National University of Ireland, Galway
Ollscoil na hÉireann, Gaillimh

# A Comparison of the Effects of Decommissioning, Catch Quotas, and Mesh Regulation in Restoring a Depleted Fishery

J. Paul Hillis Vilhjálmur Wiium

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## Abstract

Possible means of rehabilitating the many depleted fisheries in European waters now form a topic of great interest and relevance. This paper uses bioeconomic analysis to predict returns for the Irish Sea *Nephrops* fishery from rationalisation through three types of management regulations. These regulation measures are (a) decommissioning, i.e., reducing fleet size, (b) catch quotas, while maintaining fleet size, and (c) mesh size regulation. The analysis clearly demonstrates the gains to be obtained from rationalising the *Nephrops* fishery. In addition, socio-economic implications of trying to preserve employment levels while rationalising are examined. This is done by attempting to anticipate the reactions of the industry to the different management processes. The paper concludes that the current performance of the fisheries compared to potential profitability is extremely poor. Substantially improved returns would result from strong management control. However, trying to preserve social equity, while theoretically possible, would necessitate complicated constraints to the operation of the management system.



**Keywords:** Fisheries management, decommissioning, catch quotas, mesh size regulation, Irish Sea, *Nephrops*

**JEL Classification:** Q21, Q28

# 1 Introduction

The overexploitation of most of the commercially important fish stocks of the world is well documented by now. Improving the situation is proving a very difficult task. Various attempts have been made, but most have failed. Overcapacity is a chronic problem in fisheries, and low income levels of fishermen are also widespread. The main difficulty in restoring a depleted fishery comes from the fact that it is not possible to move from an equilibrium of depletion to an improved situation without sacrifices. This is because fish stocks must be rehabilitated before harvest can be increased, and such rehabilitation always takes time (see e.g., Clark, 1985, p. 7). These sacrifices can take various forms, such as income reductions in the short run and unemployment for members of the industry.

The main fisheries in the Irish Sea are a good example of depleted fisheries. However, they are also fisheries where it seems reasonable to assume that remedy is possible. The fish stocks in the Irish Sea are relatively isolated with only few countries involved in harvesting. Restoration of a growth overfished fishery implies reducing that overfishing to improve profitability. The advice of the International Council for the Exploration of the Sea (ICES) to the EU Commission and the EU Council so far consists of advising total allowable catches for the next year only. If ICES advice covered further ensuing years, it could be shown that the fishery would start recovering, provided that the advised catch reduction was actually adhered to and implemented.

In this paper the focus is on the *Nephrops* fishery of the Irish Sea. The paper analyses and compares three possible management systems for the *Nephrops* fishery. They are: (a) reducing fleet size, i.e. decommissioning, (b) introducing catch quotas, while maintaining the size of the fleet, and (c) imposing mesh regulation. All these management options reduce fishing mortality, thus increasing the stock size of *Nephrops*, but each has different effects on costs in the industry. Incidentally, if the objective of decommissioning is to reduce effort by a specific factor, then it follows that remaining boats must be prevented from investing in increased on-board capacity, which they will be tempted to do in response to incipient improvements in the fishery due to the increased stock size. The objective is to maximise, or failing that, improve returns from the fishery, while at the same time minimising the sacrifices of fishermen. Maximising returns while minimising sacrifices seems to correspond well to most governments' stated objectives for fisheries.

The next section briefly describes the methodology behind the analysis. Then the results of simulation runs for the *Nephrops* fishery are reported followed by a discussion and analysis of the results.

## 2 Methodology

The model used to describe the biology of fish stocks is a modification of the Beverton and Holt (1957) dynamic pool model (see e.g., Hannesson, 1993). In the model a fish population consists of a number of different cohorts. Let $N_t$ denote the number of fish in a single cohort at time $t$; recruitment being given and occurring at $t = 0$, i.e., $N_0 = R$. If $w_t$ represents the average weight of fish at time $t$, then the total biomass of the cohort, $B_t$, is

$$B_t = N_t w_t \tag{1}$$

Average weight, $w_t$, is assumed to increase with the age of fish, but at a decreasing rate, such that the proportional weight change, $\dot{w}/w$, decreases with time[1].

The function $N_t$ is assumed to change over time as

$$\frac{dN}{dt} = -(M + F)N \tag{2}$$

where $M$ the natural mortality rate and $F$ is the fishing mortality rate for cohort $t$.

Without going too much into detail, it can be shown (e.g., Hannesson, 1993, p. 67) that sustainable annual yield from a fish stock consisting of multiple cohorts equals

$$Y = \sum_{i=t_{\min}}^{t_{\max}} \frac{F_i}{F_i + M} \left(1 - e^{-(F_i+M)}\right) w_i R e^{-\sum_{j=t_{\min}}^{i-1}(F_j+M)} \tag{3}$$

where $t_{\min}$ is the age at which fish are recruited, $t_{\max}$ the age at which they disappear from the stock, and $t > t_{\min}$. Equation 3 simply takes the yield from each cohort, recognising that fishing mortality differs among cohorts, and adds them up to get the total yield from the stock. In this model the only variable that can be affected by policy is fishing mortality. By regulating fishing effort, e.g., the number of vessels, days at sea, or minimum mesh size, different levels of fishing mortality may be reached. For example, Figure 1 shows two yield curves, one where the age at first capture is relatively low — representing a small mesh size — and the other where the age at first capture is relatively high — representing a large mesh size. If effort is such that fishing mortality equals, say, 1.0, then changing from a large mesh size to a small mesh size results in a lower sustainable yield.

[1] $\dot{w}$ represents the change in weight as time passes, i.e., $dw/dt$. Divide with $w$ and the outcome is proportional change in weight over time.

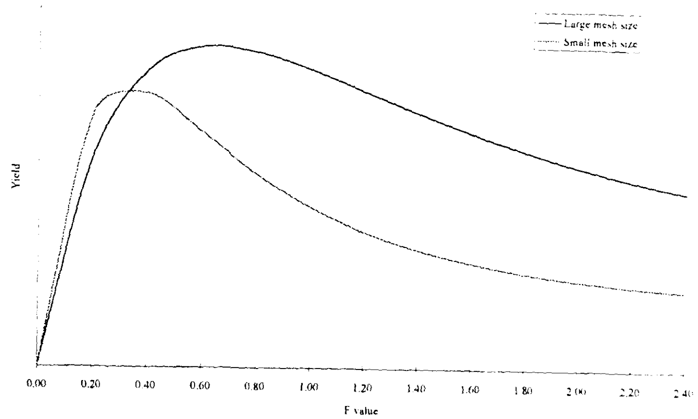


Figure 1: Beverton-Holt yield curves

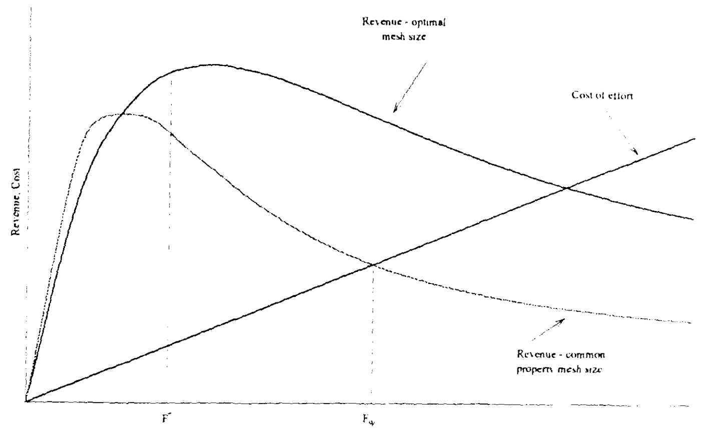


Figure 2: Revenues and costs

Using the standard assumptions that $F$ and costs are proportional to fishing effort[2], and price of fish is constant, then costs and revenues for the fishery can be expressed diagrammatically as in Figure 2. At $F^*$, fishing mortality and mesh size are such that profits are maximised. As the figure is drawn, considerable resource rent in generated at $F^*$, but the size of this rent, of course, depends on the exact relationship between costs and revenues.

If the fishery is operating as common property and is not regulated, then $F^*$ is not an equilibrium point. Each fisherman has an incentive to try to capture a larger share of the resource rent. To do so, fishermen will increase effort through the process of *factor stuffing* (Copes, 1990) As well, they will tend to reduce mesh size in order to capture all fish that possibly can be

[2]The age subscript on $F$ is dropped for notational ease. One can think of $F$ as a vector with as many elements are there are cohorts.

sold, but in the process they will move to a lower yield curve. This will lead to a situation such as $F_{cp}$, where all the resource rent is dissipated at a rate of fishing mortality that is too high.

The model can be extended to allow for dynamic optimisation. The objective function is to maximise present value of profits by choosing fishing mortality through time. One way of representing this is

$$\max_{\{F_t\}} PV = \max_{\{F_t\}} \int_0^\infty e^{-\delta t}\pi(F_t)dt \qquad (4)$$

where $\delta$ is the discount rate, or the marginal rate of time preference. This function is maximised, subject to the constraint that the fishery should be at a steady state. This model will not be explored further here, except that it can be shown (see, e.g., Clark, 1985, p. 131) that the optimal solution of $F_t$ will be at age $t_\delta$ which satisfies

$$\frac{\dot{w}(t_\delta)}{w(t_\delta)} = M + \delta \qquad (5)$$

Since $\dot{w}/w$ decreases with age, it is clear that as the discount rate increases, the optimum harvesting age of the fish population falls. The model thus predicts that as the discount rate rises, the fishing mortality rate will increase.

## 3 Application of the model

Simulation runs were applied to the *Nephrops* fishery using Equation 3 to analyse the effects on profits of changes in effort and mesh size over a 20 year period. The biological data necessary to run the model is obtained from ICES (ICES, 1997). The yield is calculated using $F$ values ranging from 0.9 of the initial $F$ to 0.1 of the initial $F$. Revenue for each level of $F$ is obtained by multiplying catch weight with the corresponding unit price at age. The unit price is derived from EU published guide prices (see Hillis and Keogh, 1997).

Information on costs in the *Nephrops* fishery is scarce. The data used here come from two surveys, one of the Republic of Ireland (Hillis and Whelan, 1992) and the other of Northern Ireland (Thomas, 1996). The data indicate that at the time of survey 40% of costs were operating costs, i.e., costs that vary with fishing effort, and 25% were fixed. The remaining 35% of costs consist of wages and returns to owner. From the data it is not possible to distinguish the two and in the remainder of the paper they will be referred to interchangeably as *value added* or *profit*. In the event of restoration of an overfished fishery, the balance between owners' returns and crew pay will tend to alter as the improved biological conditions, and the likely reduced levels of crew employment in the ports, allow owners to capture increased proportions of the generated rent for themselves. They may do this by offering crew members guaranteed minimum levels of earnings which exceed current levels of share-based crew pay, though at reduced proportions of the boats' total revenue. If value added increases, the way in which the share of the crew will change depends on a number of imponderables, such as the countervailing power of labour unions, (which will tend to make it increase), and the amount of redundancy created by reduced fishing effort, (which will tend to make it decrease). Apart from assuming that shares of crew and owner maintain the same proportion, it is not easy to predict changes in the relative shares.

The three regulatory schemes to be analysed are simulated as follows. *Decommissioning* reduces effort, and hence $F$, by reducing the number of boats in the fishery. When a boat is removed from the fishery all costs related to it, fixed and variable, become zero. This is equivalent to all cost in the fishery being variable; in the simulations all fishing costs are reduced proportionally to reductions in $F$. On the other hand, *catch quotas* reduce effort , and $F$, by reductions in effort without changing the number of boats. The exact implementation of the quota system is not elaborated upon here, but it is assumed that quotas are not transferable in order to minimise displacement of workers. Since the number of boats is not changing, fixed costs are not affected. Therefore, the effect of catch quotas is to reduce only variable costs when $F$ falls. Finally, *mesh size regulation* does not affect costs at all. When mesh size is increased, the recruitment pattern in the fishery changes. The proportion of small fish caught falls as the mesh size increases. Selectivity data from Wileman (1992) are used to calculate the quantity of fish retained at each mesh size.

Since profit streams into the future are calculated, the issue of future discounting arises. The choice of discount rate has long been a debated issue. Discounting future streams of payments has the effect of reducing gains in the future as compared to undiscounted payment streams. Fishermen are often accused of being short-sighted, which is equivalent to having a high discount rate. In fact, Hillis and Whelan (1994) report findings for Irish fishermen of discount rates of 28% regarding money and of about 55% regarding the value of uncaught fish. With a very high discount rate less weight is put on the future and more on the current time period. Therefore, the higher the discount rate the more opposed fishermen will be to regulatory measures that lead to sacrifices in the near future and gains in only the distant fu-

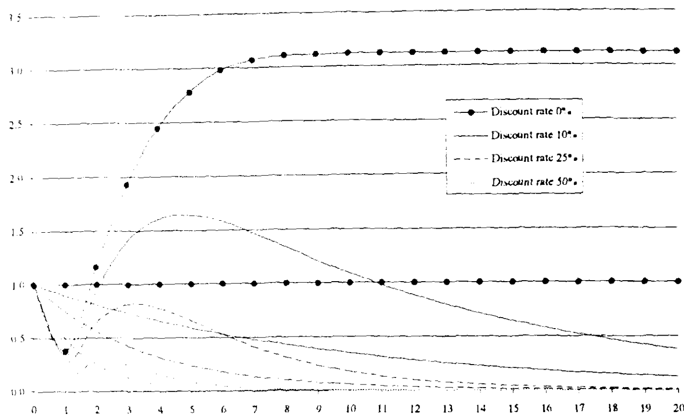


Figure 3: Annual future profits for $F = 0.5$ at various discount rates

ture. However, from society's point of view a very high discount rate may be irrational. The most obvious reason is that the higher the discount rate the less important are the preferences and welfare of future generations in benefit-cost calculations. Governments tend to choose discount rates for public projects in the range of 3% to 7% plus the rate of inflation. Since the objective with the current analysis is not to find the most appropriate discount rate, the analysis is undertaken without specifically choosing one. Rather, results are presented using discount rates of 0%, 10%, 25% and 50%.

Choosing among the three regulatory schemes is not the only decision to be made by a management authority. The speed at which the new regulation is implemented is an important consideration. It is normally accepted in the economics literature that when moving from one equilibrium to another the optimal way is to make immediate changes (e.g., Clark, 1985). However, fishermen that are affected by the policy change may object strongly to drastic measures that reduce their incomes considerably in the short run. The simulation here is carried out both for immediate and gradual changes in effort and mesh size, allowing for a comparison between the two approaches.

# 4 Results

Figures 3 and 4 illustrate the effects of future discounting on predictions over a 20 year period for annual and cumulative values, respectively, of streams of profits resulting from immediate reductions in $F$ to 0.5 of its initial value ($F_{\text{init}}$) compared to those resulting from no change in $F$. Profits for no change in management are normalised to 1.0. Thus, a value of 1.5 indicates a 50% increase in profits from a status quo situation, while a

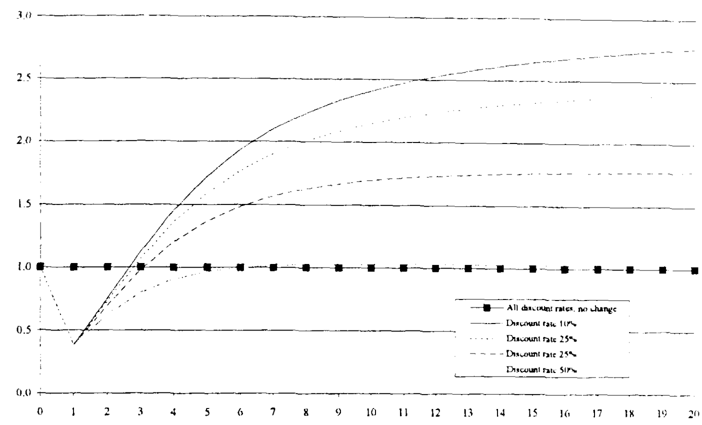


Figure 4: Cumulative future profits for $F = 0.5$ at various discount rates

value of 0.8 indicates a 20% reduction in profits. In Figure 3, but not Figure 4, it is necessary to discount the 'no change' streams to demonstrate the effect. Figure 3 clearly shows how high discount rates reduce long term gains more than immediate losses, changing an extremely large net gain with 0% discounting into a minutely small one with 50% discounting.

Figure 4 shows the effect of discount rates on annually accumulated profits. While with 0% discounting annual increments make the cumulative value rise towards infinity, discounting at non-zero rates eventually reduces the annual increments virtually to zero making the plot horizontal. The rates shown illustrate the progressive reduction with the discount rate increasing from 0% to 50% of the factor of increase in accumulated profits in year 20 from over 2.5 (and rising) down to only marginally over 1.0.

Table 1 gives predictions of accumulated undiscounted revenue and profits discounted at 0% (i.e. undiscounted), 10%, 25% and 50% resulting from implementation of the three management regimes. Both revenue and profits are normalised to equal 1.0 if no regulatory change is undertaken. The table consists of three parts, one for each management measure. For quota management and decommissioning the table reports results from immediate reduction in $F$ to 0.7, 0.5, and 0.3 of $F_{\text{init}}$, in addition to a gradual change where $F$ is reduced to $0.5F_{\text{init}}$ by five annual decrements of $0.1F_{\text{init}}$ each. For mesh size, the table shows the predicted effects of immediate increases from the current level of 75mm to 100mm, 110mm, and 120mm. Also reported is a gradual increase to 120mm over a four year interval by 15mm increase in the first year and 10mm in each of the following three years. The shaded cells of the table indicate years where the fishery is still at a loss as compared to a status quo situation. In addition, for each year the highest values of revenue and profit are printed in bold type, and results from gradual changes

Table 1: Effects of catch quotas, decommissioning, and mesh size regulation on cumulative revenue and profit, selected years, $F$ values, and mesh sizes

| Parameter | Year | F reduction catch quota | | | | F reduction decommissioning | | | | Mesh size increases | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Discount. rate | | Reduced F/initial F | | | | Reduced F/initial F | | | | Size of increased mesh | | | |
| | | 0.7 | 0.5 | 0.3 | *.1>.5* | 0.7 | 0.5 | 0.3 | *.1>.5* | 100 | 110 | 120 | *Grad* |
| **Revenue** 0% | 1 | 0.773 | 0.592 | 0.381 | *0.930* | 0.773 | 0.592 | 0.381 | *0.930* | 0.686 | 0.577 | 0.485 | *0.809* |
| | 2 | 0.860 | 0.712 | 0.499 | *0.922* | 0.860 | 0.712 | 0.499 | *0.922* | 0.806 | 0.711 | 0.621 | *0.823* |
| | 3 | 0.936 | 0.828 | 0.626 | *0.923* | 0.936 | 0.828 | 0.626 | *0.923* | 0.925 | 0.851 | 0.769 | *0.851* |
| | 4 | 0.997 | 0.930 | 0.748 | *0.929* | 0.997 | 0.930 | 0.748 | *0.929* | **1.030** | 0.981 | 0.911 | *0.886* |
| | 5 | **1.045** | 1.014 | 0.855 | *0.935* | **1.045** | 1.014 | 0.855 | *0.935* | **1.117** | 1.093 | 1.038 | *0.963* |
| | 10 | 1.159 | **1.231** | 1.162 | *1.135* | 1.159 | **1.231** | 1.162 | *1.135* | 1.340 | 1.394 | **1.395** | *1.321* |
| | 20 | 1.217 | **1.346** | 1.332 | *1.297* | 1.217 | **1.346** | 1.332 | *1.297* | 1.456 | 1.554 | **1.589** | *1.551* |
| **Profit** 0% | 1 | 0.686 | 0.384 | -0.006 | *0.912* | 0.924 | 0.780 | 0.548 | *0.991* | 0.040 | -0.294 | -0.577 | *0.417* |
| | 2 | 0.956 | 0.754 | 0.348 | *0.953* | **1.206** | 1.170 | 0.931 | *1.078* | 0.387 | 0.086 | -0.200 | *0.440* |
| | 3 | **1.202** | 1.129 | 0.753 | *1.025* | 1.457 | **1.554** | 1.348 | *1.195* | 0.759 | 0.523 | 0.258 | *0.521* |
| | 4 | 1.400 | **1.457** | 1.143 | *1.111* | 1.656 | **1.883** | 1.739 | *1.324* | **1.097** | 0.939 | 0.715 | *0.633* |
| | 5 | 1.551 | **1.724** | 1.487 | *1.198* | 1.806 | **2.149** | 2.082 | *1.453* | **1.376** | 1.298 | 1.123 | *0.880* |
| | 10 | 1.909 | 2.409 | **2.458** | *1.966* | 2.161 | 2.829 | **3.046** | *2.302* | 2.083 | 2.254 | **2.259** | *2.022* |
| | 20 | 2.092 | 2.768 | **2.991** | *2.545* | 2.343 | 3.186 | **3.576** | *2.921* | 2.447 | 2.758 | **2.871** | ***2.750*** |
| **Profit** 10% | 1 | 0.686 | 0.384 | -0.006 | *0.912* | 0.924 | 0.780 | 0.548 | *0.991* | 0.040 | -0.294 | -0.577 | *0.417* |
| | 2 | 0.941 | 0.734 | 0.328 | *0.951* | **1.190** | 1.149 | 0.910 | *1.073* | 0.368 | 0.065 | -0.221 | *0.438* |
| | 3 | **1.165** | 1.074 | 0.695 | *1.016* | 1.419 | **1.498** | 1.288 | *1.179* | 0.706 | 0.461 | 0.194 | *0.511* |
| | 4 | 1.340 | **1.363** | 1.037 | *1.091* | 1.595 | **1.787** | 1.631 | *1.292* | **1.002** | 0.826 | 0.594 | *0.608* |
| | 5 | 1.471 | **1.592** | 1.329 | *1.163* | 1.725 | **2.016** | 1.922 | *1.400* | **1.241** | 1.131 | 0.939 | *0.810* |
| | 10 | 1.766 | **2.148** | 2.105 | *1.729* | 2.019 | 2.569 | **2.694** | *2.032* | 1.815 | **1.900** | 1.848 | *1.668* |
| | 20 | 1.898 | 2.402 | **2.473** | *2.090* | 2.150 | 2.822 | **3.060** | *2.423* | 2.074 | 2.254 | **2.272** | *2.137* |
| **Profit** 25% | 1 | 0.686 | 0.384 | -0.006 | *0.912* | 0.924 | 0.780 | 0.548 | *0.991* | 0.040 | -0.294 | -0.577 | *0.417* |
| | 2 | 0.916 | 0.699 | 0.295 | *0.947* | **1.164** | 1.112 | 0.874 | *1.065* | 0.335 | 0.029 | -0.256 | *0.436* |
| | 3 | **1.103** | 0.982 | 0.599 | *1.001* | 1.355 | **1.403** | 1.188 | *1.153* | 0.616 | 0.357 | 0.087 | *0.496* |
| | 4 | **1.239** | 1.205 | 0.861 | *1.057* | 1.492 | **1.626** | 1.451 | *1.238* | 0.844 | 0.637 | 0.392 | *0.568* |
| | 5 | 1.333 | **1.369** | 1.067 | *1.107* | 1.586 | **1.790** | 1.657 | *1.313* | **1.014** | 0.853 | 0.636 | *0.702* |
| | 10 | 1.512 | **1.697** | 1.513 | *1.393* | 1.764 | **2.117** | 2.102 | *1.640* | **1.352** | 1.300 | 1.158 | *1.150* |
| | 20 | 1.553 | **1.773** | 1.621 | *1.486* | 1.805 | 2.194 | **2.209** | *1.741* | **1.430** | 1.405 | 1.283 | *1.275* |
| **Profit** 50% | 1 | 0.686 | 0.384 | -0.006 | *0.912* | 0.924 | 0.780 | 0.548 | *0.991* | 0.040 | -0.294 | -0.577 | *0.417* |
| | 2 | 0.863 | 0.627 | 0.226 | *0.939* | **1.109** | 1.036 | 0.799 | *1.048* | 0.267 | -0.045 | -0.330 | *0.432* |
| | 3 | 0.978 | 0.800 | 0.411 | *0.971* | **1.227** | 1.214 | 0.991 | *1.101* | 0.439 | 0.155 | -0.121 | *0.467* |
| | 4 | **1.044** | 0.906 | 0.534 | *0.997* | 1.293 | **1.321** | 1.115 | *1.141* | 0.547 | 0.287 | 0.022 | *0.499* |
| | 5 | **1.079** | 0.966 | 0.608 | *1.014* | 1.328 | **1.381** | 1.189 | *1.167* | 0.609 | 0.364 | 0.108 | *0.543* |
| | 10 | **1.114** | 1.029 | 0.690 | *1.056* | 1.364 | **1.444** | 1.271 | *1.217* | 0.673 | 0.447 | 0.204 | *0.613* |
| | 20 | **1.116** | 1.031 | 0.693 | *1.058* | 1.365 | **1.446** | 1.274 | *1.219* | 0.675 | 0.450 | 0.207 | *0.615* |

are reported in italics.

By looking at revenue and undiscounted profits in Table 1 it is evident that, under both quotas and decommissioning, profits are restored faster to initial levels than revenue, whereas revenue and profit follow each other closely under the mesh size regulation. This is, of course, explained by the fact that costs are reduced under the first two schemes, outweighing some, or all, of the revenue decrease.

Above it was predicted by the profit maximisation model that, as the discount rate increases, so will the optimum fishing mortality rate (Equation 5). Table 1 supports this hypothesis. For instance, by looking at the quota regime in year 20, the highest profit at a 10% discount rate comes at $F = 0.3$.

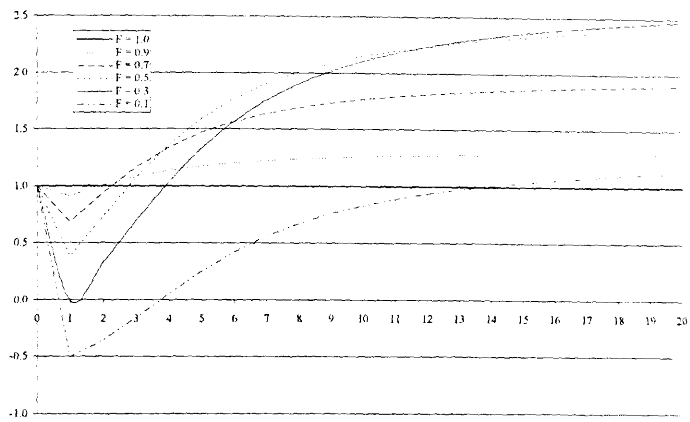


Figure 5: Effects on cumulative profits from immediate reductions in $F$ at 10% rate of discount

However, at a discount rate of 50% the highest profit occurs at $F = 0.7$. This result holds for the other management options as well. This supports the hypothesis that the more short-sighted people are, the harder they will exploit their fisheries.

Figure 5 shows changes in accumulated streams of profits for a fleet of unchanged size resulting from immediate reduction of $F$ to 0.9, 0.7, 0.5, 0.3 and 0.1 of $F_{\text{init}}$, discounted at 10%. $0.5F_{\text{init}}$ gives the highest factors of increase from year 4 until about year 13, after which values with 0.3 $F_{\text{init}}$ are slightly higher. Figure 6 gives similar information with regard to increases in minimum legal mesh size from 75mm to 90mm, 100mm, 110mm and 120mm. In contrast with $F$ reduction, no mesh size increase shows an increase in accumulated profit until year 4, when 90mm does so, after which the mesh size showing the greatest increase in accumulated profit gradually increases until in about year 17 when returns with 120mm slightly exceed those with 110mm. Figures 5 and 6 illustrate the situation shown in Table 1, of $F$ reduction catching up faster to the profits from an unchanged situation that increasing mesh size.

The effects of a gradual reduction compared with an immediate one are compared in Figures 7-12 inclusive, discounted at 10% (Figures 7 and 10), 25% (Figures 8 and 11) and 50% (Figures 9 and 12). For catch quotas and decommissioning $F$ is reduced to $0.5F_{\text{init}}$ immediately and by five equal annual decrements (Figures 7, 8, 9), while minimum mesh size is increased to 120mm immediately and by four increments through intermediate values of 90mm, 100mm and 110mm (Figures 10, 11, 12).

It is clear that for quotas and decommissioning immediate reductions result

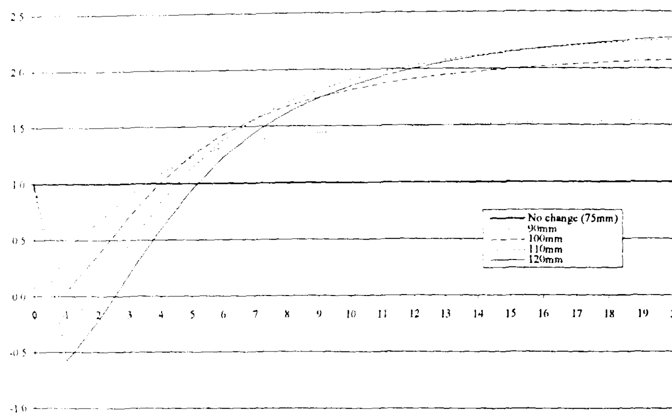


Figure 6: Effects on cumulative profits from immediate increases in mesh size at 10% rate of discount

in higher profits than gradual reductions. However, gradual changes lead to less severe sacrifices initially. With mesh size regulation the difference between immediate and gradual increases in mesh size depends heavily on the discount rate. At a very high discount rate, such as 50%, a gradual increase is, in fact, better than an immediate increase. However, at that discount rate not changing mesh size at all is superior to increasing mesh size. The initial sacrifice of immediate increases in mesh size is very high with losses fully wiping out any profits, cutting well into operating costs in the first 2-4 years.

As shown in Table 1, and illustrated in Figures 7-12, decommissioning in all cases gives the highest returns, followed by catch quotas with mesh changes yielding the lowest increases in profits. In fact, at 50% discounting, mesh size regulation yields no increase in profits at all, never catching up to the initial profit level and resulting only in losses. This can be attributed to the differing amounts by which fishing costs are depressed by the three methods under comparison. Decommissioning reduces all costs commensurately with reduction in $F$, while catch quota only reduces running costs, but mesh regulation has no reductive effect at all on fishing costs.

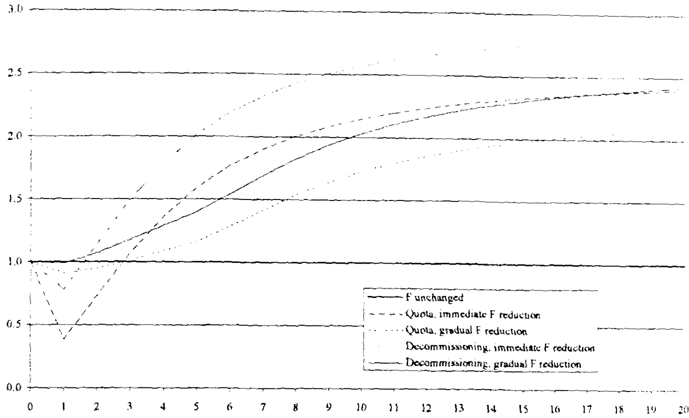


Figure 7: Comparison of quota and decommissioning to $F = 0.5$ at 10% rate of discount

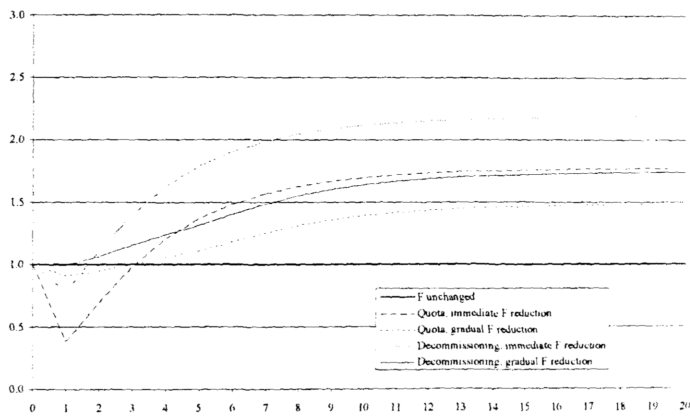


Figure 8: Comparison of quota and decommissioning to $F = 0.5$ at 25% rate of discount

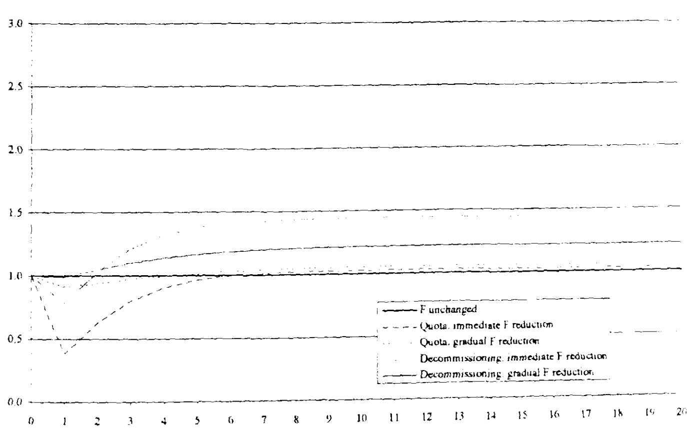


Figure 9: Comparison of quota and decommissioning to $F = 0.5$ at 50% rate of discount

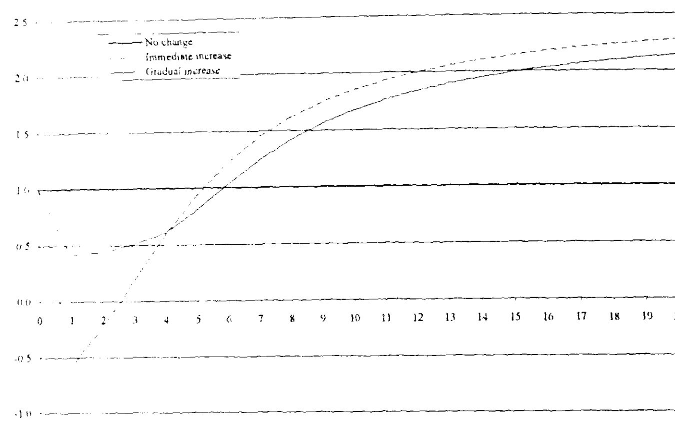


Figure 10: Immediate and gradual increase of mesh to 120mm at 10% rate of discount

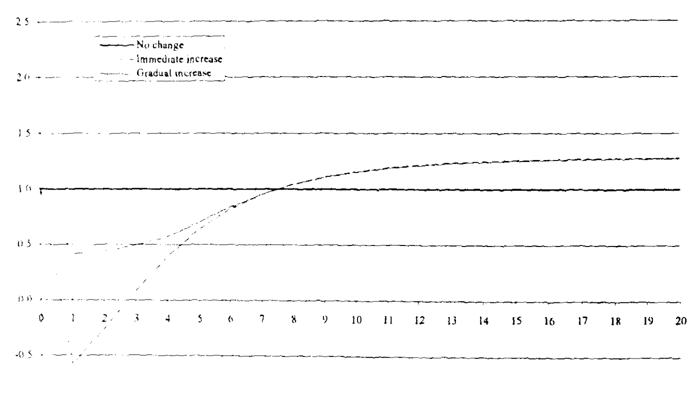


Figure 11: Immediate and gradual increase of mesh to 120mm at 25% rate of discount

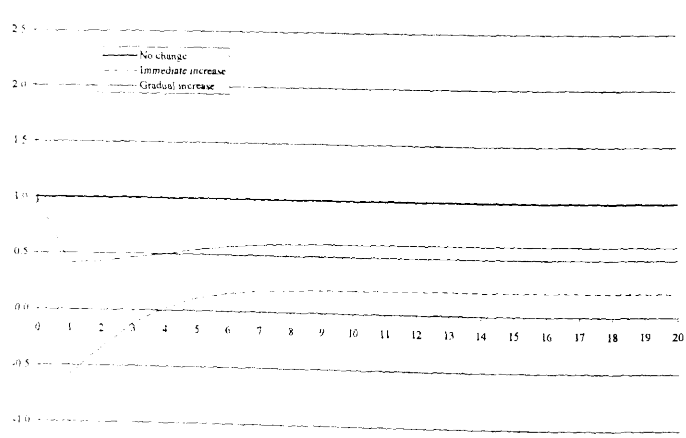


Figure 12: Immediate and gradual increase of mesh to 120mm at 50% rate of discount

# 5 Discussion and conclusion

The first striking result of the analysis is how poorly the current management system in the *Nephrops* fishery performs when compared to what the fishery could yield. Reducing $F$ to 0.7 of $F_{\text{init}}$ by decommissioning would result in a 20% increase in profits after year 2, and 65% increase after year 4. Another notable result of the analysis is how quickly profits recover after a reduction in fishing rate mortality. For instance, from Table 1, even a dramatic reduction in $F$ to 0.3 manages to recover to the status quo profit level in year 3, when discounting at 10% and 25%. Even at 50% rate of discounting, profits catch up in year 4. Catch quotas are not quite as successful, but recover relatively quickly, except at 50% rate of discount. Mesh size regulation performs the most poorly of the three, and, at a 50% discount rate, never manages to recover to the status quo level.

Of the three management options, decommissioning appears as the best strategy from this analysis. This is due to the reduction in overcapacity from removing boats out of the *Nephrops* fishery, thus increasing the efficiency of the fleet. Since catch quotas are assumed non-transferable in the simulation, they do not reach the same level of efficiency. The mesh size regulation does not affect the cost structure of the fishery at all, thus not changing the efficiency level of the fleet. However, in the analysis the cost of decommissioning was not taken into account.

One problem with decommissioning, also affecting the performance of mesh regulation, is that it does not, *per se*, address the common property nature of fishing. Fishermen still have the incentive to race for the fish and indulge in factor stuffing. In fact, if profits in the fishery are expected to double, as Table 1 predicts in some cases, then fishermen are almost guaranteed to begin to compete for that extra profit by increasing the capacity of their vessels, thereby dissipating some, or even all, of the increased profits, unless prohibited from doing so.

Due to the factor stuffing problem of decommissioning, catch quotas seem to be an attractive option. Under a quota system fishermen cannot increase their catches in excess of the quota, reducing the factor stuffing incentive. The burning question in terms of quotas is the cost of monitoring and enforcement. This is really an empirical question that needs to be specifically addressed for the *Nephrops* fishery. It is generally accepted that monitoring and enforcement costs of a quota system exceed the costs of an effort based system. However, in a recent study in Nova Scotia, O'Boyle and Zwanenburg (1996) found that for some fisheries other costs outweighed the higher enforcement costs making the overall management cost of a quota system actually less than that of an effort based system.

A benefit of a non-transferable catch quota system is that, since the fleet size is fixed, minimum employment disruptions will occur. From a policy perspective this is often a very important issue. However, the cost of the higher employment level is the reduction in efficiency. For instance, by looking at Table 1, for an immediate reduction in $F$ to 0.5 of initial $F$, the accumulated profit after 5 years, with a quota system, is 59% higher than the status quo profit, while decommissioning would result in 101% increase in profits. Is that a price we are willing to pay for maintaining jobs in the fishing industry? Here we have a political question, the answer to which will undoubtedly be much debated.

As is apparent, both from Table 1 and Figures 7-12, immediate changes in effort normally outperform gradual changes in the long run. The only situation where this is not true is increasing mesh size to 120mm while discounting future profits at a rate of 50%. The reason is the enormous drop in profits initially. But, apart from this case — which can be argued to be an extreme one — gradual changes achieve lower returns than immediate changes. Nonetheless, a case can be made for changing effort gradually rather than immediately. Under a gradual scheme the initial sacrifices of fishermen are not as severe. Consider, for instance, reducing $F$ immediately to 0.5 via catch quota. The resulting profits in year 1 will be reduced to 38% of the profits if no change had been made. Compare this fall in profits to a return of 91% of the status quo profits, which is what a gradual decrease would yield in year 1.This reduction could well be small enough for a carefully targeted compensation scheme — covering loss of earnings — to be less costly than a typical decommissioning scheme. It seems it would be much easier to convince fishermen to participate in a gradual quota scheme rather than an immediate one. A politician would, without a doubt, prefer the gradual option.

Another concern that often is expressed in fisheries is the level of employment. If this is an issue, then gradual changes are likely to be preferred over immediate ones. If an immediate reduction in $F$ results in a job loss of $x$ jobs greater than a gradual reduction, do the higher profits under the immediate scheme justify the increased job loss? Again, we are faced with a political question that requires careful consideration.

A third concern is the market share of *Nephrops* products. An immediate, and drastic, reduction in fishing mortality rates leads inevitably to reductions in harvest. This has repercussions into the processing sector and ultimately affects the market share of Irish fish products in world markets. It is conceivable that a substantial drop in market share for, say two years, will not be possible to recover, because the buyers have found new suppliers. This is a most serious issue, because many years of hard marketing work could be lost.

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Department of Economics

National University of Ireland, Galway

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