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CREATING ASSET ACCOUNTS FOR A COMMERCIAL FISHERY OUT OF EQUILIBRIUM: A CASE STUDY OF THE ATLANTIC SEA SCALLOP FISHERY

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This paper demonstrates a methodology for constructing asset accounts for a commercial fishery in which the stock, harvest, and effort level are out of sustainable equilibrium. The paper adopts the framework used by the U.S. Department of Commerce Bureau of Economic Analysis in its preliminary 1993 Integrated Economic and Environmental Accounts and follows methodologies recommended by the National Research Council committee constituted to review those efforts. The accounts were constructed for the period 1985 to 1995 for the Atlantic sea scallop fishery, a significant commercial fishery, using information obtained with the cooperation of the National Marine Fisheries Service from existing databases constructed for management purposes. No significant additional data collection was required for the purpose of this study. Differences between the net rent and user cost values of the stocks over this period indicate the inefficient exploitation of immature scallop populations.

I. BACKGROUND

I.A. *Accounting for Natural Resource Assets*

Significant limitations in our system of national economic accounting have long been recognized, including its exclusion of non-market production and its failure to treat natural resources as economic assets (Maler, 1991). Thus, for example, rebuilding commercial fish stocks is not counted as a form of capital formation, though rebuilding stocks leads to a higher future income stream at the cost of a current economic sacrifice. Academic economists have produced a considerable amount of research over the years aimed at expanding the economic accounts in these directions. Path-breaking research of this nature was published more than two decades ago (Nordhaus and Tobin, 1973; Eisner, 1988).

This issue was given heightened emphasis in the 1980s by the emergence of sustainable development as a catchphrase for the need to integrate economic development and environmental protection. Sustainable development was defined by the influential Brundtland Commission (World Commission on Environment and Development, 1987) as development that meets the needs of the present generation without sacrificing the ability of future generations to meet their needs as well. Economists were quick to point out the analogy to the standard Hicksian definition of income embodied in national economic accounts: the maximum amount of consumption attainable in the present period without forcing consumption levels to be lowered in a subsequent period. Economists demonstrated

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that under simplifying assumptions net national product represents an exact measure of sustainable consumption, provided that all assets and consumption are included in the accounts (Weitzman, 1976; Hartwick, 1989).

In the United States, in response to a directive from the Clinton administration in 1993, the Bureau of Economic Analysis (BEA) undertook a work program that led to the publication in 1994 of a preliminary set of capital accounts for some natural resources. First-phase results covered land and sub-soil minerals (Bureau of Economic Analysis, 1994a, 1994b). That program was halted shortly thereafter by a Congressional directive pending an independent review of the methodology and data used in the estimates.

The independent review has been provided by a committee organized by the National Research Council under the chairmanship of William Nordhaus of Yale University (Nordhaus and Kokkelenberg, 1999). That committee strongly supported the development of environmental and natural resource accounts as extensions to the core national income accounts and emphasized their policy importance. Its report states "There are many examples of how comprehensive economic accounts can bring benefits. These include better estimates of the impact of regulatory programs on productivity, improved analysis of the costs and benefits of environmental regulation, and more effective management of the nation's public lands and resources. Augmented national accounts would also be valuable as indicators of whether economic activity is sustainable" (p. 15).

However, the Panel report expressed doubt regarding the feasibility of constructing resource accounts for wild fish, since "data on fish stocks are unreliable because wild fish are fugitive assets and there is no reliable census of the fishes" (p. 168). This is essentially the reason why the Bureau of Economic Analysis had not included fisheries in its initial work program, even though marine fisheries are one of the few important natural resources of which stocks have significantly declined. This omission motivated the research project behind this article, a case study to test whether such accounts can be compiled for a significant commercial fishery with reasonable accuracy and at reasonable cost.[1] The few prior efforts to construct fishery asset accounts assumed unrealistically that sustainable equilibrium prevailed in the fisheries (Tai, Noh, and Abdullah, 2000).

I.B. *The Atlantic Sea Scallop Fishery*

The Atlantic sea scallop fishery was selected for a case study on several criteria: recreational fishing for scallops is negligible, the bycatch of scallops by other trawlers and of other species by scallop boats is not too important, the fishery is fairly homogeneous with respect to gear types, and the various management plan amendments have generated a considerable amount of accessible biological and economic information and research.

In addition, the fishery is consistently within the top ten commercial fisheries in the value of landings. It provides employment to more than 3,000 full-time fisherman in New England and the Mid-Atlantic region, though this level of effort

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[1] The project has been supported by the Pew Charitable and the Marine Policy Center of Woods Hole Oceanogaphic Institute and through cooperation from the National Marine Fisheries Service and its New England Fisheries Research Center.

far exceeds that required to harvest the resource efficiently (Rago, Lai, and Correia, 1997, p. 10). The fleet of about 250 large off-shore scallop dredges that accounts for 80–90 percent of the catch operates mainly out of New Bedford, Cape May, Hampton Roads and Newport News. These boats sail with a crew of up to seven men, staying at sea for days and shucking their catch on board. The fishery grew rapidly over the 1970s and 1980s but, like many others, was crippled by excess capacity and over-harvesting and was forced by regulation and by financial losses to retrench.

The Atlantic sea scallop (*Placopecten magellanicus*) is potentially a highly renewable resource. Once through its drifting larval stages and settled onto old shells or rocky bottom at depths of 20–100 meters, the scallop grows rapidly. Most reach sexual maturity at around age three, when a fertile female will release 2 million eggs at spawning. Egg production increases with the scallop's size, which increases rapidly between ages three and five. Survival of larvae is highly variable due to predation and the vagaries of ocean current and bottom conditions when larval scallops settle to the bottom, so recruitment[2] of young scallops into the fishery at about age three is quite variable. No stock-recruitment relationship has been established for the Atlantic sea scallop.

Large populations of sea scallops are found on the George's Bank, in the New York Bight, in the mid-Atlantic DelMarva region, and, to a lesser extent, in the Gulf of Maine. These do not appear to be separable populations, since larval scallops can be transported long distances, and they are now managed as one resource area. The fishery has been managed by the New England Fisheries Management Council since 1982 under a series of management plans and amendments. Initial management efforts set minimum weight and shell height restrictions on the catch but this mechanism was inadequate to prevent increasing excess capacity and over-fishing. Revisions in 1994, imposed limits on new entry into the fishery, restrictions on the number of days that permit holders could spend at sea, and restrictions on crew size, along with gear restrictions intended to reduce harvests of immature scallops. In addition, incidental to the collapse of groundfish stocks and closure of most of George's Bank to bottom fishers, large areas of the traditional scallop dredging grounds were put off limits. This has led to rapid recovery of stocks in the closed areas but more intensive over-fishing outside them. Despite these measures, fishing mortality was found to be far above the threshold level of over-fishing defined by the 1996 Sustainable Fisheries Act, requiring further mortality reductions of about 70 percent to allow stocks to rebuild as required by the law. These drastic requirements triggered further reductions in allowable days at sea and retention of closed fishing areas.

Recruitment, stock size, harvests, and effort levels in the scallop fishery are all subject to short-term and longer-term change, violating the sustainable equilibrium assumptions in simple bioeconomic fishery models (Schaefer, 1954). The longer-term change is driven by the fisheries management agency's policy of rebuilding stocks to a level consistent with maximum sustainable yield, as required by law, but not consistent with maximum economic yield. This policy

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[2] Recruitment to the fishery takes place when the young scallop grows to harvestable size, typically during its third year.

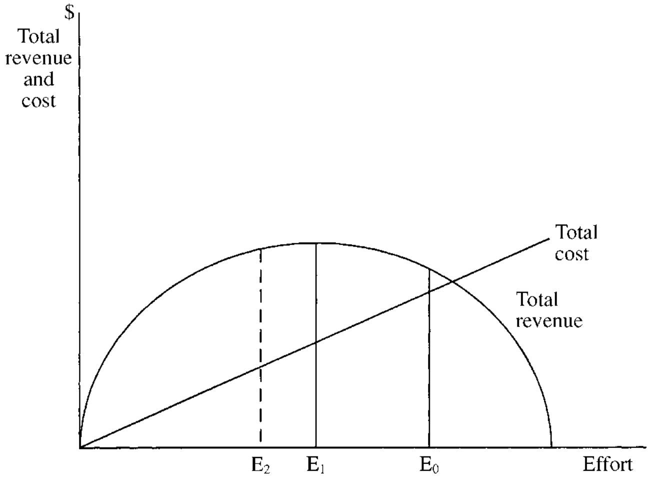

Figure 1. Present and Future Status of the Fishery

implies reductions in fishing mortality and effort over the study period and thereafter. The situation can be understood with reference to Figure 1, a standard diagram often used in basic fisheries economics. The diagram plots sustainable harvest and revenue levels, along with cost levels, as functions of fishing effort. The management plans for the scallop fishery call for reducing effort from a level like E_0, at which rents are nearly dissipated, to a level like E_1, consistent with MSY, but not E_2, representing MEY. The discounted present value of future harvests and increases in biomass reflect this transition toward higher rents. Thus, this accounting differs from earlier simulations that compare hypothetical stocks and stock values under unregulated free entry and economically optimal management (Henderson and Tugwell, 1979).

II. METHODOLOGY OF THE STUDY

II.A. *Physical Stock Assessment*

Estimates of the numbers and weight of scallops subject to harvest (recruited) in the fishery have been estimated for many years by the National Marine Fisheries Service's Northeast Fisheries Science Center. These estimates are made principally to support the Stock Assessment Review Committee and the New England Fisheries Management Council in making important in fisheries management decisions. Consequently, both the estimation methods and the underlying data are subject to careful review and criticism by fishermen and others. Though estimation methods and data collection procedures have been refined over the years, the estimates are consistently based on two fundamental information series:

(1) Data on the scallop harvest, which are collected both at the port from dealer logs and on board from vessel trip reports. Records of the scallop catch are kept by size. Data on landings are supplemented by on board

sampling information of the ratio of discarded to kept scallops in the catch, also by size.

(2) Data on scallop abundance, which have been collected since 1975 through annual sampling. Sampling is conducted by means of carefully plotted and controlled tows of a scallop dredge in fishing areas. Following the same procedures each year, research vessels follow a stratified random sampling scheme, conducting tows in different geographical grids at various depths and latitudes. Results are averaged into indices of mean abundance, in numbers and biomass per tow. Size distributions are kept and used to distinguish new recruits from fully recruited scallops. Abundance data, particularly of scallops just large enough to be captured in permitted gear, are adjusted to reflect the selectivity of the mesh size of towed nets. Adjustments are also made for the time within the sample year at which the samples are taken.

Statistical estimation techniques are used to derive estimates of size and weight of the scallop population in fishing areas. The modified DeLury method (Conser, 1991, 1995) that is used is based on a simplified population model. The model assumes that the harvestable scallop population at the start of year (t) consists of the harvestable scallops at the start of the previous year ($t-1$) plus scallops that became harvestable during the course of the previous year, both quantities diminished by the natural mortality rate affecting harvestable scallops; and less the number of scallops in last year's catch. Or, to put it even more simply, this year's harvestable population is last year's *plus* additions due to the recruitment of young scallops *minus* mortality due to fishing and natural causes.

The DeLury model thereby defines defines a set of recursive equations for the stock of catchable scallops and for the catch:

$$N_{t+1} = (N_t + R_t) \exp[-(m_t^f + m_t^n)] \tag{1}$$

where:

N_t = the number of catchable scallops in the population at the start of year t;
R_t = the number of newly catchable scallops that enter the population during year t;
m_t^f = the instantaneous rate of fishing mortality during year t;
m_t^n = the instantaneous rate of mortality from natural causes during year t.

$$C_t = (N_t + R_t) \exp(-m_t^f) \tag{2}$$

where:

C_t = the number of scallops harvested in year t.

Since no stock-recruitment relationship for Atlantic sea scallops has been established, R_t is estimated for future years beyond the study period at its average value across years within the study period. Estimates for years during the study period are based on statistical estimates of the DeLury model.

For estimation purposes the DeLury model holds that equation (1) is subject to a proportional error. It then assumes that the numbers of mature scallops and new recruits in the population are proportional to their numbers in the abundance survey samples, aside from random measurement errors. A weighted least-squares regression analysis technique is used to estimate the population numbers and other parameters from data on sample abundance and the annual harvest. A full description of the methods used to estimate the Atlantic sea scallop's abundance, physical stock, and fishing mortality are presented in reports of the National Marine Fisheries Service (Richards, 1996; SARC-23, 1997; Rago *et al.*, 1997).

Table 1 presents estimates of the numbers of harvestable scallops and new recruits in the population from 1985 to 1995, along with estimates of the numbers of scallops harvested and lost through natural mortality. The physical accounts include only harvestable scallops because the economic resource consists of the stock that can *legally* be exploited at current prices and technology. Comparable estimates of the population weight are derived by applying survey estimates of mean weight per recruit and mean weight per full recruit to the population estimates.

TABLE 1

PHYSICAL STOCK ACCOUNT: ATLANTIC SEA SCALLOPS, 1985–95
(MILLIONS OF SCALLOPS)

Year	Catchable Stock at Start of the Year	New Recruits During the Year	Harvest During the Year	Natural Mortality During the Year	Catchable Stock at End of Year
1985	273.7	569.2	312.9	57.3	472.7
1986	472.7	599.1	545.1	97.9	428.8
1987	428.8	753.0	623.6	52.8	505.4
1988	505.4	890.9	630.5	117.5	648.3
1989	648.3	823.2	733.5	199.3	538.7
1990	538.7	1061.3	985.9	238.0	376.1
1991	376.1	634.8	669.5	83.5	257.9
1992	257.9	402.3	512.7	17.1	130.4
1993	130.4	579.1	321.5	81.9	306.1
1994	306.1	483.9	497.1	76.1	216.8
1995	216.8	733.7	394.1	137.6	418.8

Source: Rago, Lai, and Correia (1997).

The annual harvest has regularly exceeded the numbers of catchable scallops in the population at the start of each year, showing that the fishery is highly dependent on the young scallops just reaching harvestable size during the year. This implies that both the harvest and the scallop population are subject to the random fluctuations of scallop reproduction. It also implies that much of the harvest consists of three-year-old scallops that have not realized the impressive growth in size that occurs in the subsequent two or three years.

II.B. *Choice of Valuation Methods*

Following the approach adopted by the BEA, physical stocks have been valued in accordance with two conceptually different measures, the *marginal rent* and the *marginal user cost* of a harvested fish. The marginal rent from a scallop is its dockside price less the marginal cost of catching it and bringing it ashore in saleable condition. It is essentially the current liquidation price of the asset, analogous to the stumpage value of a commercially grown tree prior to felling. This valuation approach has been widely employed in the construction of natural resource asset accounts by the Bureau of Economic Analysis and by other researchers, mainly because of its practical advantages. It can be implemented using only current market transactions data on prices and costs and requires no forecasts of future market conditions.

However, asset markets are intrinsically forward-looking. The value of a durable asset is derived from the stream of economic benefits that it is expected to generate, discounted back to the present period at a rate representing the opportunity cost of capital. The marginal net rent approach to asset valuation can be justified in these terms only by appealing to the famous Hotelling theory, which states that arbitrage in competitive markets will tend to ensure that the marginal returns to holding an asset will be the same over all holding periods (Hotelling, 1931). The theory implies that if the current liquidation price is depressed, arbitrageurs or speculators will buy up some of the resource and withhold it from the market in order to sell it in a future period. Doing so depresses future returns and raises the current liquidation price until the present value of returns are equalized across periods. Under these assumptions of well-functioning asset markets, the marginal net rent can be used as a proxy for an asset price based on discounted future returns.

The Hotelling theory must be qualified for all sorts of reasons and empirical support for it is weak (Devarajan and Fisher, 1981; Smith, 1981). Support is especially weak in the case of marine fisheries in which the absence of harvesting rights to the wild stock discourages potential investors from conserving the stock for future harvest even it if might be potentially profitable to do so. Should one fisherman forgo some present harvest, he would have no assurance of reaping the reward of higher future catches. Those fatter and more numerous scallops would probably be scooped up in another boat's dredge. Only if the fisheries management agency were able to impose an efficient level of harvesting on the collective fishery would the Hotelling theory rise to a threshold of plausibility, and this achievement has so far been elusive. The absence of adequate conservation incentives suggests that scallops, like other marine fisheries, are harvested until their liquidation value has fallen well below their potential value as a resource for future exploitation (Gordon, 1954). Nonetheless, the net rental value of the stock provides a useful benchmark for comparative purposes.

The alternative marginal user cost value is an estimate of the discounted present value of the future net rents that would result if a scallop were *not* captured in the current period but left to grow. Since scallops grow rapidly between ages three and five at a rate exceeding any plausible rate of time discount, their discounted future harvest value tends to exceed their current value for quite a few years after recruitment. This imbalance is reinforced by the price premium enjoyed by larger scallops, in terms of dollars per pound. For example, in 1998 annual average prices ranged from $4.63 per pound for three-year-old scallops, just large enough to be harvested, to $6.89 per pound for large seven-year-old scallops (Edwards, 1999). In truth, the imbalance should be further reinforced by their enormous fecundity, which increases with scallop size. A scallop left in the sea to grow and spawn will contribute mightily to the future stock. However, since no reliable stock-recruitment relationship has been established for the Atlantic sea scallop, because of the wide inter-annual variability in survival rates for scallop spat, this factor cannot be quantified.

The marginal user cost measure is based on estimates of the increase in harvestable biomass in future years resulting from a marginal decrease in fishing mortality in the current year. NMFS staff biologists and economists make such estimates when they conduct the economic analyses supporting fisheries management plan amendments. The increment in the future harvest and in the surviving biomass are both included in the user cost approach because an increase in unharvested biomass in a future year is valuable because of its growth and reproductive potential. Because the fishery is out of equilibrium and managed inefficiently, it cannot be assumed that the future stock and harvest will be at intertemporally efficient levels.

This calculation makes use of empirical estimates of the relationship between scallop age, size, and weight. It also incorporates estimates of natural mortality rates, which will kill off a certain fraction of survivors each year. More significantly, this measure requires estimates of fishing mortality in future years, since a scallop left alive in the current year will not have much time to grow—or to reproduce—if it is immediately captured in the next year. Though future fishing mortality is uncertain, it is the principal target on which fisheries management restrictions on fishing effort are aimed. Therefore, the best available forecast of future fishing mortality in future years is the target schedule set out in the most recently adopted fisheries management plan.

As before, future harvests and surviving biomass are valued in terms of their estimated net rental values. Monetary calculations have been carried out in constant prices and, accordingly, an inflation-adjusted real interest rate of 3 percent per year has been used as a discount factor. Three percent corresponds roughly to the annual yield on inflation-adjusted U.S. treasury bonds, consistent with the discount rate applied by the regulatory agency in developing future harvest plans. The calculations were performed over a time horizon extending out through the year 2010.

Details of the Net Rent Valuation Approach

The calculation of the net rental value of the harvestable scallops in the population at time t follows equation (3), in which π_t is the net rental value, p_t^w the dockside price per pound of scallops of average weight w at time t, N_t^w is the number of scallops of weight w in the population at time t, c_t is the marginal cost of harvesting a pound of scallops at time t, and $\sum_w wN_t^w$ is the total population weight of harvestable scallops at time t.

$$\pi_t = \sum_w p_t^w wN_t^w - c_t \sum wN_t^w \tag{3}$$

Data on dockside scallop prices at various fishing ports are collected regularly by the National Marine Fisheries Services and used in their economic evaluation of management plan options. Since most scallops are harvested by dredgers and shucked at sea, prices are quoted in dollars per pound of scallop meat. Annual average prices were available for the entire period. Price premia for scallops of various sizes were available only for the single year 1998 but the percentage premia were assumed to have been stable throughout the period 1985–95.

Marginal harvesting costs, in principle, are the incremental costs of capturing and marketing an incremental quantity of scallops—the total variable costs, in other words. Such costs are also collected and estimated by the National Marine Fisheries Service for use in their management plan evaluations. They have been defined in several different ways in NMFS documents. For this study, total variable costs are defined to include vessel operating costs, such as fuel, ice, supplies, and a portion of maintenance expenses, and vessel labor costs. The costs of vessel ownership, such as depreciation, interest, and insurance, are regarded as fixed costs because an increase in harvest within the range estimated in this study would require no increase in fleet capacity. The scallop fishery, like many others, is considerably overcapitalized. To illustrate, full-time scallop dredgers are restricted in the current management plan to 120 days at sea per year and a plan amendment under consideration would reduce that limit to 51 days at sea. It has been estimated that only 72 to 100 vessels operating at an economically viable rate of capacity utilization would be sufficient to bring in the harvest at the targeted levels of fishing mortality but there are more than two hundred licensed scallop fishing boats in the industry.

Labor costs are considered variable because one limit on harvesting is crew size, since shucking at sea is a very labor-intensive process that has not been feasibly mechanized. Crew sizes are adjusted by vessel operators but an increase in harvesting does require an increased labor input. Estimation of labor costs in the scallop fishery is complicated by the fact that crews are traditionally rewarded by the "lay" system, which apportions the trip's revenues (net of some costs) to owner, captain, and crew. The specific allocation may vary across ports, boats, and time. However, since crews are drawn from a surprisingly wide geographical area, even as far away as Texas, and can be assumed to have alternative employment opportunities, their labor costs can be translated into an equivalent hourly or daily wage rate. Survey data have been used to express variable costs, so defined, as a percentage of revenues and this relationship has been assumed to hold over future as well as current periods.

Details of the Marginal User Cost Valuation

The increase in future harvests and harvestable biomass that would result from a marginal increase in the current scallop population was estimated by comparing a base case in which future fishing mortality is regulated according to the extant fisheries management plan with an alternative case in which fishing mortality is marginally reduced only in the current period and thereafter conforms to the same planned mortality schedule. The alternative case generates a higher estimated biomass and harvest in future years because of the scallop's potential for growth. Again, the rationale for assuming that future fishing mortality conforms to that scheduled in the extant management plan is that all management measures are targeted on achieving that level of mortality. In the absence of an estimated stock–recruitment relationship, recruitment in each future year over a ten-year horizon was assumed to be equal to average annual recruitment in the 1985–95 estimation period. Mean weight per recruit was assumed to be unchanged in future years from the average during the 1985–95 period. Moreover, natural mortality was assumed to continue to be equal to that estimated for the 1985–95 period.

The estimating procedure is detailed for the year 1995, the final year for which user cost values were generated. Using these assumptions, starting with data for 1995, the DeLury model outlined in equations (1) and (2) was used recursively to estimate biomass and catch in 1996 and future years, using figures for future fishing mortality from the plan schedule. The surviving stock numbers in each year after 1995, net of natural and fishing mortality, were incremented in average age by one year, starting from the 1995 stock.

$$a_t = \frac{a_t^N N_t + a^R R_t}{N_t + R_t} \tag{4}$$

where:

a_t = the average age of catchable scallops in the population at the start of year t;

a_t^N = the average age of the already catchable (fully recruited) scallops at the start of year t;

a^R = the average age of newly catchable scallops (recruits), assumed constant in each year.

$$a_{t+1}^N = a_t + 1. \tag{5}$$

The average age of already catchable scallops at the start of year $t + 1$ is equal to one plus the average age of newly recruited and already catchable scallops at the start of the previous year. This assumes that the fishing gear is not selective for scallops of different ages once the minimum recuitment size is reached. It also assumes that all recruitment occurs at the start of the year, since estimates of the numbers of recruits are already adjusted for recruitment that takes place within the year.

Then, the change in biomass was estimated by using empirical relationships between age and shell height and between shell height and weight. These equations estimated by NMFS fisheries scientists can be used to establish a relationship between weight and age.

$$W = \exp\,[-11.7656 + 3.1693 \ln H], \tag{6}$$

where W is weight of scallop meat in grams and H is height of scallop shell in millimeters;

$$H = 145\,[1 - \exp\,(-0.2783\,\mathrm{A} - 0.755)]. \tag{7}$$

Over the relevant range of scallop shell heights, the resulting relationship is approximately linear, so that average scallop weight can be expressed as a function of average scallop age.

$$w_t = f(a_t) \tag{8}$$

The alternative estimate was generated using the same procedure with the single exception that fishing mortality in the initial year, 1995, was reduced by a small amount. Fishing mortality in subsequent years remained equal to that in the base case, which conformed to management plan targets. The differences in catch and surviving stock, both calculated in weight, were calculated for 1996 and future years out to 2010. A small reduction in the current harvest yields higher future harvests and biomass because of the scallop's significant unrealized growth potential when harvested shortly after recruitment, as has been typical in the fishery.

The increment in harvest and harvestable biomass were then valued according to the net rent method described above, assuming constant prices and a constant schedule of percentage premia for larger scallops. Then, the present value of the stream of incremental future values was calculated using an inflation-adjusted real interest rate of 3 percent per year. Finally, this present value was divided by the reduction in the 1995 harvest of scallops due to the assumed marginal reduction in fishing mortality in that year.

The discounted present rental value of the harvested and surviving biomass over the period $j = 0$ to $j = T$ is given by the equation

$$V = \sum_{j} \{(1/(1 + i)^{j}[(p_j - c_j)w_j C_j + (p_{j+1} - c_{j+1})w_{j+1} N_{j+1}]\}, \tag{8}$$

where:

V = the discounted present rental value of future biomass stocks and harvests;
p_j = the average price applicable to the population and catch in year j;
c_j = the marginal harvesting costs in year j;
i = the rate of time discount;
w_j = the average weight of population and catch in year j.

The augmented value of the discounted future rental value of biomass stock and harvest was estimated under the assumption of a small reduction in fishing mortality and catch during the initial year. Fishing mortality in the initial year was assumed lower by an amount $(m_0^f - \Delta m_0^f)$.

$$V^* = (p_0 - c_0)w_0(C_0 - \Delta C_0) + (p_1 - c_1)w_1 N_1 + \sum_{j=1}^{T} \{1/(1 + i)^{j}[(p_j - c_j)w_j C_j + (p_{j+1} - c_{j+1})w_{j+1} N_{j+1}]\} \tag{9}$$

$$U = (1/w_0 \Delta C_0)(V - V^*) \tag{10}$$

This user cost estimate measures the discounted rental return from leaving an additional pound of scallops alive in the population to grow and augment future harvests and biomass. The user cost measures the marginal value of the scallop population as a "going concern," in contrast to its current liquidation value.

The user cost measure was constructed for each year in the period 1985–95, using projected biomass and harvests out to the future year 2010. The estimating procedure has been described in some detail for the 1995 estimate. Estimates for earlier years 1985–94 were derived by similar procedures, except that estimates of actual fishing mortality for those years were substituted for those prescribed in management plans.

III. Results of the Analysis

The asset accounts constructed for the Atlantic sea scallop fishery for the period 1985 are presented in Table 2. They show a physical biomass that grows substantially until 1990 and then declines even more dramatically from that time until 1995. This fluctuation reflects the unusually high recruitment to the fishery during 1989 and 1990, as indicated in Table 1.

TABLE 2

Value Accounts, 1985–95

Year	Biomass Stock (million pounds)	Net Rent Value ($ per lb)	User Cost Value ($ per lb)	Net Rent Stock Value (million dollars)	User Cost Stock Value (million dollars)
1985	20.29	1.40	4.48	28.41	90.90
1986	25.37	1.49	4.43	37.80	112.39
1987	30.70	1.08	4.22	33.16	129.55
1988	30.90	1.08	3.59	33.37	110.93
1989	35.07	0.95	3.09	33.32	108.37
1990	35.01	0.90	3.06	31.51	107.13
1991	25.35	0.98	2.95	24.84	74.78
1992	16.49	1.45	3.64	23.91	60.02
1993	18.85	2.20	3.36	41.47	63.34
1994	17.35	1.49	4.51	25.85	78.25
1995	22.62	1.59	5.49	35.96	124.18

The estimated resource values are marked by a preponderance of scallop user costs over their net rental value throughout the period. On average, the value of a scallop left in the ocean to grow and reproduce, thereby increasing future harvests and harvestable biomass, was three times greater than its liquidation value, its net rental value brought to the dock. This imbalance is characteristic of an inter-temporally inefficient pattern of resource exploitation. It demonstrates that the potential gains from an additional investment in resource conservation in the scallop fishery throughout this period were great. In an inter-temporally efficient fishery, the current harvest would be curtailed until the returns from further stock conservation would be no greater than the net rent from a marginal increase in the current year's catch. In the scallop fishery between 1985 and 1995, each dollar in net operating income sacrificed in the name of conservation would have brought a return in future harvests of three dollars, measured at its discounted present value.

It has been suggested that this difference can be explained by the use of the risk-free discount rate for estimation purposes, a rate lower than the risk-adjusted cost of capital facing fishermen in private markets, which would lead them to value future harvests less than calculated above. The use of a higher discount rate in the analysis would reduce the user cost estimate relative to the net rent estimate. Though private costs of capital are higher than the 3 percent real interest rate used in the calculations, the principal explanation is the much higher—nearly infinite—implicit discount rate facing individual fishermen as the result of insecure harvesting rights. Investments in stock conservation are highly discounted because no individual fisherman is assured of reaping benefits from his decision to forego an immediate harvest. This explanation is confirmed by the fact that Canadian scallop fishermen, who also face private market costs of capital but enjoy secure harvesting rights, harvest almost no immature three-year-old scallops and maintain a much lower overall exploitation rate on their scallop resource (Repetto, 2001). Because the growth rate of three- and four-year-old scallops is so high and is amplified by the applicable price premia for larger scallops, the private cost of capital would have to be far higher than it is to justify the premature harvesting observed in the U.S. fishery. The discrepancy between the net rental and user cost values of the scallop resource is mainly the consequence of the management agency's inability to enforce an intertemporally efficient harvesting regime in the face of the underlying market failure.

Both valuation measures move in rough parallel to each other over the period and vary inversely to variations in the physical stock. Movements in the net rental value are governed primarily by changes in scallop prices, which vary inversely to the catch. Movements in the user cost value of scallops, however, are more significantly affected by movements in fisheries mortality, since the return obtained from conserving the current rapidly-growing stock depends on the rate at which it will be depleted by harvests in the ensuing years. The rise in the user cost measure in the final years of the period is influenced by the targeted decline in fisheries mortality during the period 1996–2005, as adopted as the fisheries management plan target and implementing policies. Similarly, the decline in the user cost value during the middle years of the 1985–95 period is largely attributable to the heavy fishing mortality experienced during the early years of the 1990s. Thus, the user cost value is inherently a forward-looking measure that capitalizes the fruits of future conservation investments and can be used to evaluate conservation policies.

Valued in 1995 by the user cost measure, the scallop fishery resource was an asset worth approximately 125 million dollars—not an insignificant amount. However, this represents a biomass stock at most 20 percent as large as that stock which would produce the fisheries' maximum sustainable yield, according to the Fisheries Management Council's estimates (New England Fisheries Management Council, 1998). In other words, in rough terms the potential capital gain that would result by rebuilding the scallop stock to its most productive level is probably of the order of a half-billion dollars, exclusive of any additional increases in net rental values that would result from rationalization of fishing effort. Increases in net rental values would be expected as well, because larger and more abundant scallops could be harvested with far more catch per unit effort than currently achieved in the fishery. Some empirical indication of this potential gain is available from the experience in the closed areas of George's Bank, in which, according to sample survey data, scallop populations have evidently rebounded markedly in abundance and average size after fishing pressure was reduced. Partial opening of some of these closed areas to scallop boats has allowed an increased harvest with lower overall fishing mortality.

IV. SUMMARY

In broader context, this case study demonstrates that it is feasible to construct resource asset accounts for marine fisheries in accordance with accepted economic methodologies, relying mainly on data already available from National Marine Fisheries Service research and management studies. Such accounts shed light on important management and regulatory issues. Though there is no census of the fishes, fisheries scientists are able to estimate population sizes of important commercial stocks with reasonable accuracy, and do so for crucial management decisions. This demonstration should encourage the Fisheries Service and the Bureau of Economic Analysis to consider extending such resource accounts to other fisheries as well and to adopt resource accounting for marine fisheries as a regular part of any future Integrated Economic and Environmental Accounting work program.

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