Integrated Environmental and Economic Accounting for Commercial Exploitation of Wild Fish Stocks

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Abstract. The paper discusses compilation of economic accounts for wild fish stocks. The methods proposed in the System of National Accounting (SNA) satellite system, the System for Integrated Environmental and Economic Accounting (SEEA) are discussed and their usefulness assessed in simple examples. The paper proposes some methods for estimating the value of commercially exploited fish stocks and the cost of exploiting them.
The paper uses data on some important fish stocks in Icelandic waters to give examples of results from using the proposed methods and indicate the degree of uncertainty involved in the estimations. The values of the fish stocks are estimated by using the prices of share quotas and by using direct estimations of the sum of discounted expected future profits. Estimations of fixed-price value of the fish stocks are also discussed.

Keywords: Environmental national accounting, commercial fisheries, value of fish stocks, cost of exploitation.

1. INTRODUCTION

Conventional national accounting, the System of National Accounts (SNA), does not take into account changes in the volume or the value of various natural assets like wild fish stocks. It is not difficult to think of instances where the national accounting aggregates will give very misleading information about the state of the economy because changes in important natural assets are not included. A fish stock, which is being seriously overfished, can yield high income and rapid economic growth while the catches are high. When the stock eventually collapses the depletion of the natural asset becomes apparent and its consequences enter into the accounting books of the national accountants. This should not happen in the case of agriculture where the changes in the volume and the value of cattle should be duly recorded in the national accounts as well as in the farmer’s individual accounts. Nor should it happen in aquaculture.

All accounting records revenues, costs, assets and liabilities. For a wild fish stock to be treated as an economic asset, it, and its use, has to be controlled by somebody. Until quite recently exploitation of fish stocks was rarely controlled. The introduction of 200 miles EEZ for many coastal states around 1980 and the establishment of some regional management bodies have created the judicial possibilities for control over the exploitation of many fish stocks. Still the actual control over the exploitation of many fish stocks is very limited. Besides the judicial side of the control over wild fish stocks and the difficulties of policing compliance with official regulations the control over fish stocks is also limited by lack of biological and ecological knowledge about the fish stocks and their habitat and lack of control over the factors affecting the growth of these stocks. If it is to be reasonable to do proper accounting for a fish stock there must exist sufficient biological knowledge about the stock to make it possible to manage the stock so that it will give reasonably predictable benefits to those that exploit it. The exploitation of the stock must also be managed.

It must be admitted that even in the best of cases the predictability of the annual growth of a fish stock and the efficiency of its economic exploitation is far less than in the case of cattle farming or fish farming. It is therefore important in accounting for wild fish stocks to take this uncertainty into account. In all accounting the effects of some extraordinary events are recorded separately. The wear and tear of a building is recorded as depreciations in the accounts but if the building is destroyed in a fire then the loss would be recorded in the asset account but not recorded as cost. Stocks of finished goods would be depreciated for ordinary damages and disappearances but the loss, caused by large scale theft, would only be recorded in the asset accounts but not as cost. Proper economic costs are those that can be avoided through alternative utilitsation of the assets.

It will be proposed in this paper that the cost of exploitation of a fish stock should be related to forecasted growth of the stock rather than the actual growth. This gives better information for the managers of stock. It does not give proper information for the managers of the stock if high depletion cost is estimated for a year when the harvest was reasonable while unpredictable environmental factors caused the stock to grow very little, nor if low depletion cost is estimated for a year when the harvest was set unreasonably high while the unpredictable environmental factors caused large increase in the volume of the stock. The ratio between the actual growth in the stock and the predicted growth is obviously an indicator of the control that there exists over the growth of the fish stock.

It is preferable in all national accounting to use theoretical models as little as possible. On the other hand it is also important that the national accounts supply data that are consistent with theory. One of the aims of the national accounts is to create data which can be used for estimating and testing theoretical models. It will be argued in this paper that in economic accounting for fish stocks some modeling work is unavoidable in most cases.

Fisheries are different from most other industries in that there exists no market mechanism which ensures that the industry, or the individual firms, are managed in an optimal manner. It follows that all data on prices, profitability etc. reflect the efficiency of the management of the fisheries. These data cannot be treated *prima facie* as reflecting efficient outcomes. For this reason this paper argues that accounting for fish stocks and their exploitation needs to rely on bioeconomic modelling and the estimation of the efficiency of the fishery management. Obviously, the fishery management also needs this kind of bio-economic modelling. Properly done accounting for fish stocks should be an essential tool for the management of the stocks.

Valuation of fish stocks for commercial fisheries has been chosen here not because other uses (recreational fishing, nature watching and other enjoyment of nature) are unimportant but because in a number of cases the value that the fish stocks have for the commercial fisheries is by far the largest part of the total value of the fish stocks and also because, in spite of all too many gaps in the data on commercial fisheries, they provide more hard economic and biological facts that can be relied on for estimation.

This paper will propose methods for estimating the value of fish stocks and the cost of exploiting them and it will use the most important fish stocks in Icelandic waters to exemplify the methods. This paper argues that it is important to compile economic accounts for fish stocks in those cases where there exists sufficient biological and economic information to make sensible estimates for such accounts. The author of this paper believes that there exists sufficient information for compiling economic accounts for the Icelandic cod stock and some other stocks in Icelandic waters. But he also believes that there are several stocks which are exploited by Icelandic fisheries for which compilation of economic accounts is not possible today.

2. USING PRICES OF QUOTA SHARES

The basic method in the SNA for estimating money value of some asset is to use the observed price in the market. This method can be used for estimating the value of some fish stock exploited by some fisheries when the access rights are traded in some markets. This is the case for most commercially important fish stocks in the waters around Iceland. Table 1 shows the value of all access rights of all commercial fisheries exploiting the main stocks in Icelandic waters.

	1994	1995	1996	1997	1998
Cod	32.2	62.0	86.3	131.8	131.2
Haddock	4.2	5.8	8.8	12.1	13.2
Saith	3.6	3.4	3.4	5.3	6.4
Redfish	6.2	10.4	15.0	20.8	22.1
Catfish			1.5	2.2	2.2
Greenl. h.	4.4	3.0	3.0	4.8	4.6
Plaice	1.4	1.5	1.6	1.7	2.5
Shrimp	6.5	21.4	24.0	33.0	25.7
Nephrops	1.2	1.0	0.9	1.0	1.2
Herring	1.4	3.5	8.0	8.8	8.2
Capelin	5.5	6.0	15.0	19.0	22.8
Total	66.5	117.9	167.5	240.4	239.9

Table 1: Values of all access rights. Valued at the end of year prices of quota shares. Unit: billions of IKR.

The end of year prices of quota shares have been used to estimate the value of all access rights. For some of these species (capelin, herring, off-shore shrimp, plaice) all access rights are in the form of ITQs while for other species a significant portion of the total catch is taken by vessels outside the main quota system. Most important is that since 1994 more than 14% of the TAC for cod has been allocated to vessels outside the main quota system, mainly to vessels below 6 GRT that use only handline and/or longline. A small catch is also taken by foreign vessels. The value of these access rights can be estimated from the excess prices that vessels that have licences for these fisheries fetch compared to the prices of comparable vessels that do not have such licences.[1] A somewhat easier method has been used for compiling table 1, namely to estimate the value of the access rights outside the main quota system on the basis of the prices of quota shares assuming that these access rights would give the same part of the total catch for all future periods as was estimated by the Ministry of Fisheries by the beginning of the ongoing quota year.

In the case of transferable quota shares there are two reasons why the quota prices might deviate from the monetary value of the assets for the commercial fishery. Firstly, while the permanent entitlements to the exploitation of some stock in the forms of quotas and

[1] Flaaten, Heen and Salvanes (1995) used this method to estimate the value of access rights in Norway.

licences may have many characteristics of property-rights, their legal status in Iceland[2] is inferior to that of property rights to other assets. The prices of these rights are therefore bound to reflect the (political) risks associated with the entitlements to the exploitation.

On the other hand it is frequently observed that the prices of the entitlements to fish from some stock tend to reflect marginal short run profits rather than marginal long run profits. The introduction of the management of the resource often coincides with a situation of serious depletion of the resource and the existence of large over-capacity in terms of fleet and fishermen. There are numerous cases showing that this state of affairs can last for a long period of time. In the case of Iceland there exists evidence that the prices of quota shares are determined by short run profits rather than discounted expected future long-run profits. (See Danielsson, 2000). The evidence also show that the prices of quota shares do not reflect the predictions that the Marine Research Institute (MRI) makes concerning the expected future development of some important stocks (notably cod and shrimp). There even exists evidence that show that the agents in the market for quota shares do not adjust their prices, which are set in IKR/kg of allocated quota, when the total allocated quota are changed at the start of a new quota year. (Ibid)

In 1996 the combined profits from fishing and fish processing in Iceland is estimated to have amounted to 3 billions IKR. The value of the quotas allocated during the quota year from September 1st 1995-August 31st 1996 valued at the average price of rental quotas during this quota year was 17.5 billions IKR. Adding to this sum estimated value of the access rights for those vessels that are not in the main quota system the total value of all access rights during this quota year amounts to almost 20 billions IKR, which is more than a third of the total revenue from fishing. (See Danielsson, 2000, pp. 9-11)

The high prices of quota shares have led to the contradictory situation where the net asset price (or the liquidation price) of fishing firms is frequently higher than the market value. By the end of 1997 the market value of 9 fishing firms that were registered on the Icelandic Stock Exchange was 46.0 billions IKR. The quota shares of these firms by the end of 1997 are not readily available, but the value of their holdings of quota shares on September 1st 1997, valued at the prices of quota shares by the end of 1997, amounted to 57.0 billions IKR. This sum is 24% above the market value of these firms. The total net asset value of these firms can be estimated to 71.4 billions IKR or 55% above the market value of these firms. (Ibid) These figures indicate that the prices of quota shares in Iceland greatly overestimate the value of the fish stocks in terms of discounted expected future long run profits from exploiting them.

When there are no firm reasons to assume that the prices of quota shares may give seriously distorted estimates of the discounted expected future long run profits from exploiting the fish stocks these prices should be regarded as the best estimates of the value of the fish stocks. It is also relatively easy to obtain these data, at least compared to the difficulties encountered when the value of the fish stocks is estimated by constructing elaborate models using some more or less ad hoc assumptions concerning future prices and costs. It is though important to stress here three considerations. Firstly, that according to bioeconomic theory, the adjoint variable is equal to the rental price of the resource only if the total quota is set at the optimal level. If the quotas are not set at their optimal level the observed rental prices of quotas do not have to be equal to the shadow rental price. In other industries, the national accountant assumes that competition ensures that market prices are efficient prices and therefore that he or she can use data on prices to get good estimates of the efficient values of the goods and services produced by these industries. In the case of fisheries the national accountant can only assume that the prices reflect efficient utilisation of the resources if the fisheries management is approximately optimal. And how can she investigate if the fisheries management is approximately optimal? In most cases only by constructing a model for estimating the optimal fisheries management. This model must therefore be constructed, either by the national accountant, or by the institutions responsible for the management of the fisheries.

The second reason why the national accountant, who has access to data on market prices of freely tradable quota shares, needs to construct a bioeconomic model for completing the necessary estimations for his environmental accounting is that while the prices of quota shares give easily accessible estimates for the money value of the fish stocks they do not give any indication of what part of the change in this money value is due to changes in the price of the access rights and what part should be estimated as a volume change. To make these estimations it is necessary to construct and estimate a model for estimating the present value of expected future profits from exploiting the fish stocks.

Thirdly, it will be argued in this paper that all proper estimation of the cost of using the resource have to be based on some modelling work.

3. ESTIMATIONS USING RECENT PROFITS

In a number of cases the knowledge of the biology and the economics of the fishery is so limited that it can be reasonably argued that the net profits from last year's (or the average of last few years operations) is the best estimate of future profits. The best estimate of the value of the fish stock is then the estimated net profit divided by

[2] As far as I'm aware this is also the case in other countries where fisheries are managed with ITQs.

appropriate rate of interest. This section will discuss this kind of estimations.

One of the main problems facing a statistician estimating the value of individual fish stocks is that fisheries are rarely single species fisheries and even when the fisheries are single species fisheries the available accounting data show revenue and cost of fishing many species. In fisheries managed with ITQs it can be reasonably expected that the rental prices of quotas indicate the relative marginal profit from fishing the different species. It was argued above that in the case of the Icelandic quota system the quota prices reflect the short-run marginal profits. To use this information to estimate the relative profitability of fishing for the different species data on revenues and costs for 5-7 main sectors of the Icelandic fishing fleet were collected together with the composition of their catches and the average landing prices for the different species for the years 1992-1996.[3] The relative prices of different fish species were assumed the same in all sectors and this used to estimate the revenue from the different species. The costs were divided crudely into perfectly fixed and perfectly variable parts and cost of fishing for individual species estimated by assuming the revenue minus variable cost of each sector proportional to the value of the quotas used for the fishing. As the accounting data did not distinguish between vessels in the main quota system and vessels outside this system this method was also used for estimating the variable cost of fishing for the different species for vessels outside the main quota system. For those species where there is no quota and those where there is insufficient data on the quota prices the share in costs was assumed proportional to the share in revenue. The fixed costs were assumed to be proportional to the revenues. This method of estimation gave the results shown in table 2.

	1992	1993	1994	1995	1996
Cod	1,456	2,828	4,083	4,043	2,537
Haddock	-328	-743	-1,494	-1,214	-1,238
Saith	91	-311	-541	-673	-524
Redfish	445	466	-27	225	510
Catfish					-253
Greenl. halib.	347	660	-263	-1,045	-989
Plaice	8	-139	-192	-205	-269
Herring		-38	522	968	1,220
Capelin		-529	-547	-784	-292
Nephrops			-27	-39	-64
Shrimp	-1,041	-942	-744	1,288	1,663

Table 2: Net profit in millions of IKR

If nothing further is known about future profitability of the exploitation of these stocks it seems reasonable to estimate the value of the different stocks by simply dividing the net profit by an appropriate rate of interest.[4] Table 3 shows the results from such estimations interest rate of 8%. Large uncertainty associated with many fish stocks make this rate of interest rather low and the estimates of asset values rather high.

	1992	1993	1994	1995	1996
Cod	18.2	35.3	51.0	50.5	31.7
Haddock	-4.1	-9.3	-18.7	-15.2	-15.5
Saith	1.1	-3.9	-6.8	-8.4	-6.6
Redfish	5.6	5.8	-0.3	2.8	6.4
Catfish					-3.2
Greenl. halib.	4.3	8.2	-3.3	-13.1	-12.4
Plaice	0.1	-1.7	-2.4	-2.6	-3.4
Herring		-0.5	6.5	12.1	15.2
Capelin		-6.6	-6.8	-9.8	-3.7
Nephrops			-0.3	-0.5	-0.8
Shrimp	-13.0	-11.8	-9.3	16.1	20.8
Total	12.2	15.6	9.6	32.0	28.7

Table 3: Asset values in billions of IKR

Table 3 shows the values of the stocks at the average price during the year. Many entries in the table are negative indicating negative asset values. It does not seem reasonable that an asset, which can be disposed of without cost, can have negative asset value. It therefore seems reasonable to set the asset value to zero in those cases. When asset values are estimated in this way from the profits of the fisheries it seems reasonable to use average profits and/or average asset values for some recent years.

Comparing asset values in tables 1 and 3 shows that in almost all cases the asset values in the former table are much higher than the asset values in the latter table.

Bioeconomic theory would predict that the estimates in table 3 are appropriate when the stocks are exploited in the vicinity of optimum. The same theory would also predict that if some stock is seriously overfished it can be expect that profitability of fishing from the stock can be increased by allowing the stock to grow to its optimum level and then maintain the level of exploitation in the vicinity of this optimum. To be able to use these relationships in the estimation of the value of some stock there must exist a reasonably reliable bioeconomic model, which can be used to estimate the potential of the stock.

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[3] Most of these data have been published in Concerted Action (1999). The quota prices used in the calculations are published in NEI (1999).

[4] Statistics Norway has used this method for estimating the value of fish stocks (or fisheries) in Norway. See Hass and Sørensen (1998). This method is also used by Flåm (1993) and Kjelby (1993). Flåm (1993) assumes that "all stocks are in equilibrium, giving maximum sustainable catch" (p. 1), while Kjelby (1993) gives the value of the cod fisheries as the stocks were exploited at the time. She then goes on to estimate their value if the stocks were exploited at the Maximum Sustainable Yield.

But if there exist reliable estimates of the biological and economic relationships necessary to construct such a model it should be possible to improve the estimates of the value of such stocks given in table 3 by taking into account the biological (and economic) potential of the stock. These estimates will obviously be higly relevant for the management of the stocks.

4. USING BIOECONOMIC MODELS

This section will discuss estimations of the money value of commercially exploited fish stocks using the present value method and a simple bioeconomic model which can be relied on for the estimation of future economic rents from the exploitation of the fishery. Such models are described in a number of places. (See e.g. Clark, 1990).

Given some objective function it is possible to derive optimal harvest paths from these models. The objective function can take into account profits, consumer surplus, risk aversion, and (social) adjustment costs. The most common objective functions are the sum of present value of future profits and the sum of present value of future profits and consumer surplus (welfare).

It will be assumed here that the optimal harvest path ($\tilde{H}_t$) is given by:

$$\tilde{H}_t = q(t, S_t) \tag{1}$$

where S_t is the stock size at the beginning of year t.

The value of the fish stock can now be defined as the present value of expected future profits from this optimal harvesting strategy. If $V_t(S_t)$ is the value of the stock of size S_t at the beginning of year t then:

$$V_t(S_t) = \sum_{k=0}^{\infty} \frac{p_{t+k}\tilde{H}_{t+k} - c_{t+k}e(t+k, \tilde{S}_{t+k}, \tilde{H}_{t+k})}{(1+i)^k} \tag{2}$$

where $\tilde{S}_t = S_t$ and $\tilde{S}_{t+k} = \tilde{S}_{t+k-1} + g(\tilde{S}_{t+k-1}) - \tilde{H}_{t+k}$ for k =1,2,…. . and g is the growth function.

The Icelandic cod stock will now be used to exemplify the discussion above. The MRI has developed a model of the cod stock in Icelandic waters which is sufficiently reliable to be used for this kind of estimations. The MRI uses a Beverton and Holt cohort model for this stock and uses a Ricker recruitment function to analyse the long-run effects of some exploitation of stock. The MRI also includes the cod stock in a multispecies model including shrimp and capelin. These multispecies considerations will be ignored in this paper.[5] For the sake of simplicity the MRI model will be approximated here by a Schaefer model. With r =0.5242 and K =2,720,000 tons the Schaefer model gives the same maximum sustainable yield of 356,000 tons when the stock is 1,360,000 tons as the MRI model.

To make the model directly applicable to Icelandic conditions it is necessary to solve some tedious problems relating to timing. The accounting data are based on the calendar year while the quotas are set for the quota year which, for most species[6], starts on September 1st and ends August 31st. The estimates of the size of the cod stock is done during the first half of the year and are based on catches up until the end of the preceding year and on research fishing during March of the present year. Here the estimates of the fishable biomass will be treated as referring to the size of the stock by the beginning of the year and it will ignored that the quota year for cod is not the same as the calendar year. It will also be assumed (quite unrealistically) that this information is available to the authorities before the harvest of the year is decided.

The MRI uses a cohort model and is able to predict some of the variations in the growth rate of the cod stock. In this paper the Schaefer model will be used throughout for predicting growth of the cod stock and for calculating optimal harvest paths, values of the stock and the cost of exploiting the stock. But the estimates of the size of the stock will always be MRI's estimates based on the cohort model.

The time of estimation or forecasting will be indicated for all variables below. $X_{t_1}^{t_2}$ will refer to the value of the variable X at time t_1 as it is estimated or forecasted at time t_2. If X is a stock variable then t_1 refers to the beginning of period t_1.

The biology in the Schaefer model (see e.g. Clark, 1990) is described by the logistic growth function:

$$G_{t+k}^t = rS_{t+k}^t(1 - S_{t+k}^t / K) + \phi_{t+k} \tag{3}$$

where G_{t+k}^t is the growth of the stock in period $t+k$ as it is forecasted at the beginning of period t, S_{t+k}^t is the size of the stock by the beginning of period $t+k$ as it is forecasted by the beginning of period t and ϕ_{t+k} is a stochastic error term.

The following functional form is commonly used for the harvest function:

$$H_{t+k}^t = \kappa E_{t+k}^t (S_{t+k}^t)^\gamma \tag{4}$$

where κ is the catchability coefficient and γ is the elasticity of the CPUE with respect to the size of the stock. This parameter is of central importance when the value of a fish stock is estimated.

In most estimations of the size of fish stocks there is implicit some relationship between the size of the stock

[5] This model is described in Danielsson *e.al.* (1997).

[6] Two important exceptions are capelin and herring.

and the CPUE. In those cases where the size of the stock is estimated on the basis of CPUE data some relationship between the CPUE and the size of the stock must be assumed. When the VP analysis is used then catch per unit of standardised effort must be estimated. In Iceland the catch per unit of standardised effort is estimated by trawling certain areas in a standardised manner using the same equipment each year. Using the MRI data for the period 1985-2000 to estimate the equation:

$$\ln(CPUE_t) = a + \gamma \ln(S_t^{2000}) + \phi_t \qquad (5)$$

gives quite high values on γ and a value of a which is significant and negative. This result might indicate that the relationship between CPUE and the size of the stock is more complicated than the estimated equation allows. The data points observed indicate that the relationship might be S-shaped. This needs to be studied further when more data points showing this relationship at different stock sizes become available. In the calculations below it will be assumed that the equation is valid with a forced to zero giving γ =0.8.[7]

If the unit cost of effort is constant (c_{t+k}^t) then the cost function becomes:

$$C_{t+k}^t = c_{t+k}^t E_{t+k}^t = \frac{c_{t+k}^t}{\kappa} (S_{t+k}^t)^{\gamma} H_{t+k}^t \qquad (6)$$

It will be assumed below that $c_{t+k}^t = c_t^t$ for k =1,2,… .

If equation (6) is used to predict future costs (as will be done below) it is implicitly assumed that productivity in the fishing industry and the prices of the factors of production develop in such a way that equation (6) is true. This would happen if the increase in the real prices of the factors of production are equal to the increses in their productivity at given stock sizes.

It will be assumed below that demand has constant price elasticity. The inverse demand function can then be written as

$$p_{t+k}^t = p_t^t (H_t^t)^{\varepsilon} (H_{t+k}^t)^{-\varepsilon} \qquad (7)$$

where ε is the constant elasticity of the demand.

The bioeconomic model is now complete and can be used to estimate some optimal harvest rule. This can be done in more or less sophisticated manner concerning the choice of utility functions, modelling of uncertainty and adjustment paths. Linear deterministic models like the one developed above give a bang-bang solution, i..e. if the stock is below its optimal level all fishing should be stopped until the stock has reached its optimal level. (See Clark, 1990, p. 93.) There are several common sense objections to this solution mostly based on various fixed costs associated with actual fishing and ignored in the simple bioeconomic model, fixed cost in fishing capital, fixed cost in training of fishermen and fixed costs in marketing of fish products. It is extremely difficult to estimate these variables. It is also very difficult to incorporate them realistically into a complete bioeconomic model. For these reasons it will be assumed here that the following simple harvest rule can be assumed to be reasonably optimal.[8]

$$\tilde{H}_t^t = \alpha H_{t-1}^t + (1-\alpha)\lambda S_t^t \qquad (8)$$

where α is a smoothing parameter to reduce the variability of catch levels. This smoothing can be argued on the basis of cost efficiency and on the basis of reducing the effects of errors in the individual stock estimates on the harvest level. It is though obvious that a high level of α will occationally be associated with high cost of overfishing. Ideally, the value of α should be based on some considerations concerning uncertainty, aversion to risk and fluctuations and adjustment cost. Here α is simply set equal to 0.5.

If λ is set equal to $\tilde{H}/\tilde{S}$ where $\tilde{S}$ and $\tilde{H} = g(\tilde{S})$ are the long run optimal value for the stock and the harvest, the harvest rule in equation (8) will direct the stock size and the harvest levels to these optimal values. In this case it is sufficient to estimate $\tilde{H}$ and $\tilde{S}$ to get an estimate for λ. Here, these variables will be estimated on the basis of the deterministic version of the model as the estimation of the effect of uncertainty is a straightforward but time consuming exercise. It will be assumed that the Icelandic fisheries face a demand function for cod with constant elasticity of 10.[9] This elasticity will be used to predict all future prices as it will be assumed that no other information on future prices is available.

If the management aims at maximising present value of future profits the value of $\tilde{S}$ can be obtained by solving first the equation:

[7] Danielsson *e.al.* (1997) used γ =0.7 based on the study by Helgason and Kenward (1985).

[8] The profit (and present value) functions are usually fairly flat in large area around the optimal solution. In simple deterministic models the difference in the present value of profits when the optimal adjustment path had been used, i.e. catches cut down to zero without cost while the stock increased from half of the optimal level to the optimal level, then the present value of profits would be around 5% more than the present value of profits when the simple catch rule in the text is used to calculate the optimal catches. This difference becomes smaller when the stock is closer to the optimum long run level $\tilde{S}$.

[9] This number is an approximation of the elasticity of the demand function used in Danielsson *e.al.* (1997).

$$i = \frac{\partial G}{\partial S} - \frac{\partial C/\partial S}{(1-1/\varepsilon)p(F(S)) - \partial C/\partial H} \qquad (9)$$

If the management seeks the socially optimal solution the value of $\tilde{S}$ can be obtained by solving:

$$i = \frac{\partial G}{\partial S} - \frac{\partial C/\partial S}{p(F(S)) - \partial C/\partial H} \qquad (10)$$

and then use $\tilde{H} = g(\tilde{S})$ to calculate the sustainable catch. (See Clark, 1990, p. 139)

The solutions of equation (9) and (10) depend on the values of p_t^t, S_t^t and c_t^t as these values are used as a base in each case. κ is set equal to 1, p_t^t is set equal to the average price of cod in period t and c_t^t is then adjusted so that the formulas above give the estimated profits in the period . Table 4 shows the solutions to these equations for the values of p_t^t, H_t^t, S_t^t and c_t^t in 1992-1996. The monopoly solution in equation (9) gives higher values for the optimal stock levels and lower levels for the optimal harvest levels as expected. Therefore λ is also lower in this case than in the case when the objective of the fisheries management is to maximise social welfare or the discounted sum of profits and consumer surplus. The differences are though fairly small as it is assumed that the elasticity of demand is quite large or 10.

	1992	1993	1994	1995	1996
Actual stock and harvest levels, unit price and cost					
S_t^t ('000 tons)	640	630	590	560	675
H_t^t ('000 tons)	268	252	179	169	182
p_t^t (IKR pr. kg)	76.41	79.16	103.85	104.24	81.14[10]
c_t^t	12,474	11,791	13,343	12,697	12,322
Optimal values. Objective: maximise profits					
$\tilde{S}$ ('000 tons)	1,623	1,579	1,517	1,497	1,588
$\tilde{H}$ ('000 tons)	343	347	352	353	346
$\lambda = \tilde{H}/\tilde{S}$	0.2114	0.2198	0.2318	0.2357	0.2181
Optimal values. Objective: maximise social welfare					
$\tilde{S}$ ('000 tons)	1,573	1,534	1,478	1,461	1,542
$\tilde{H}$ ('000 tons)	348	351	354	355	350
$\lambda = \tilde{H}/\tilde{S}$	0.2210	0.2286	0.2393	0.2427	0.2271

Table 4: Optimal stock and harvest levels

The average value of λ is 22.3% in the case when the objective is to maximise the present value of profits, while it is 23.2% if the objective is to maximise the

and then use $\tilde{H} = g(\tilde{S})$ to calculate the sustainable catch.

discounted sum of future profits and consumer surpluses. In the calculations below it will be assumed that 23% is the optimal value of λ.[11]

When λ has been determined it is possible to calculate the value of the stock. Table 5 shows the value of the cod stock at the beginning of each year valued at current prices (i.e. average prices during the year). It also shows the value of the stock using 1992 prices.

Beg. of year:	1992	1993	1994	1995	1996
Stock (S_t^t)	640	630	590	560	675
Value ($V_t(S_t^t)$)	130	147	213	218	152
Value ($V_{1992}(S_t^t)$)	130	129	125	122	133

Table 5: The size of the fishable cod stock, as estimated at the time and its value at current and 1992 prices. Units: '000 tons and billions of IKR

The estimates in table 5 are very much higher than the estimates of the value of the cod stock in table 3. In most cases they are also much higher than the estimates of the value of the cod stock in table 1.

The estimates in table 5 depend on the time of the estimation and what is known at that time about future profitability of the fisheries exploiting the stock and its future growth. As estimates of the values of assets at some given point in time are frequently made some time later it has been allowed here that the estimations of the values of the cod stock utilise the prices of cod and the cost of fishing in the year after the point in time which the estimates refers to. The estimates use only information about the profitability of the cod fisheries in the first year. The profitability of all later years are based on predictions assuming that prices change according to changes in Icelandic supply with the price elasticity of demand of 10 and using equation (7). The MRI estimates of the size of the fishable stock of cod by the end of each year becomes available in May/June during the following year.

The SEEA-handbook advocates the use of the so called net price method for the estimation of the money value of some natural assets. (SEEA, 1993, p. 60-61 (§163-165)). "In this case, the net price (net proceeds) of the asset is the actual market price of the depleted raw material minus actual exploitation costs including a normal rate of return

[10] The decline in the price of cod in 1996 may seem odd at first, but it is largely explained by the fact that the freezer trawlers share in the total cod catch declined from 26% in 1995 to 14% in 1996. The price per kg of cod (live weight) is, of course, much higher in case of freezer trawlers.

[11] This number is very close to the 22% which was the ratio advocated by the Working Group on the Rational Exploitation of Fish Stocks. See Vinnuhópur um nýtingu fiskistofna (1994), p. 2. After receiving this report the Icelandic government decided on a catch rule where the TAC for the next quota year should be 25% of the estimated size of the fishable cod stock. This has been interpreted as 25% of the average of the estimated size of the stock by the beginning of the year and the forecasted size of the stock one year later.

of the invested produced capital. The price is then multiplied by the total quantity of depletable stock of the corresponding natural asset." (SEEA, 1993, p. 61-62, (§163).) This method has in some cases been used for the estimation of the value of fish stocks.[12] This method can be used for the estimation of the value of non-renewable natural assets where the unit cost of extraction is nearly constant but it cannot be used for the estimation of the value of renewable natural resources like fish stocks where the growth rate of the resource and the cost of extraction depend on the size of the physical stock. In such cases the value of the resource is a non-linear function of the size of the physical stock.

5. ESTIMATING COST OF EXPLOITATION

The SEEA advocates the use of the maintenance cost method for estimating cost of overfishing, or depletion, of fish stocks. (See, SEEA, 1993, pp 19-20 (§58) and p. 94 (§265)). According to this method the cost of fishing in excess of the growth of the stock, causing a depletion in the stock, is equal to the profits foregone if the catch would be limited to the sustainable level. It follows that "(t)he maintenance cost concept implies that uses of the environment that have no impacts on nature have a zero (monetary) value. For instance, if water is used, and it is available in sufficient quantities, water abstraction has no maintenance costs. The same is true of fishing and logging if natural growth compensates for exploitation." (SEEA, 1993, pp 19-20 (§58).)

The maintenance method refers to sustainability of the actual stock, i.e. to the actual growth or decline in the stock. In fisheries management the regulations (TACs, days at sea, number of licenses) have to be decided before the fishing starts. It means that these regulations have to be decided before the growth of the fish stock in the period is known. In such cases it does not seem appropriate to estimate the cost of fishing on the basis of comparison of the actual harvest and the highly uncertain growth of the fish stock in the period. In economics proper cost of using an asset are those changes in the value of the asset that follows from their normal use. Other changes in the value of the assets should be recorded as Other changes in volume of assets. This means that the cost of using the fish stock should relate to some forecasted growth of the stock in the period rather than the actual growth.

These definitions of cost will now be used to estimate the cost of exploiting the Icelandic cod stock in the years 1992-1996. It should be stressed at the outset that the calculations above are not intended to be accurate. There are several difficulties involved in making accurate calculations of this kind. One such difficulty relates to the timing of the fisheries management decisions and the knowledge available at that time as discussed in the previous section.

Table 6 shows estimations of maintenance cost for Icelandic cod. It shows the total harvest of cod in the year (H_t^t), profit from fishing cod per '000 tons (cf. table 2 above), the size of the fishable cod stock by the start of the year as estimated at the time (S_t^t), the estimate of the size of the cod stock at the end of the year made by the beginning of the following year (S_{t+1}^{t+1}) and the forecasted size of the stock at the end of the year, forecasted at the beginning of the year using equation (3) (S_{t+1}^t).

	1992	1993	1994	1995	1996
H_t^t	268	252	179	169	182
$\pi_t(H_t^t)$	5.4	11.2	22.8	23.9	14.0
S_t^t	640	630	590	560	675
S_{t+1}^{t+1}	630	590	560	675	889
Cost I (-)	-54	-449	-685	2,744	2,988
S_{t+1}^t	629	632	653	624	759
Cost II (-)	-61	20	1,447	1,520	1,178

Table 6: Estimations of maintenance cost.
Unit: '000 tons and millions IKR

If the cost of exploiting the cod stock is estimated by the maintenance cost method and assuming that the profit per ton is independent of the volume of the catch (i.e. that there are no fixed costs), then:

$$\text{Maintenance cost} = \text{Profit pr. '000 tons} * (S_{t+1}^{t+1} - S_t^t) \quad (11)$$

The result is shown in the row labelled Cost I.

The next row shows the size of the fishable cod stock by the beginning of the following year as it is forecasted at the start of the year when the management decisions are taken (S_{t+1}^t). Forecasting of the growth in the cod stock was made using the Schaefer model described in the previous section and ignoring the information that the scientist at the MRI use in their cohort models.

The cost of exploiting the cod stock, estimated by the formula:

$$\text{Maintenance cost} = \text{Profit pr. '000 tons} * (S_{t+1}^{t} - S_t^t) \quad (12)$$

is shown in the row labelled Cost II. In 1992 the two cost estimates give almost the same result because the actual growth in the stock (as estimated by the beginning of 1993) is almost the same as the growth that was estimated by the beginning of 1992. In 1994 the actual growth in the stock is much smaller than what was predicted. In spite of large decrease in the catch Cost I estimates positive depletion cost in 1994. Cost II, on the other hand, estimates negative depletion cost (i.e. investment in the

[12] See e.g. Repetto (1999), which uses this method to estimate the value of US Atlantic sea scallop fishery.

stock). In this case the difference between Cost I and Cost II should be recorded as Other volume changes. In 1995 and 1996 actual growth in the cod stock was quite high compared to expected growth making Cost I estimates showing much higher investment in the stock than Cost II. The only method for estimating the cost of using an asset which is consistent with the estimates of the value of the asset is to estimate the cost during the year as the decrease in the asset's (fixed price) value. By using the model in the preceding section it is possible to estimate the depletion costs for the Icelandic cod stock using this method. The depletion cost (or the value of the investment in the stock if the cost is negative) can be estimated on the basis of the forecasted growth of the stock as:

$$Cost_t^d = V_t(S_{t+1}^t) - V_t(S_t^t) \qquad (13)$$

Table 7 shows the estimated cost of exploiting the Icelandic cod stock in the years 1992-1996 using this method (Cost IV=$Cost_t^d = V_t(S_{t+1}^t) - V_t(S_t^t)$). The table also shows the estimated cost if the actual growth of the stock, as estimated by the beginning of the following year (S_{t+1}^{t+1}), is used (Cost III=$V_t(S_{t+1}^{t+1}) - V_t(S_t^t)$).

	1992	1993	1994	1995	1996
$V_t(S_t^t)$	130	147	213	218	152
$V_t(S_{t+1}^{t+1})$	129	143	209	233	169
Cost III (-)	-0.9	-3.7	-3.9	14.4	16.6
$V_t(S_{t+1}^t)$	129	147	221	227	159
Cost IV (-)	-1.0	0.2	7.8	8.3	7.0

Table 7: Estimations of depletion cost.
Units: '000 tons and billions of IKR

The methods used for compiling table 7 give much higher values for depletion cost and for the value of increases (investments in) the stock than the maintenance method used for compiling table 6. This depends on the fact that the Icelandic cod stock was in a depleted state during the years under considerations. If the stock is above its optimal size the maintenance method gives higher values for depletion cost than the methods used for compiling table 7.

Tables 6 ans 7 show that there can be large differences between the estimates of depletion costs where forecasted growth of the stock ($S_{t+1}^t - S_t^t$) is used compared to estimates where actual growth of the stock ($S_{t+1}^{t+1} - S_t^t$)[13] is used. If depletion cost is estimated using the forecasted growth in the stock the difference between the growth in the stock as forecasted at the beginning of the year and the actual growth in the stock as it is estimated by the beginning of the following year ($S_{t+1}^{t+1} - S_{t+1}^t$) must be recorded as Other changes in volume of assets in the physical accounts and the value of this difference must be registered as Other changes in volume of assets in the monetary accounts.

Depletion cost is associated with the decrease or the increase in the volume of the asset. If the volume of the asset remains the same, i.e. if it is managed sustainably, there is no depletion cost. Both methods discussed above give that result. But a renewable resource like a fish stock can be managed in a sustainable manner but still be far from being optimally managed. If a fish stock is in a seriously depleted state and kept there through sustainable catches, it is inefficiently managed. It is possible to calculate the cost of this inefficiency by using the model above.

The definition of the value of the stock discussed in the previous section refers to the estimated optimal management of the Icelandic cod stock. Associated with this definition is the definition of income from the exploitation of the resource as income (profit) from the optimal exploitation. Let $\tilde{H}_t^t$ be the optimal harvest in period t and $\tilde{S}_{t+1}^t$ the forecasted stock by the beginning of period $t+1$ if the catch in period t is $\tilde{H}_t^t$, i.e.

$$\tilde{S}_{t+1}^t = S_t^t + g(S_t^t, N_t^t) - \tilde{H}_t^t = S_t^t + g(S_t^t, N_t^t) - q(S_t^t) \qquad (14)$$

In this case the optimal income from the exploitation of resource is:

$$R_t^{opt} = \pi_t(\tilde{H}_t^t) + V_t(\tilde{S}_{t+1}^t) - V_t(S_t^t) \qquad (15)$$

Using that equation (2) gives that

$$V_t(S_t^t) = \pi_t(\tilde{H}_t^t) + \frac{1}{1+i} V_t(\tilde{S}_{t+1}^t) \qquad (16)$$

equation (15) can be rewritten as:

$$R_t^{opt} = i\left[V_t(S_t^t) - \pi_t(\tilde{H}_t^t)\right] \qquad (15')$$

The actual income (rent), on the other hand, is:

$$R_t^{act} = \pi_t(H_t^t) + V_t(S_{t+1}^t) - V_t(S_t^t) = \pi_t(H_t^t) + Cost_t^d \qquad (17)$$

[13] Actually, $S_{t+1}^{t+1} - S_t^t$, as compiled in the tables, is the difference between the estimated size of the stock at the beginning of the year, as it was estimated at the beginning of the year, and the estimated size of the stock at the end of the year, as it was estimated at the beginning of the following year. At the latter date the estimate of the size of the stock at the beginning of the year (i.e. S_t^t) are revised on the basis of new data. This revision is ignored here as all other (still later) revisions of these estimates.

The difference between the optimal and the actual income is the measure of the inefficiency cost of suboptimal (usually excessive) harvest levels.

$$-Cost_t^{ie} = R_t^{opt} - R_t^{act} = \pi_t(\tilde{H}_t^t) - \pi_t(H_t^t) + V_t(\tilde{S}_{t+1}^t) - V_t(S_{t+1}^t)$$
$$= i\left[V_t(S_t^t) - \pi_t(\tilde{H}_t^t)\right] - \pi_t(H_t^t) - Cost_t^d \qquad (18)$$

The SNA records the actual rent in fishing as part of the annual production, i.e. $\pi_t(H_t^t)$, but that part of the income which consist of a decrease or an increase in the value of the environmental asset ($V_t(S_{t+1}^t) - V_t(S_t^t) = Cost_t^d$) is not included. This omission should be corrected in the environmentally adjusted satellite accounts. Neither the SNA nor the environmentally adjusted satellite accounts are supposed to record the inefficiency cost, $Cost_t^{ie}$. Frequently, this cost is very important as shown in table 8.

	1992	1993	1994	1995	1996
$\tilde{H}_t^t$ (‘000 tons)	147	145	136	129	155
$\pi_t(\tilde{H}_t^t)$ (mio. IKR)	800	1,626	3,098	3,074	2,168
$Cost_t^{ie}$ (-) (bn. IKR)	-9.8	-8.6	-4.9	-4.9	-2.4

Table 8: Estimations of depletion and inefficiency cost.

The depletion cost can be positive or negative depending on if the stock is forecasted to decrease or increase given the period’s harvest. The inefficiency cost, on the other hand, would be positive in most cases. It should though be noted that when the optimal management is defined in terms of maximisation of the sum of discounted profits and consumer surplus it is possible that the actual harvest strategy brings higher profits than the optimal strategy. In such cases $Cost_t^{ie}$ may become positive. If the optimal management is defined in terms of maximization of the sum of discounted profits $Cost_t^{ie}$ must be negative.

According to the definition above there is some inefficiency cost if the catch in the present period is not optimal. This means that there are costs associated with the under-utilization of a natural resource. A special case would be if the natural resource would not be exploited at all. If the Authorities ban all commercial exploitation of some natural assets, which could profitable exploited by some industries, this policy has a cost (inefficiency cost), which is equal to the profit foregone by not exploiting the natural assets in an optimal manner.

6. COMPLETE ACCOUNTS FOR COD

It is now possible to set up the complete satelite account for the Icelandic cod stock. Table 9 shows the physical accounts for the Icelandic cod stock.

Unit: ‘000 tons	1992	1993	1994	1995	1996
Opening stock	640	630	590	560	675
Forecasted growth	257	254	242	233	266
Harvest	-268	-252	-179	-169	-182
Depletion	-11	2	63	64	84
Other ch. in vol.	1	-42	-93	51	130
Closing stock	630	590	560	675	889
Opening stock, as estimated in 2000	546	582	588	565	692

Table 9: Physical accounts for the Icelandic cod stock

The bottom line in table 9 shows the size of the cod stock at the beginning of the year as it was estimated in MRI’s last report, MRI (2000). These estimates are not used in the calculations of the environmental accounts for the Icelandic cod stock but have been included in the table to indicate the estimation error. This paper suggests that instead of continuous revisions of the estimates of the size of the stock and its value as new information comes along the first estimates should not be revised. The errors in the stock estimates will therefore be adjusted through the post Other changes in volume of asset.

Table 10 shows the monetary accounts for the Icelandic cod stock for the period 1992-1996.

Unit: billion IKR	1992	1993	1994	1995	1996
Opening stock	130	147	213	218	152
Depletion cost (-)	-1.0	0.2	7.8	8.3	7.0
Other changes in volume of asset	0.1	-3.9	-11.7	6.1	9.6
Closing stock at Last year’s prices	129	143	209	233	169
Holding gain/loss	18	70	9	-81	
Closing stock	147	213	218	152	
Efficiency cost of harvesting (-)	-9.8	-8.6	-4.9	-4.9	-2.4
GDP	398	411	435	452	486

Table 10: Monetary accounts for the Icelandic cod stock

The closing stock and the holding gains/losses were not available for the year 1996.

Table 10 shows that Other volume changes are large compared to the depletion costs. This indicates the degree of control that there exists over the growth of the Icelandic cod stock.

It should be remembered that in this paper all estimates of the value of the cod stock are based on the price and cost of only one year. The large decline in the value of the cod stock in 1996 is caused by a sharp decline in the profitability of the cod fisheries in that year and reflected in the accounts by large holding losses. It may seem more realistic to use the prices and costs during some recent years to forecast future profits. The resulting estimates would then be smoother than those in table 10.

The inefficiency cost shown in table 10 is not part of the accounts but included here as this cost is so large and because it is implicit in the method used for calculating the value of the cod stock. The GDP at current prices for the period 1992-1996 is shown for comparison.

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