International Council for the Exploration of the Sea

CM 1993/D:67

Economic Aspects of the Yield per Recruit Curve

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As fishermen strive to maximise profit from catch, it is desirable to consider Yield per Recruit (Y/R) in financial terms. Application to Y/R data of financial values with a size differential based on that in EC withdrawal prices, results in an increased peak in F max values in the plot of the Y/R function, showing that yield at F max exceeds yield at current F values to a greater extent in financial terms than it does in weight-based terms.

INTRODUCTION

The traditional omission of economic parameters from stock assessments procedures has the problem that it fails to grasp an opportunity to strengthen the significance and applicability of the assessment. Inclusion of financial values, of earnings and if possible costs permits a much fuller and more realistic assessment of the implications of overfishing and of a future situation sought in which the level of effort and thus of fishing mortality would be set as close as possible to the level yielding maximum sustainable profit.

MATERIAL AND METHODS

To illustrate the steps involved in moving from the yield per recruit curve presented in current ICES Working Group Reports (e.g. Anon. 1992) to maximum sustainable profits, examples have been chosen from the Irish Sea of a severely overfished fish stock, cod, and a species optimally fished or slightly underfished in biological terms, the eastern Nephrops stock. The analysis presents the increase in profit corresponding to reduction of F (fishing mortality) from F current to F max shown on the yield per recruit curve in figure 1, and shows time paths of change in yield in weight, catch value profit untreated and future discounted at an annual rate of 25%. The reductions in F values selected are immediate reductions by 40% and by 60% (to 0.6 and 0.4 respectively of

initial F) and reduction by six successive steps of 10% of initial F to arrive at 0.4 of initial F.

In calculating profit, fixed costs i.e. overheads, costs of which the level does not change with the level of fishing activity) were taken as 20% of current revenue, and variable costs (i.e. running costs, which are proportional to the volume of activity undertaken), were taken as 30%, leaving 50% of current revenue as profit, which here is taken as including crew pay which, being share-based, depends on catch revenue in the same way as owners profit net.

The dashed lines give the level of costs where the size of the fleet is deemed to be reducable, since in such a situation all costs of a vessel may be considered variable. the increase in profits with this system is obviously somewhat greater than with a fleet of fixed size (reducing effort by reducing fishing time) but has obvious repercussions on employment. However, to avoid duplication, this paper examines effects of reducing F for the fixed fleet situation only. The values approximate to values reported for Northern Ireland (Davis & Banks 1985) and for the Republic of Ireland (Crutchfield et al. Data regarding boats' costs and earnings tend rather quite variable and to be sensitive, so achievement of extreme accuracy is neither realistic nor appropriate. It may however be observed that the values chosen represent a fishery in reasonably good condition, and in recent years especially there are numerous examples of boat profits (including crew shares) at levels far below 50% of revenue. In such cases, reduction of F will lead to greater factors of increase of profit than are realised for the same effort reduction starting from 50% of initial revenue though the absolute levels of profit achieved will be somewhat less.

Since large fish are generally more valuable per kilo than small fish, reduction of F will result in an increase in catch revenue in the middle and long-term greater than that in catch weight; and since reduction in F implies reduction in fishing costs the increase in profits resulting from reduction of F will exceed the increase in revenue.

The common economic practice in assessing the balance of benefits against costs in any enterprise is to reduce further streams of revenue and expenditure by an annual discounting rate to represent the progressive decreasing in value attached to transactions with increasing distance into the future viewed from now, the Net Present Value (NPV). For example, the Irish Department of Finance uses a rate of 5% for this purpose, and the British Treasury 4%. However these modify the behaviour of changes with time in profit after reduction of F only very slightly. Since there is strong evidence that boat owner's and skipper's thinking is based on very much higher future discounting rates, a discounting rate of 25% has been applied to simulate the scenario as viewed by the fishermen; there are indications that in many cases the fishermen's discounting rate may actually be much higher than this (Hillis and Whelan, 1992).

RESULTS

Changes in catch weight, catch revenue, undiscounted profit and profit future discounted at 25% per annum are shown in Table 1 and in Figures 2 and 3. Table 1 gives the main parameters of interest; percentage change in the first year, 1993 of the period examined and in he last year, 2005, by which time values resulting from single changes in F at the beginning of the period should have stabilised, and those resulting from six successive changes should have almost done so. The extent and duration of initial loss are of great importance, as is the duration of the period of cumulative loss, i.e. until long-term gains outweigh initial losses. Overall gain (or loss) over the period is shown as a percentage of one years weight, revenue or profit at initial F values and this is also given divided by the number of years to present it as an average percentage change over the whole period.

The results clearly confirm that gains in revenue are greater than those in catch weight and that gains in profit are substantially greater than those in revenue, in the case of cod; with eastern Nephrops, the situation is similar, but with losses in catch weight and in revenue (apart from differences in 2005) which become gains in the case of undiscounted profit. Discounting of profit reduces gains more than losses (since they will occur later) and reduces, and in some cases reverses the net present value of the aggregate accuring changes in discounted profit.

Regarding the immediate reduction in F giving the greatest gains it will be seen that for the long term gains 0.4, is better that 0.6 with cod, but in eastern Nephrops 0.6 is better than 0.4 in both short and long term. For cod, within the range of these values the greater immediate reduction gives much greater increases in the long term and better mean increases over the period stepwise reduction greatly reduces the magnitude of initial loss, but does so at the cost of spreading it over a longer period of years it will be noticed that, while the annual increase with cod, in 2005 is almost as great after stepwise reduction to 0.4 of initial F as it is with immediate reduction to that value, the mean annual increase in gains is very much less, reflecting the much less rapid rise towards the maximum obtained in this way.

Looking at the three F reduction values with cod, reduction to 0.6 of initial F has the advantage of a combination of relatively small initial loss coupled with shortness of initial loss period. However 0.6 of initial F is still too high a value for this species and for long term results, 0.4 immediate or stepwise give greater gains in year 2005 and in the case of profits, greater gains over this period as a whole. The choice between the two rates of reduction to 0.4 of initial F is a trade off between the very substantial immediate losses with immediate reduction, and the very slow upward movement towards the level of asymptotic gains with stepwise reduction so that while annual values in 2005 are very close, the mean

annual gain over the whole period with stepwise reduction is very much lees than that with immediate reduction to 0.4 of initial f gives in every case greater gains than stepwise reduction, gains with the latter simply never catch up.

Discussion

With cod, Figure 2 shows that reduction to 0.6 and 0.4 of initial F (Fi) results in initial decreases of slightly less than 40% and 60% respectively as there will already be some improvement due to growth in the latter part of the year; long term catch weights stabilise at +19% for F=0.6 Fi and +32% for F=0.4Fi. Net gain over the period is least with the stepwise reduction to 0.4Fi, since the descent of F to the value closest to F max is so slow. The greater average unit value of the older fish increases long term gains in revenue to considerably higher levels, +27% and +47% for F=0.6Fi and 0.4Fi respectively. Again, taken over the period as a whole, the stepwise reduction is least productive. When profit (undiscounted) is considered, the lower level of costs at F=0.4 Fi than at F=0.6Fi makes the stepwise F=0.4 Fi gain higher than that for F=0.6Fi although still considerably less than immediate F=0.4Fi. With profit discounted at 25%, net gains over the period (total and mean) are drastically reduced and, as Figure 2D shows, results with stepwise reduction to 0.4Fi are poorest, as by the year 2000, when gains start to exceed those for 0.6Fi the net present values of any gains are already heavily discounted.

In the case of eaten Nephrops by contrast where F=1.0Fi is approximately optimal , catch weights at 0.6Fi and F-0.4Fi represent underfished situations and never equal that at Fi. Due to the greater unit value of older Nephrops, however, revenue in 2005, is slightly higher (+6.9%, +2.5%, +0.2%) with reduced F values, though clearly not enough to compensate for the initial losses. With the reduction of costs of inflicting F implied by the effect of reduced F on profit , heavy initial losses (42%, 88% and ___% respectively over 3,3 and 7 years respectively) are succeed by profits rising to levels in 2005 of 38%, 46% and 35% respectively; with mean annual changes over the period of +15.8%, +7.0% and -0.1% respectively.
Application of a 25% time discounting rate gives 2005 gains of very small net present values (about 1%) however above profit with 0.1Fi but makes mean annual gains for all three reduction regimes negative.

Discussion

The analysis shows that for a seriously overfished species, cod immediate reduction of F to 0.6Fi or 0.4Fi will yield gains in catch and revenue from year 3 and profit from year 4 onwards, whilst reduction to 0.4Fi by steps of 0.1Fi delays the sharp recovery in weight and revenue until year 7 although profit is already at break-even point in year 2. However, 25% discounting affects profit from this

regime, (since it is extremely small up to year 6) much more than with the immediate reduction regimes. All in all, F=0.4 Fi yields greater gains in the long term an overall, than F=0.6Fi (and as Figure 1 indicates, F max is nearer 0.2Fi).

In the case of eastern Nephrops, the level of Fi is close to optimal in terms of catch weight, and none of the F reduction regimes effects any improvement. Revenue is slightly improved by both immediate reduction regimes with F-0.6Fi the best. Undiscounted profit shows the highest level in 2005 with F=0.4Fi (immediate), though the mean gain over the period with F=0.6Fi is greater; the delay in commencement of improvements with 0.4Fi (stepwise) is very apparent from Figure 3C. Applying 25% annual discount results in none of the three regimes showing gains over F=1.0Fi in net present value, with the long term gains realised with all three also very much reduced by the discounting process.

While it is clear that the boost given to the stock and its potential for growth by substantial immediate reduction in F plays an important part in allowing catches to increase soon thereafter, stepwise reduction has one point to commend it the very important one that initial losses are kept down to an extremely low level and it may well be that the fishery managers choice of whether to reduce F fast or slowly will depend on the acceptability of a severe initial reduction in revenue and profit. The arguments in favour of keeping losses low include not only avoidance at disruption to boats, but also avoidance of disruption to the downstream (fish merchanting and processing) and upstream (vessel supplying and servicing) industries; any attempt to devise a scheme to compensate the industry financially for the consequences of an immediate substantial reduction in F would have to take this into account.

The annual discounting of losses and gains in profit by 25% is suggested to give an explanation of why it is so difficult to commend effort reduction schemes to the industry. For state cost benefit analyses, rates of 5% and 4% are used in Ireland and the United Kingdom respectively; the gains and losses resulting from these rates would only differ relatively slightly from the undiscounted profit data. Hillis and Whelan (op.cit) showed that where money is concerned the fishermen's discounting rate was about 25%, but where money is concerned the their expressed views implied a rate of around 55%. Acceptance of this discounting rate would imply that overfished fisheries were beyond redemption. While a high discounting rate may result from working in an environment of a high degree of uncertainty and its basis in the nature of the common access resource are will understood, nonetheless the gains which can be accessed in the medium and long term by reducing effort in the short appear by most criteria to be substantial in the case of heavily fished species like cod and whiting.

It is suggested that the contribution of this paper has been to demonstrate the relationship between losses and gains in catch weight, in revenue and in profit,

along with the effect of applying a high rate of future discounting to simulate industry views of attempts to optimise F values.

Acknowledgements

The assistance of B. Deegan, D. Keogh, I. Church and E. Egan towards production of this paper is gratefully acknowledged. The work reported here is derived from work done under the European Communities FAR Project MA.1.222. The funding contribution of the Commission of the European Communities is likewise gratefully acknowledged.

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		COD			NEPHROPS EAST		
F/ F initial							
		0.6	0.4	by 0.1 to 0.4	0.6	0.4	by 0.1 to 0.4
Catch Weight	% difference 1993	-28.9	-48	-6.2	-34.4	-54.2	-8.5
	% difference 2005	19.4	32.6	32.1	-5.2	-14.6	-16.4
	Sum of % initial loss	-36	-69.6	-45.2	-156	-327.6	-282.1
	Years of loss	2	2	6	13+	13+	13+
	Years of cummulative loss	5	6	8	13+	13+	13+
	Sum of net % gain 1993-2005	153.4	215.8	124.8	-156	-327.6	-282.1
	Mean annual % gain 1993-2005	11.8	16.6	9.6	-12	-25.2	-21.7
Revenue	% difference 1993	-28.4	-47.5	-6.1	-34.6	-54.3	-7.9
	% difference 2005	27.5	46.9	46.3	6.9	2.5	0.2
	Sum of % initial loss	-32.4	-64.8	-26.9	-89.6	-195.3	-189.9
	Years of loss	2	2	6	6	9	13
	Years of cummulative loss	4	4	7	13+	13+	13+
	Sum of net % gain 1993-2005	242.3	363.7	231.3	-53.6	-186.9	-189.9
	Mean annual % gain 1993-2005	18.7	28	17.8	-4.1	-14.3	-14.6
Profit Undiscounted	% difference 1993	-32.7	-59	-6.2	-41.8	-87.6	-5.5
	% difference 2005	79.1	129.8	128.7	37.8	46.1	35.5
	Sum of % initial loss	-32.7	-59	-7.2	-79.5	-164.9	-148.8
	Years of loss	1	1	2	3	4	7
	Years of cummulative loss	2	3	2	7	10	13+
	Sum of net % gain 1993-2005	797.1	1195.4	841.1	205.4	91	1.3
	Mean annual % gain 1993-2005	61.3	91.9	64.7	15.8	7	-0.1
Profit discounted at 25%	% difference 1993	-28.4	-51.1	-5.4	-39.1	-62.9	-8.5
	% difference 2005	2.1	3.5	3.5	1	1.1	1
	Sum of % initial loss	-28.4	-51.1	-6.1	-60.1	-114.8	-164.4
	Years of loss	1	1	2	3	4	7
	Years of cummulative loss	2	3	3	13+	13+	13+
	Sum of net % gain 1993-2005	106.7	125.8	69.7	-31.6	-94.8	-43.5
	Mean annual % gain 1993-2005	8.2	9.7	5.4	-2.4	-7.3	-3.3

Table 1. Changes in catch weight, revenue, undiscounted profit and profit discounted at 25% annually, 1993-2005 corresponding to reduction of F value to 0.6, 0.4 (immediate) and 0.4 (in 6 steps of 0.1) of initial value

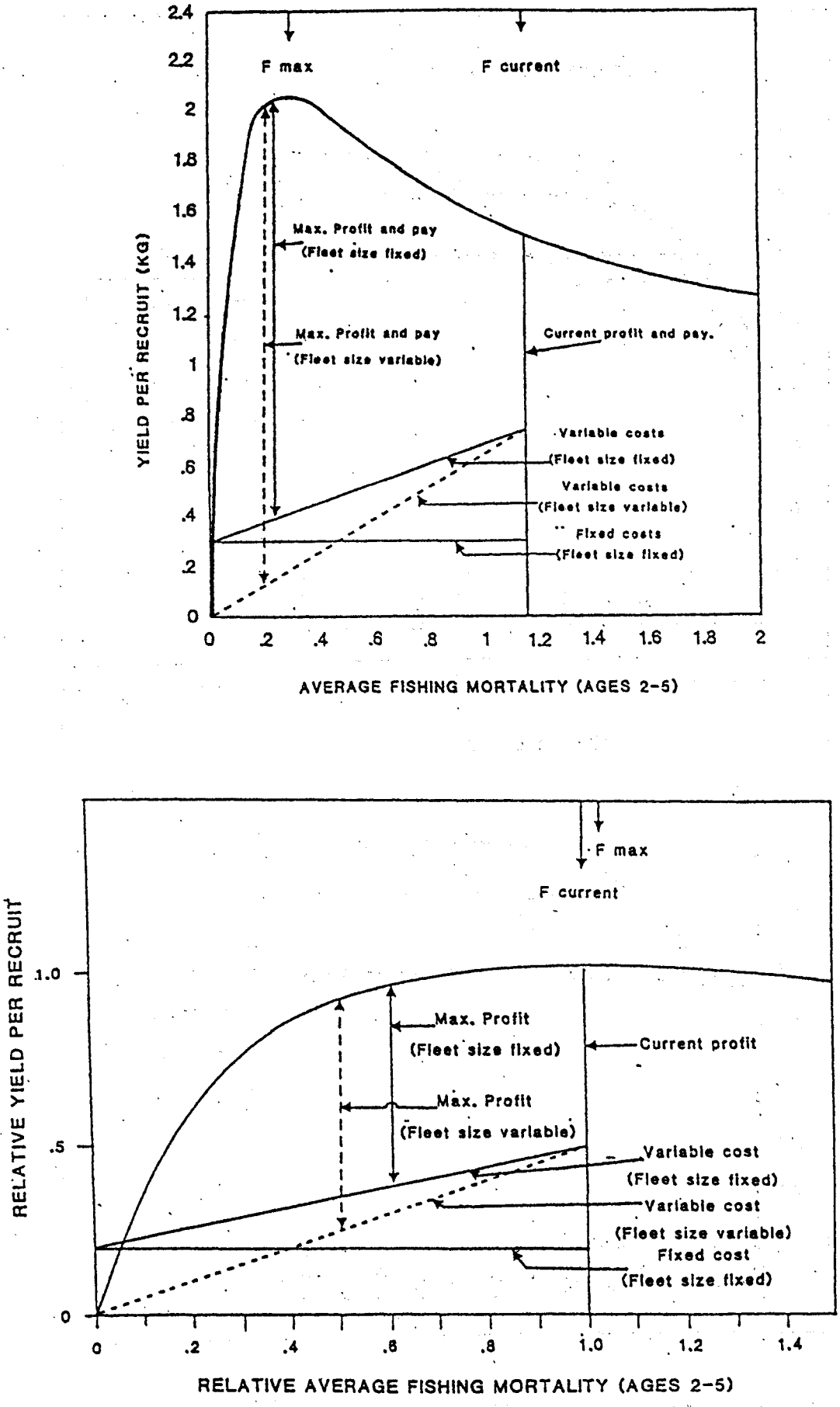
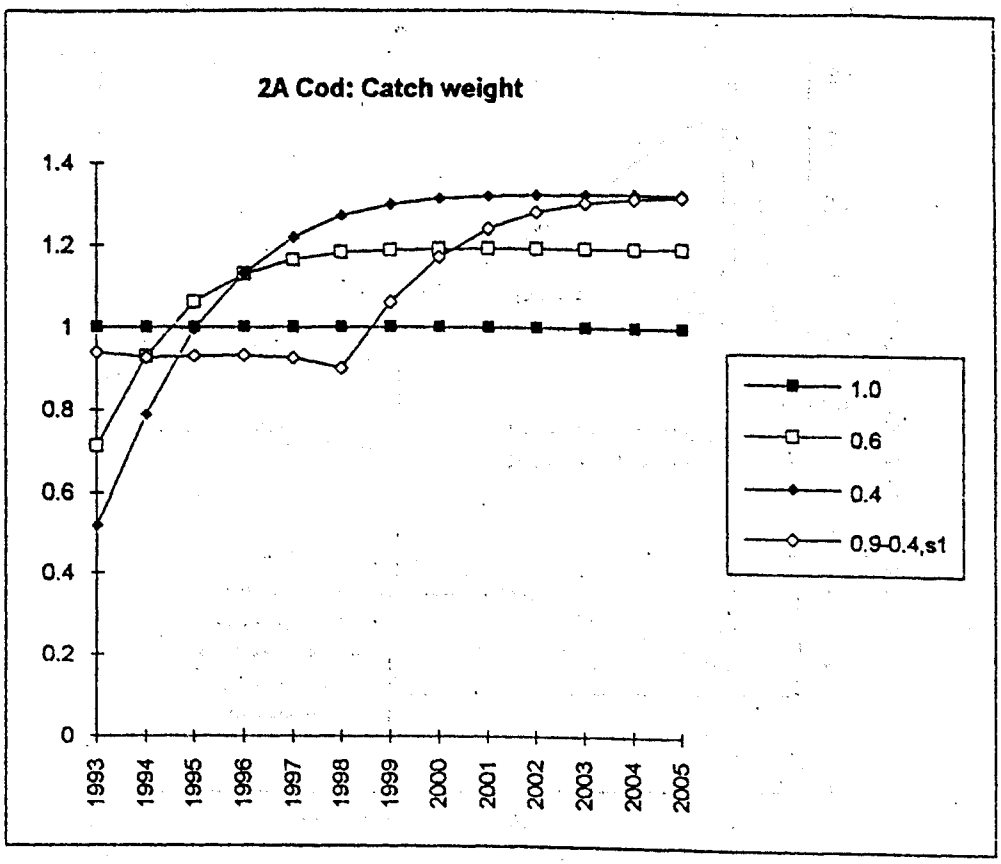


Figure 1. Yield per recruit for Cod in the Irish sea and relative yield per recruit for Nephrops in the eastern Irish sea.



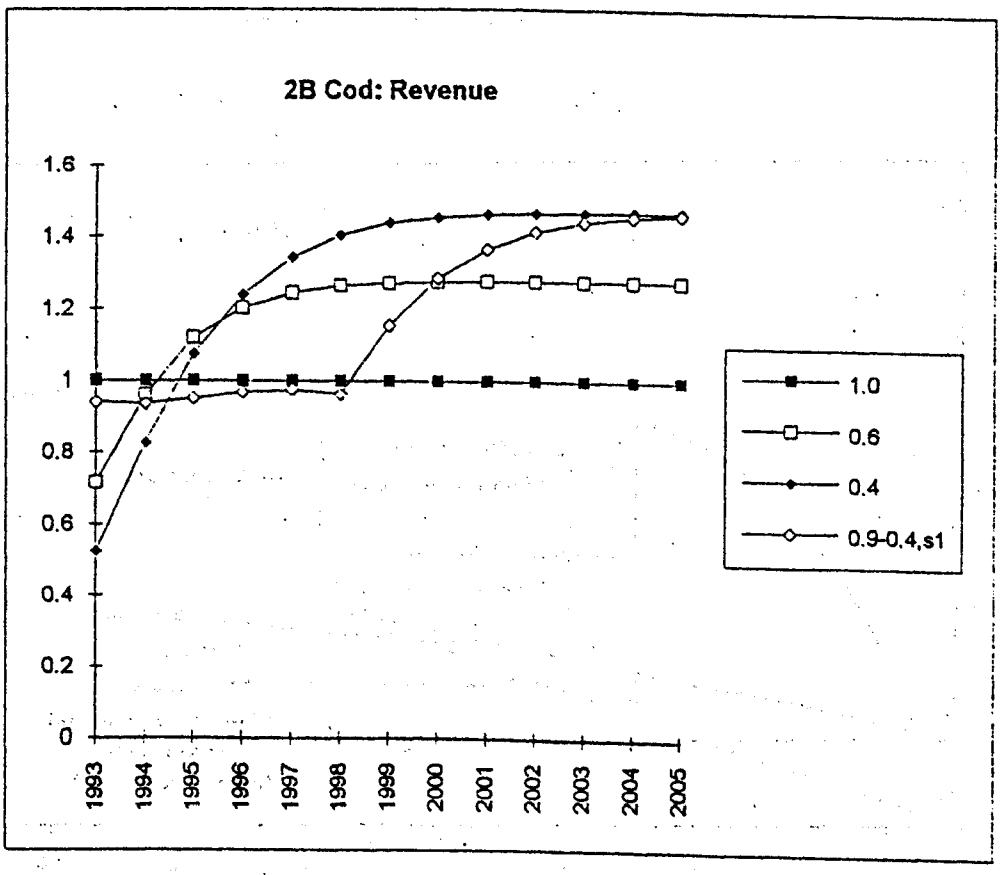
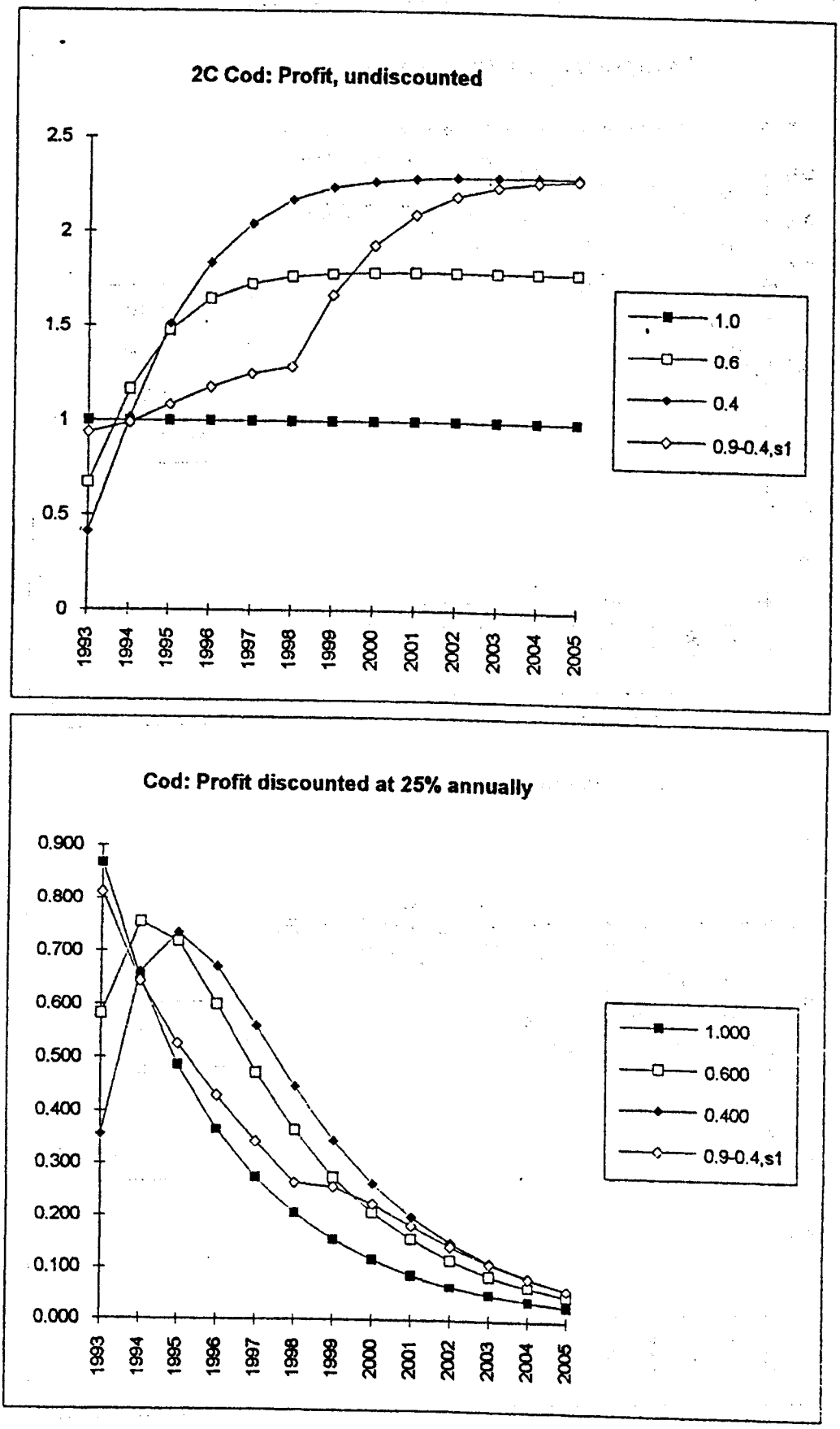


Figure 2. Cod: Changes in (A) catch weight, (B) revenue, (C) undiscounted profit and (D) profit discounted at 25% annually 1993-2005, corresponding to reductions in F values 0.6, 0.4 (immediate) and 0.4 (in 6 steps of 0.1) of initial revenue



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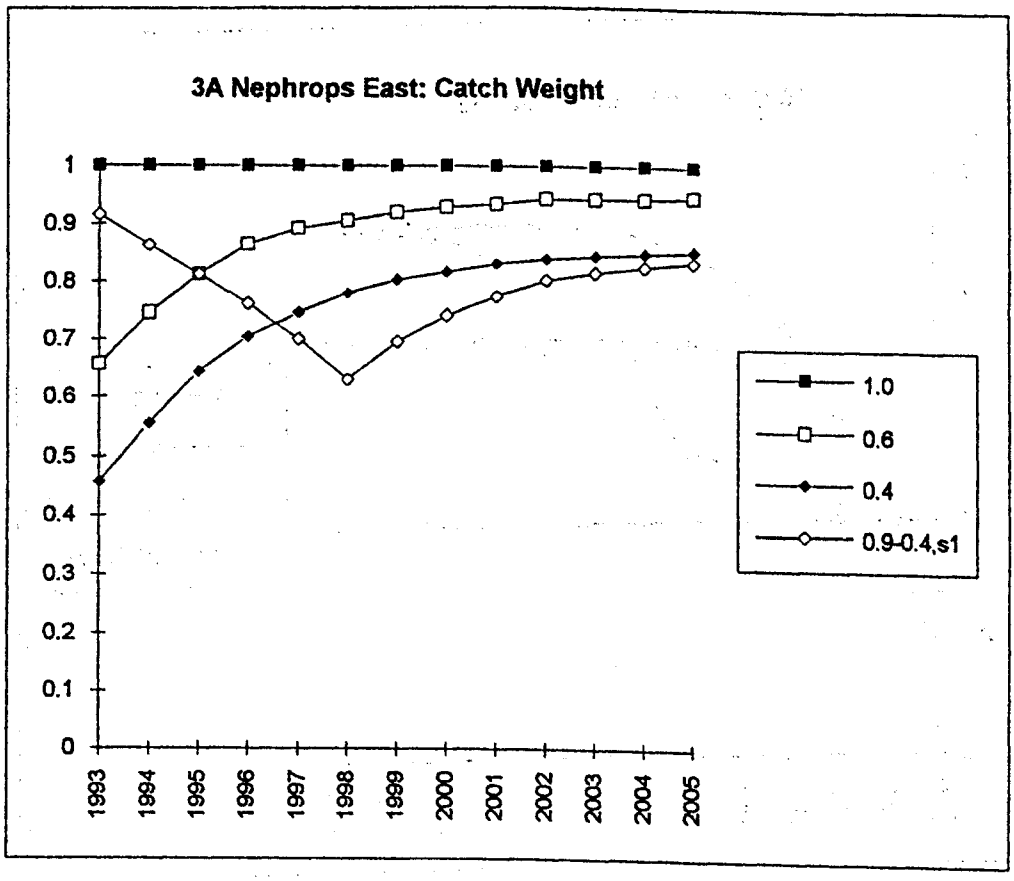


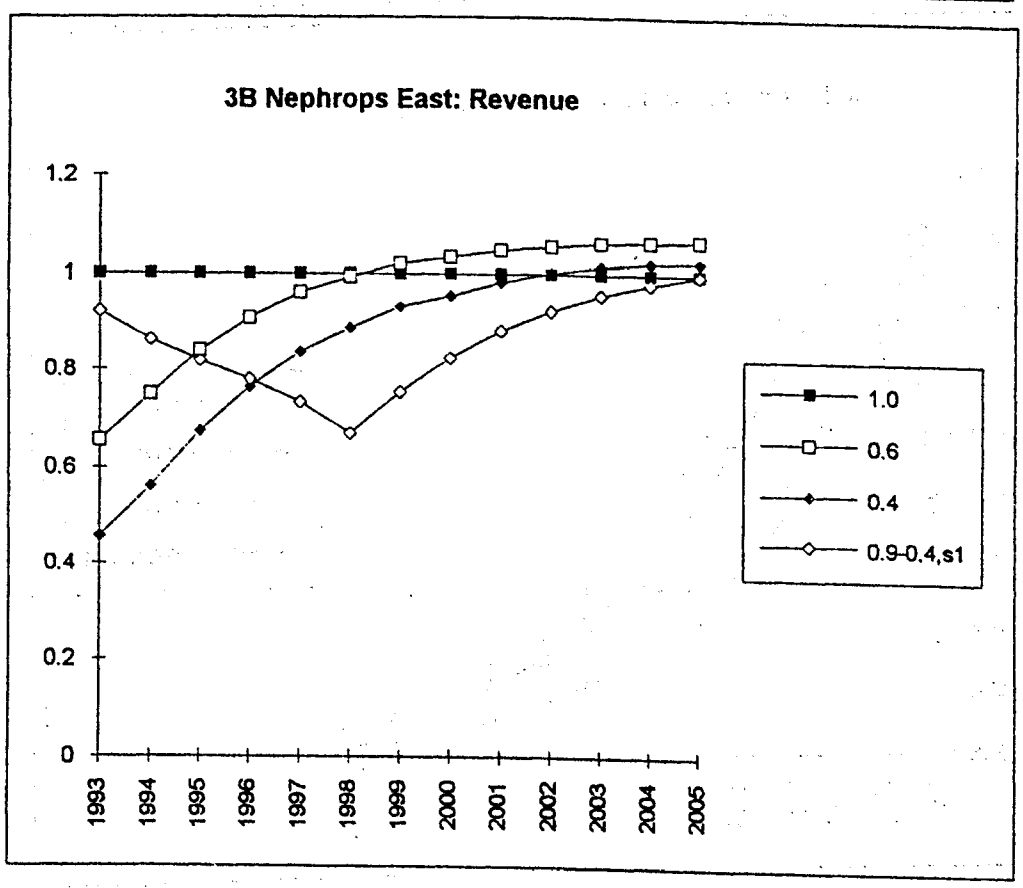
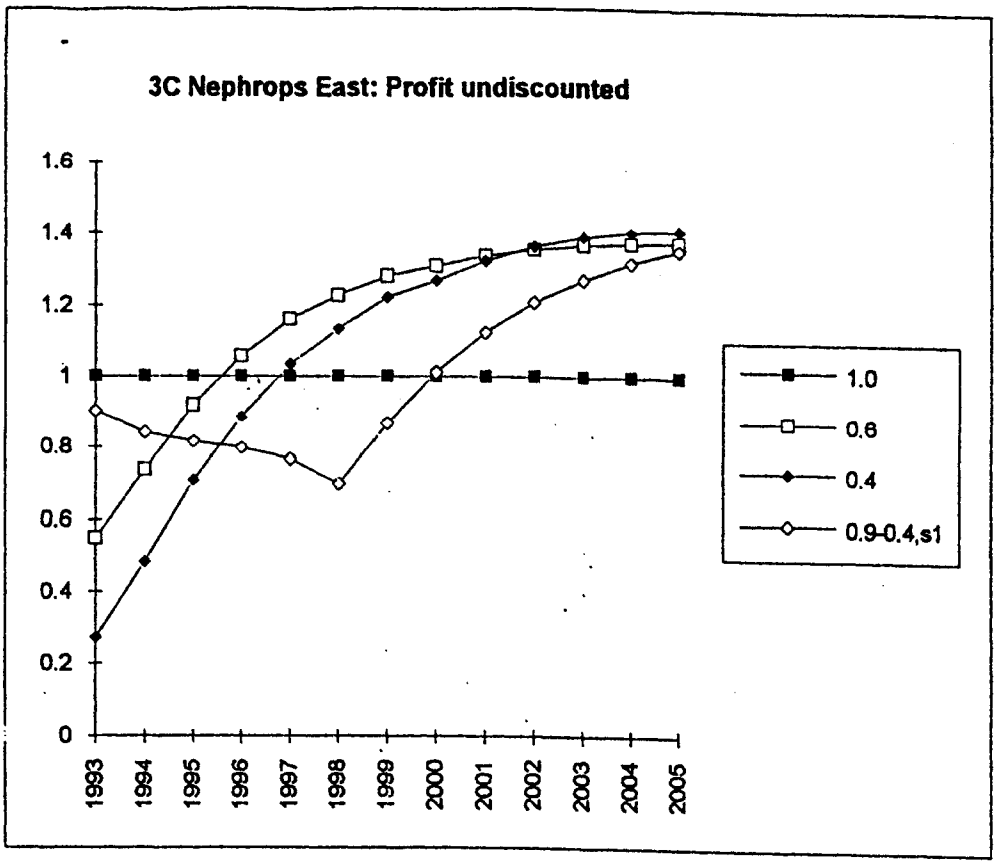
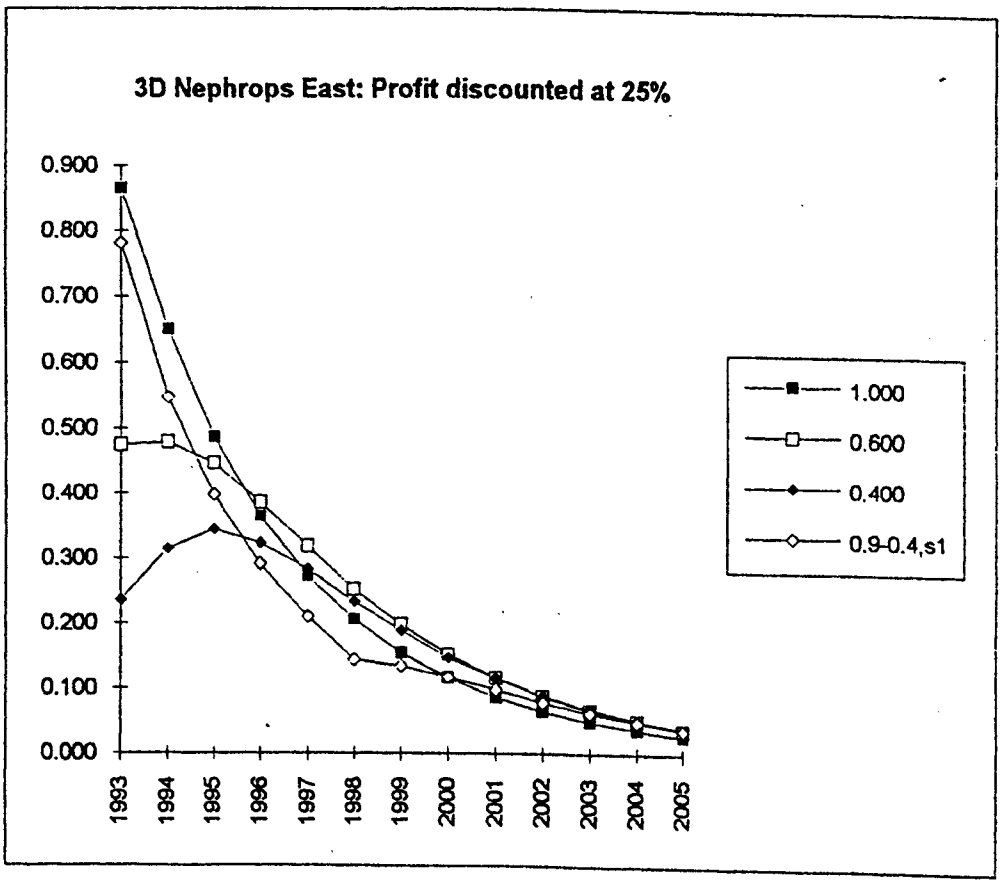


Figure 3 Nephrops East: Changes in (A) catch weight, (B) revenue, (C) undiscounted profit and (D) profit discounted at 25% annually 1993-2005, corresponding to reductions in F values 0.6, 0.4 (immediate) and 0.4 (in 6 steps of 0.1) of initial revenue





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