources and services. A recent bold attempt is Costanza et al. (1997), which places an average current economic value on the entire biosphere of \$33 trillion, an amount which is nearly double the gross national product of all the world’s countries put together (at \$18 trillion). Instead of attempting to place a specific value on ecosystems and the resources and services they provide, we carry out several analysis assuming different values for the remaining biomass of all species of creatures in the ecosystem. In this way, we are able to identify the cut off points at which one ecosystem alternative ceases to be optimal (that is, produces the best overall benefits), and the other becomes optimal.

2.1.4 Ecological-Social-Economic Values

To incorporate social concerns, we focus on inter-generational equity. This is not to say that intra-generational equity is not of concern, but clearly when dealing with such long-term problems as we do in the BTF approach, the main issue is the state of the ecosystem that future generations inherit from the current generation. Economists studying climatic change deal with similar long-range problems. In the climatic change debate, issues related to the appropriate rate of discount to use are critical. Some authors have advanced various arguments in support of low or zero discounting when analyzing problems and issues with very long

time horizons (see for instance, Cline, 1992). Other writers have advocated the use of differential discounting, where discount rates for situations with long-term payoffs or ones in ethically preferred habitats, are set lower than in other situations (see Hasselmann et al., 1997).

In this paper, we argue that since we are dealing with different human generations over very long-time horizons, it will be helpful to look at the two main components of the discount rate, that is, the *opportunity cost of capital*, and the *time preference* of a given society or country. One can see why it may not be desirable to tamper with the former component, since the opportunity cost of capital relates to investment in capital today, which could presumably benefit future generations too. We, however, argue that when dealing with inter-generational equity, the time preference component of the discount rate should be assumed to be zero for public policy purposes. It would seem reasonable to us that the current generation would prefer the ecosystem state as it was 100 years ago, were it available, than whatever ecosystem state there is today. And, in the same vein, as far as the future generation is concerned, the ecosystem they inherit then will be more valuable to them than the ecosystem we have today. In other words, it is quite reasonable to assume that a tonne of fish available to someone alive in 100 years time, but not alive today, is preferable to a tonne of fish available today. Similarly, a tonne of fish to a person alive today is more valuable to that person than a tonne of fish available to the same (dead) person in 100 years time. Since the time preference component of the discount rate deals with time flows of benefits (see Lind, 1982), it is reasonable to argue that if inter-generational equity is the goal, we have to incorporate the interest of the person who will be alive in the distant future. Doing this would imply setting the time preference component of the discount rate to zero. By doing so we put equal weights on the preferences of the current and future generations. This then means that the appropriate discount rate to apply in order to determine the appropriate public policy for managing ecosystems should be between zero and the prevailing discount rate. The actual magnitude of the discount rate applied depends on the size of the time preference component of the discount rate.

Therefore, the evaluation process here consists of (i) finding the present value of profits from the

alternative ecosystems using a discount rate that is lower than the prevailing rate of discount, and (ii) valuing the standing biomass of all species in the past and present ecosystems. The sum of the two values gives us the total ecological, economic and social benefits from the alternative ecosystems.

3. Case study: Past and present ecosystems of the Strait of Georgia

Our case study is based on the Strait of Georgia Ecosystem. This ecosystem was modeled as part of an earlier project at the UBC Fisheries Centre. The modeling results from this study are reported in Pauly, Pitcher and Preikshot (1998), which developed models of the Strait of Georgia Ecosystem (i), as it is presently, (ii) as it might have been one hundred years ago, and (iii) as it might have been 500 years ago. To reconstruct these models the authors relied on the traditional scientific data, archeological data and traditional ecological knowledge (see Salas et al. 1998; Haggan et al. 1998; Wallace 1998) Osherenko, 1998 and Jones, 1999).

For the purposes of this paper, we use only the former two ecosystem alternatives, with the 100 years ago ecosystem representing the 'past' ecosystem, and the model describing the ecosystem as it is now denoting the 'present'.

3.1 The results

The ecological results are presented in table 1. Columns 2 and 3 of the table present the standing biomass in tonnes per kilometer squared (tkm^2) for the past and present ecosystems for all the species groups found therein. Columns 4 and 5 in the same table give the corresponding potential harvests that can be taken from the past and present ecosystems. We see from these tables that there is a clear difference in both the standing biomass and the potential harvest from the two alternative ecosystems. The species composition and abundance has changed significantly over this period, with some species completely depleted or nearly so.

Table 1: Reports the biomass and harvest from the past and present ecosystems (Taken from Pauly, Pitcher and Preikshot, 1998)

	Biomass tkm²		Harvest tkm²	
	<u>past</u>	<u>present</u>	<u>past</u>	<u>present</u>
1 Phytoplankton	41	41.46	0	0
2 Kelp / sea grass	200	20.3	0	0
3 Herbivorous zooplankton	15.659	15.572	0	0
4 Shellfish	220.5	220.5	0.23	0.266
5 Grazing invertebrates	400	400	0	0.203
6 Carnivorous zooplankton	32.284	33.035	0	0.001
7 Pred. invertebrates	11	9.1	0	0.076
8 Shorebirds	0.002	0.001	0	0
9 Jellyfish	15	15	0	0
10 Herring	7.001	6	0.029	1.91
11 Eulachon	1.3	0.661	0.009	0.002
12 Small pelagics	15	14.467	0.013	0.02
13 Seabirds	0.02	0.02	0	0
14 Misc. dem. fishes	38	12.6	0.254	0.111
15 Baleen whales	1.9	0.0001	0.001	0
16 Chinook / coho	6.5	0.653	0.423	0.082
17 Hake	9	35.5	0.003	0.986
18 Dogfish	8.7	8.7	0.259	0.064
19 Sturgeon	0.02	0.0001	0.001	0
20 Transient salmon	13	6.365	0.836	1.656
21 Toothed whales	0.2	0.04	0	0
22 Halibut	0.14	0.004	0.034	0.001
23 Lampreys	0.2	0.2	0	0
24 Lingcod	1.5	0.05	0.03	0.001
25 Seals / sea lions	0.47	0.6	0	0
26 Transient orcas	0.004	0.004	0	0

Table 2 presents the annual benefits obtained under the market and Ecological-Economic valuations. The numbers reported answer the following questions. If one were to have today

the reconstructed past and present ecosystems, how much market and ecological-economic values will be made per year? What gains or losses can be expected from the past ecosystem relative to the present? (The reader should note that no results are reported in Table 1 for the Ecological-Social-Economic valuations because we present only current values here.) We see from the table that there will be a gain of 28 and 41%, respectively, in market and ecological-economic values per annum if one had the past ecosystem today. The implication of this result is that there are significant potential gains (both market and non-market) to be made if only we can have the courage to rebuild our ecosystems.

Table 2: Summary results: Annual profits in thousand C\$ per km² of the ecosystem

	<u>Past</u>	<u>Present</u>	<u>% Gain</u>
Market	31	24	28
Eco-Econ	277	198	41

Table 3 reports results from a time dependent analysis running over 20 years. To obtain this result we make two assumptions. First, we assume that if we keep to the *status quo*, the Strait of Georgia will continue to degrade. Second, if we are able to actually rebuild, we are more likely to be able to manage optimally the ecosystem from then on. We assume an increasing fishing effort over time, which will lead to an ecosystem degradation rate of 10% per year under the status quo scenario. The BTF approach seeks to counter such degradation by promoting information sharing and cooperation between shareholders (Haggan 2000). For the Ecological-Economic and the market valuations, we employ a discount rate of 4.23%. For the Ecological-Social-Economic valuation, we use the extreme discount rate of zero, implicitly implying that the discount rate in this case is equal to the time preference component. We observe from table 3 that a net present value gain of 257, 279 and 318%, respectively, for the market, Ecological-Economic and Ecological-Social-Economic valuations with the restored ecosystem. The analysis clearly indicates solid gains in all cases.

Table 3: Restoration versus Status quo annual profit in thousand C\$ per km² of the ecosystem: 20-yr horizon; Discount rate = 4.23%; 0.1 degradation/yr in status quo

	<u>Past</u>	<u>Present</u>	<u>% Gain</u>
<i>Economic</i>	428	167	157
<i>Eco-Econ</i>	3844	1375	179
<i>Eco-Socio-Econ</i>	5539	1743	218

4. Concluding remarks

This analysis shows that restoring the Strait of Georgia Ecosystem is a sound economic policy. It will help improve the potential market and non-market benefits from the ecosystem. As expected the gains are much higher when we incorporate non-market values, namely, the ecological and social values of the ecosystem. Two points need to be noted. First the Strait of Georgia ecosystem is not the best or worst managed ecosystem in the world. For ecosystems that have been better managed over time, the gains from restoration will be smaller. On the other hand, for ecosystems that have been badly managed relative to the Strait of Georgia, the gains from restoration will be higher. Finally, it is important to note that these estimates are derived under the assumption that we start off with the past ecosystem, without actually taking action and expending money to restore. This assumption makes our estimate of gains to be a bit more than if we had incorporated the cost of the restoration effort. The extension of the current work to incorporate this, and the uncertainties surrounding any restoration efforts is currently underway.

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