Department of Economics
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THE MANAGEMENT OF NEW ZEALAND'S
LOBSTER FISHERY

By Alan Woodfield and Pim Borren

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INTRODUCTION

In May 1986, the New Zealand Ministry of Agriculture and Fisheries (NZMAF 1986a) published a proposed policy for future management of New Zealand's rock lobster fishery, and sought feedback from interested parties. In response to this feedback, the Ministry replied with a revised proposal in November of the same year (NZMAF 1986b). Introducing the initial proposal, Minister of Fisheries Colin Moyle argued that the rock lobster fishery was "showing signs of being depleted", and that "No one would wish to see rock lobster stocks depleted to the point where fishermen could not get an adequate economic return from the fishery".

The purpose of this paper is to evaluate the history and proposed changes in managing New Zealand's lobster fishery, and to provide some evidence on the issue of resource depletion in this context. It is argued that the industry has been characterized by regulations which have served mainly to raise costs without reducing fishing effort to desirable levels, and that while the MAF's preferred management option of Individually Transferable Quotas (ITQ's) has much to commend it in principle, there appear to be a number of serious problems concerned with its implementation.

A POTTED HISTORY OF THE LOBSTER FISHERY

Rock lobsters are New Zealand's most valuable inshore fishery. Comprised almost entirely of the red rock lobster which is unique to New Zealand, virtually the entire commercial output is exported, mainly to the U.S., Japan, and Australia. In 1986,

exports exceeded $100m for the first time.

The fishery is currently made up of ten controlled fishery areas, one of which, the Chatham Islands, will be ignored in what follows since its stock apparently originates separately and it is a recently exploited fishery. Landings from the remaining nine areas fluctuate more than the fishery as a whole. This appears to result from the fact that at the recruitment stage, the larvae is free-floating (Annala 1983a), while, especially in southern waters, lobsters are migratory with distances of up to 290 km per year recorded (Booth 1980, Annala 1983a).

Before 1937, New Zealand maintained an open-access unregulated lobster fishery. Between 1937 and 1963, a licensing scheme served mainly to register vessels and permit data collection. Licenses were granted virtually automatically. Catch restrictions related to size and gender were introduced in 1939, while in 1952, the process of "tailing at sea" was prohibited. Until the mid-1950's, landings had been growing steadily and rapidly, and while the number of licensed vessels fluctuated considerably, there appeared little trend evident in average landings per vessel (see Figure 1).

The peak landings of the mid 1950's mainly reflected the initial exploitation of a new fishery. As the fishery matured, the weight of landings began to decline as smaller animals became more dominant in the catch. The numbers of vessels continued to rise, while total landings first fell sharply, then stabilized, before following a steady decline from the mid 1960's to the late 1970's. During this period, average landings per vessel declined

FIGURE 1: TOTAL ROCK LOBSTER LANDINGS, NUMBER OF
VESSELS, AND AVERAGE LANDINGS PER VESSEL 1945-87
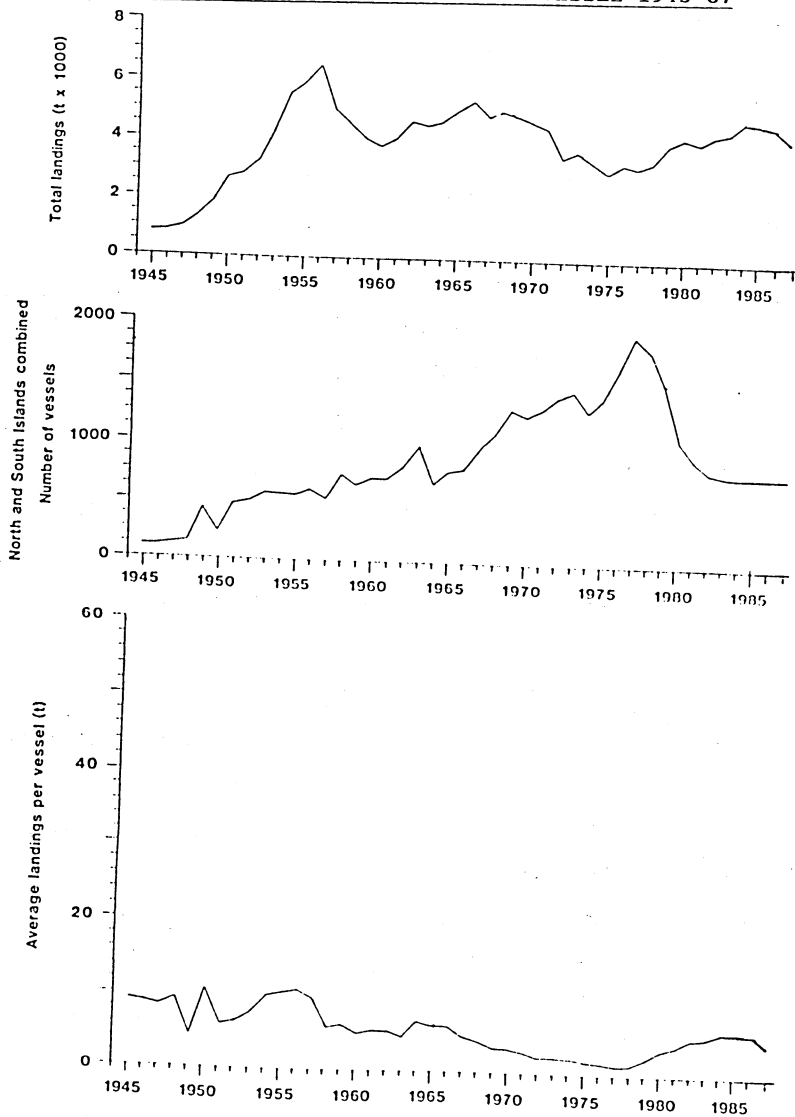
Source: N.Z. Ministry of Agriculture and Fisheries, "Rock
Lobster Fisheries: Proposed Policy for Future
Management", Figure 2 p.7. Post-1984 data from
MAF Fisheries Research Section.

substantially, from a peak of 11.2 tonnes in 1956 to a trough of 1.7 tonnes in 1977.

In 1969, additional regulations came into force, requiring lobsters to be landed alive, and requiring pots to include escape gaps for undersized fish. Nothing, however, was done to slow down the number of new fishermen entering the industry or to otherwise control their catch. Finally, in 1977 the Controlled Fisheries Act was passed and a moratorium declared on the issue of new permits for rock lobster fishing (Annala 1983b). The combined fishery was split into nine separate fishing zones, and estimates were made of the number of commercial vessels that could viably fish each area. Non-transferable licenses were issued on the basis of whether applicants could make a good case that they had "a genuine and long term commitment to the industry" (NZMAF 1986a, p 8).

While the number of vessels fell by about 50 percent between 1977 and 1981, and have continued to fall as a result of attrition (see Figure 1), two factors seriously limited the effect of the regulation. First, too many fishermen met the criterion of long-term commitment to the industry. For example, even by 1984, there were 23 percent too many vessels licensed relative to numbers "recommended" on the basis of "likely sustainable biological yields and economic (costs and earnings) assessments" (NZMAF 1986a, p 8). Second, as will be discussed in detail later, controlling the number of vessels only controls one input into fishing effort, and the remaining fishermen quickly found methods of expanding output with a fixed number of fishing licenses.

MODELLING THE LOBSTER FISHERY

The impacts of past and proposed future management of the rock lobster fishery will now be examined in the context of the well-known steady-state fishery model developed by Gordon (1954) and Schaefer (1954). Only an informal treatment will be provided here; for further analytical details, see Borren and Woodfield (1988).

First, in the absence of environmental resource constraints of food and space, the lobster stock (X) could be expected to grow exponentially at rate r. In the presence of an environmental carying capacity (K), however, the net proportional growth rate of lobsters decreases as the fish stock expands according to the equation $r(X) = r(1-(X/K))$, generating a logistic growth curve illustrated in Figure 2.

FIGURE 2: TIME PATH OF LOBSTER STOCK IN ABSENCE OF FISHING

$$X(t) = \frac{K}{(\frac{K}{X_0}-1)e^{-rt}+1}$$
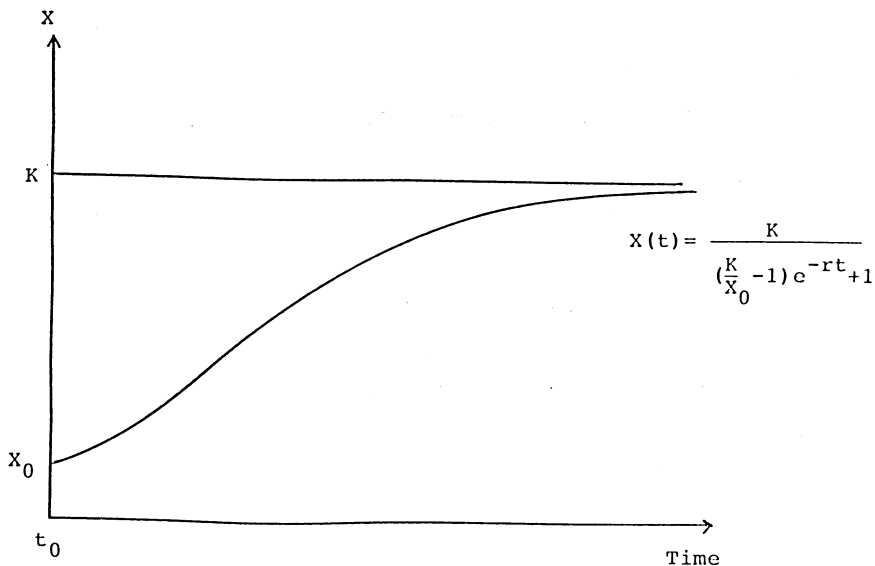
Assuming X_0 is the initial lobster stock, it can be shown that in the absence of fishing, the lobster stock will approach the carrying capacity in the long-run. If fishing occurs at a constant rate of effort $(\bar{E})$, the stock will be depleted by the (constant) catch level $\bar{h} = q\bar{E}\bar{X}$ (where q is the "catchability coefficient") and $\bar{X}$ is the constant long-run lobster stock.. Figures 3a and 3b illustrate the outcomes.

In Figure 3a, zero fishing effort implies that the lobster stock is maximized at K, while effort $\bar{E} > \bar{E}_D$ implies annihilation of the stock. As $\bar{E}$ increases from zero through $\bar{E}_D$, the long-run lobster stock declines (at a constant rate equal to $- qK/r$). Figure 3b describes the relationship (which is a quadratic in $\bar{E}$) between sustainable catch and sustained fishing effort. At $\bar{E} = 0$, catch is also zero. As effort increases, catch increases for a time, but eventually high sustained fishing rates cause such a drain on the stock that catch declines as effort increases. This does not mean that short-term increases in effort will not lead to greater catches - these, however, will not be able to be sustained over time. The maximum sustainable yield (MSY) is at $\bar{E}_S$ (which implies an effort level equal to the cube root of r/2q).

Now consider two long-run fishing levels $\bar{E}'' < \bar{E}'$ in Figures 3a and 3b. Both generate a catch of $\bar{h}_0$. At $\bar{E}''$, relatively little effort is involved since past fishing behaviour has not seriously depleted the stock. Much greater effort is required at $\bar{E}'$, since high levels of past fishing have seriously depleted the stock, as Figure 3a makes evident. Assuming a

FIGURE 3a: RELATION BETWEEN LONG-RUN LOBSTER STOCK

AND CONSTANT FISHING EFFORT
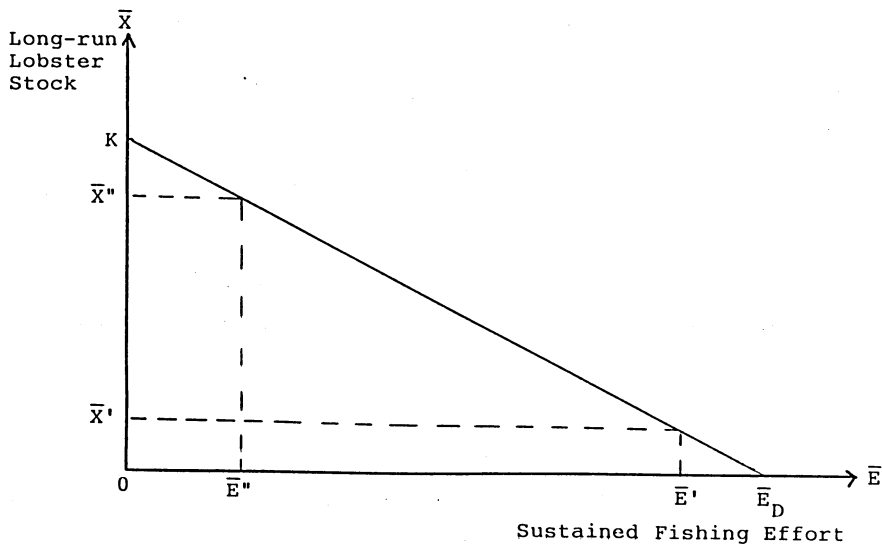
FIGURE 3b: RELATION BETWEEN SUSTAINABLE LOBSTER CATCH
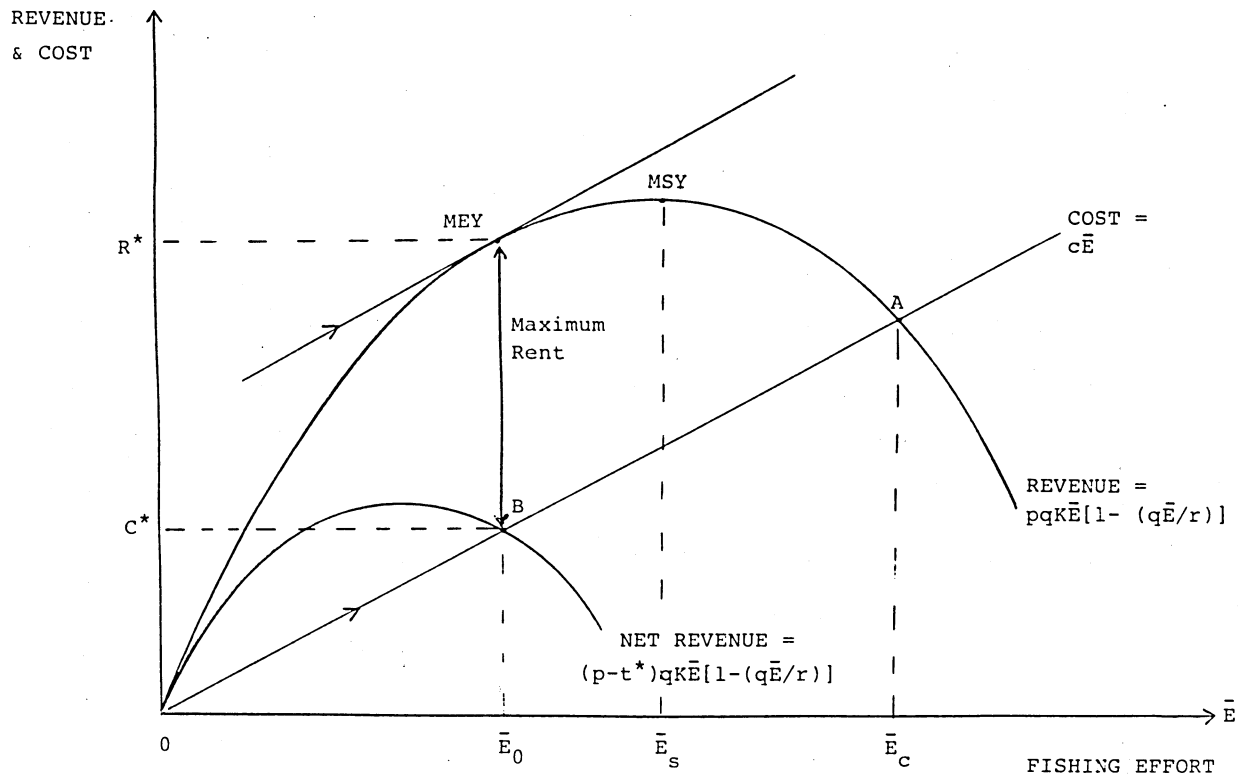
AND CONSTANT FISHING EFFORT
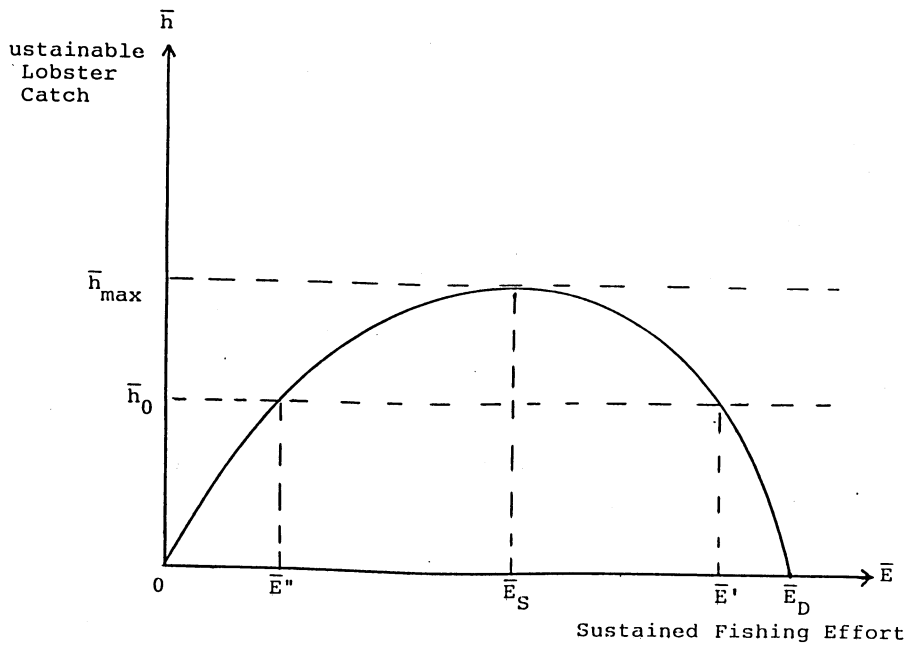
constant price p per unit of catch (which seems appropriate if New Zealand is a small fish in the world lobster pool), long-run total revenue $R = p\bar{h}$, while, if total cost (C) is proportional to fishing effort $c\bar{E}$, then the relationship between revenue and costs for the steady-state fishery can be illustrated by Figure 4. In this diagram, A represents the competitive industry zero-profit equilibrium under an open-access fishery. MSY represents the maximum sustainable yield and also maximizes the sustainable revenue of the fishery. MEY represents the <u>maximum economic yield</u>, ie, the resource rental or social surplus maximizing fishing level, implying a fishing level $\bar{E}_0 < \bar{E}_S < \bar{E}_C$. Note that $\bar{E}_0 = \bar{E}_S$ if c = 0, while, if c > 0, the competitive fishing level is either greater than, equal to, or less than $\bar{E}_S$ depending on the magnitude of c relative to p. $\bar{E}_C$, however, <u>must</u> be greater than the corresponding $\bar{E}_0$, independently of fishing costs. Further, if the fishery is at A, and actions are taken to raise c (the marginal cost of fishing effort) by a small amount, revenues will rise, effort will be reduced towards $\bar{E}_S$, but <u>no</u> resource rentals will be collected and total costs will be increased.

MANAGEMENT REGIMES AND PROPOSALS

The basic reason why there is excessive fishing in the open-access competitive fishery is that fishermen only receive payment for fish caught, and receive nothing for conservation efforts. If fishermen reason that the lobsters they leave behind will simply be caught by other fishermen rather than adding to future stocks for themselves to catch, there is little incentive to voluntarily reduce effort below the competitive level.

FIGURE 4: RELATIONSHIP BETWEEN REVENUES AND COSTS FOR A STEADY-STATE FISHERY

REVENUE & COST

MSY

MEY

COST = $c\bar{E}$

R*

Maximum Rent

A

B

C*

REVENUE = $pqK\bar{E}[1-(q\bar{E}/r)]$

NET REVENUE = $(p-t^*)qK\bar{E}[1-(q\bar{E}/r)]$

$\bar{E}_0$ $\bar{E}_s$ $\bar{E}_c$

$\bar{E}$

FISHING EFFORT

Although fishermen as a group would prefer fishing levels to be lower, as long as free- access exists, no individual fisherman has an incentive to conserve the resource. The lobster stock is a scarce resource in that heavy current fishing effort depletes the future stock available, but fishermen are encouraged to treat it as a freely available piece of common property. While defining and enforcing property rights in fisheries has proved a difficult and costly exercise, there is no way that a private owner of the fishery would simply tell fishermen to help themselves, since resource rents are completely dissipated in the process. And while a reduction in fishing effort is a necessary condition for creating positive rents, it is not sufficient. It may well be the case that regulation of a common property fishery reduces fishing effort while also dissipating the potential rents available for distribution to citizens at large.

Management strategies in New Zealand can be divided into exclusive and non-exclusive categories. Until recently, the latter predominated, and it is arguable that as means of reducing overfishing, they appear to have at best been only temporarily effective and have mainly served to increased costs articially.

An example in point is catch restriction, by size limits or by gender. These restrictions are justifiable if the increased future value of the catch exceeds the income lost by throwing fish overboard or permitting them to escape. Under common property, there is little incentive for safe return of fish, and the fact that lobsters are very slow in growing to maturity reduces the likelihood that net gains will be made by this process. These regulations do address the important issue

of the appropriate age to take lobsters, but they do not address the access problem and add to the costs of acquiring a given weight of lobster. Further, the regulations sometimes produce arbitrary and undesired side-effects. During 1988, a moratorium on assignment of fishing rights has been declared while the fishing rights implications of the Treaty of Waitangi are being reconsidered. In what appears to be an attempt to prevent overfishing in the interim, regulations from June 1 of 1988 changed the basis for measuring lobsters from tail length to tail width, drawing a hot response from South Island fishermen who claimed that southern lobsters had longer and thinner tails than northern lobsters. A Blenheim fisherman reported a 70 percent reduction in catch as a result of the regulatory change. The result may be to excessively reduce fishing effort for the southern fisheries, while no resource rents are generated as long as open- access remains. However, since it appears widely believed that northern and southern lobsters originate from the same stock, at least part of the problem for southern fisheries may arise from heavy recent fishing levels induced by the proposed move to ITQ's.

Another example is vessel, fishing gear, and fishing method restrictions. Effort may be reduced by these methods, but no resource rent is obtained. Similar conclusions hold for area and season restrictions, which lock capital into specific zones or for specific periods, increasing their costs when used at increased intensity, and raising their net interest costs during periods of enforced idleness.

A similar argument holds for regulations based on total

allowable catch (TAC). Here, when a given season's quota is caught, the fishery closes. In NZMAF (1986b, p 4), Fisheries Minister Moyle argued that if ITQ's were rejected, there would be "no alternative but to maintain the present controlled fishery regime, and to set a TAC for each controlled fishery". Yet with open-access, very intensive fishing effort is encouraged, leading to overcapitalization and wastefully idle capital during the off-season.

As for exclusive regimes, we have already noted that the restrictive licensing scheme of 1937-63 had little apparent impact on containing growth in vessels used in lobster fishing (see Figure 1). It is true that vessels grew at a more rapid rate following suspension of licensing, involving a trebling between 1964 and 1977, although this was also a period when unit fishing costs relative to lobster prices were falling rapidly, according to our index, by a factor of about 3.5. However, in December, 1977, the moratorium on the issue of new fishing permits saw the following responses. First, as is evident by inspection of Figure 1, the number of vessels operating fell dramatically in the following years. Second, both total landings and landings per vessel increased significantly as the number of vessels declined. Although the number of vessels still exceeded those "recommended", it might be thought that the regulation was having the desired effect of reducing fishing effort and restocking a depleted fishery.

Unfortunately, this was not the case. Fishing effort is not simply proportional to the numbers of vessels, but depends on vessel size, the amount of gear carried per vessel, the number of

fishing days per season, and the number of potlifts per fishing-day. As is clear from Table 1 and inspection of Figures 5a - 5k, fishermen responded to their inability to obtain new licenses by using the degrees of freedom available under a licensed but otherwise open-access fishery. That is, they increased the size and speed of their vessels, introduced more sophisticated technology, added more fishing gear, and worked longer seasons.

To illustrate further, consider Figure 6. Here, it is found that in 1980, fishermen used 0.262 vessels per tonne of catch. By 1984, vessel numbers had fallen by 30 percent to 86 percent of their "recommended" levels. Landings, however, had increased by 17 percent. Per tonne of catch, fishermen were then using 0.156 vessels, a 40 percent reduction, but at the same time had nearly doubled their pot-lifts per vessel from 3770 to 7440.

Now consider Figure 7. Here, it is found that in 1980, 1074 vessels were producing 4202 tonnes of lobster. If the regulators had supposed that pot-lifts per vessel would remain constant at their 1980 level of 3770 they might have imagined that in setting "recommended" vessel numbers of 664 in 1984, they would be implicitly recommending total pot-lifts of 2.5 million. Vessel numbers, however, turned out to be 773, and each vessel averaged 7440 pot-lifts, resulting in 5.75 million pot-lifts in total. Further, if there had been no change in the relative costs of vessel size and fishing intensity versus vessel numbers, fishermen would probably have wanted to use about 1300 vessels to catch their chosen output.

It is instructive to examine the catch pattern during

TABLE 1: INPUTS AND OUTPUT FROM THE NZ LOBSTER INDUSTRY, 1979-87

		1979	1980	1981	1982	1983	1984	1985	1986	1987
1	Vessels Licensed	1517	1074	909	815	788	773	773	773	773
2	Landings (tonnes)	4156	4204	4083	4361	4415	4941	4886	4657	3763
3	Landings (t) per Vessel	2.74	3.91	4.49	5.35	5.60	6.39	6.32	6.02	4.87
4	Vessel-days	77688	72006	67995	69048	71099	76347	72609		
5	Vessel-days per Vessel	51.21	67.0	74.8	84.7	90.2	98.8	93.9		
6	Landings (t) per 100 Vessel-days	5.35	5.84	6.00	6.32	6.21	6.47	6.73		
7	Pot-lifts (000)		4050	4020	4401	4973	5751	5791	5784	5516
8	Pot-lifts (000) per Vessel		3.77	4.42	5.40	6.31	7.44	7.49	7.48	7.14
9	Pot-lifts per Vessel-day		5.62	5.91	6.37	6.99	7.53	7.98		
10	Landings (t) per 1000 Pot-Lifts		1.04	1.02	0.99	0.89	0.84	0.81	0.81	0.68

Sources
1. NZMAF (1968a, Table 1) 1981-84, MAF Fisheries Statistics Section 1979-80, 1985-87.
2. Port of Landing data 1979-85, MAF Fisheries Statistics Section 1986-87.
4. Annala and Esterman (1986).
7. "NZ Rock Lobster Landings", Fish. Res. Div. Occasional Pub:Data Series 1980-85, MAF Fisheries Statistics Section 1986-87.

Figure 5a VESSELS AND LANDINGS
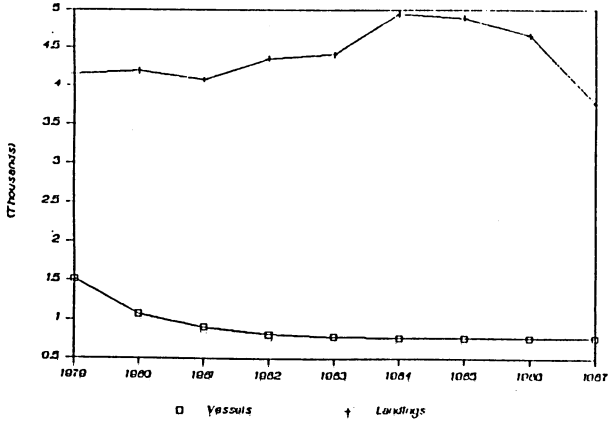
□ Vessels   + Landings

Figure 5b LANDINGS PER VESSEL
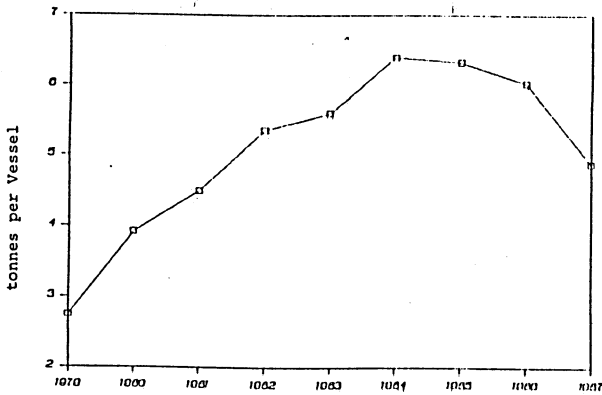
Figure 5c LANDINGS PER VESSEL DAY
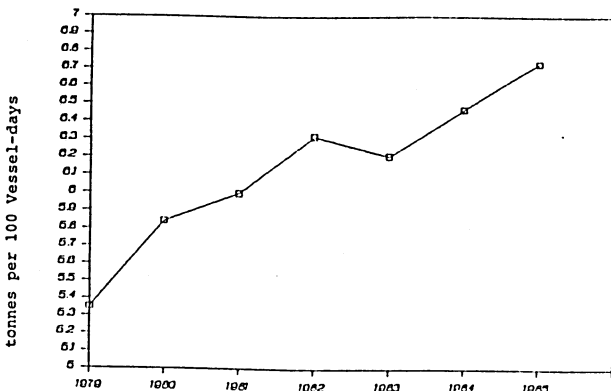
Figure 5d
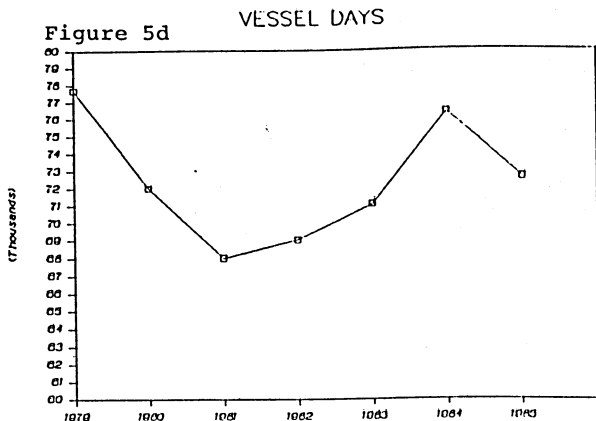
VESSEL DAYS

Figure 5e VESSEL-DAYS PER VESSEL
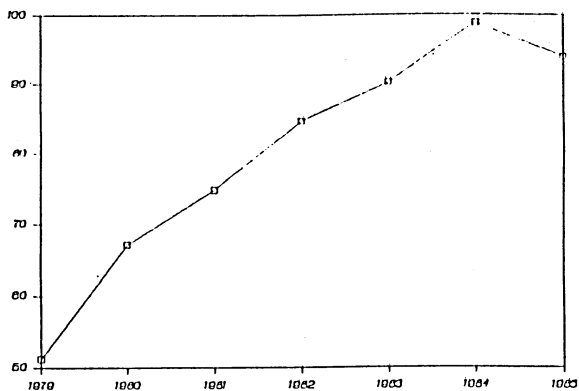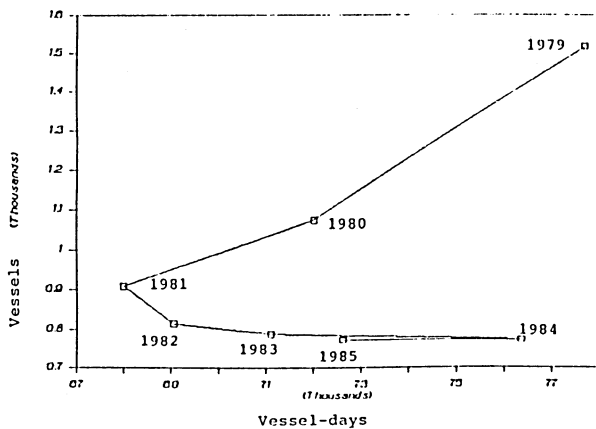

Figure 5f VESSELS vs VESSEL-DAYS
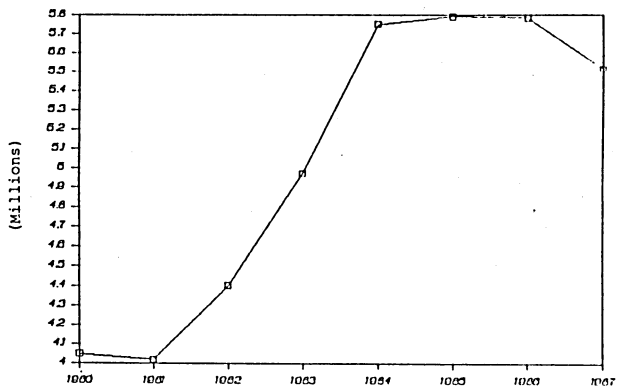
Figure 5g   POT-LIFTS

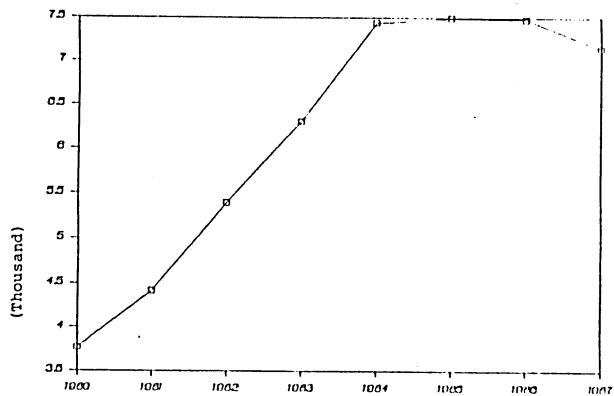Figure 5h   POT-LIFTS PER VESSEL
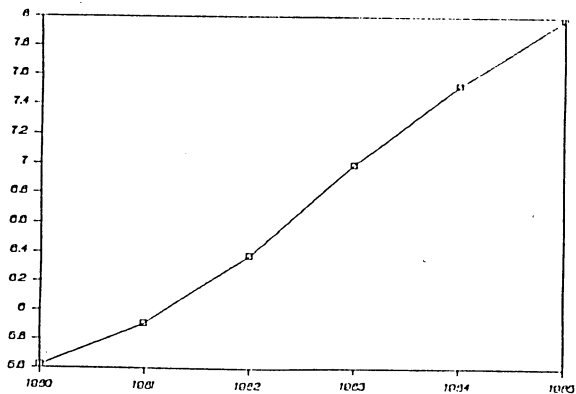

Figure 5i POTLIFTS PER VESSEL DAY

Figure 5j
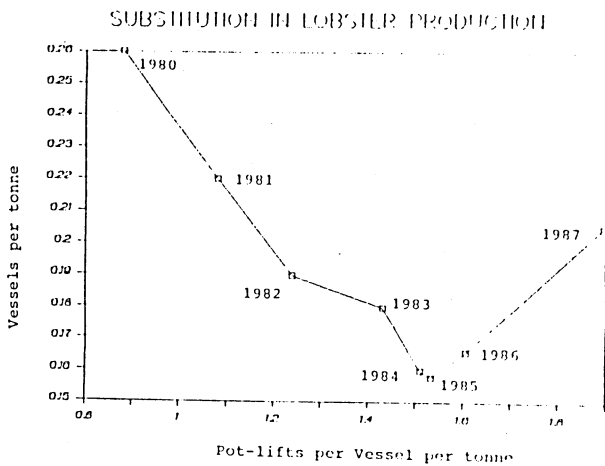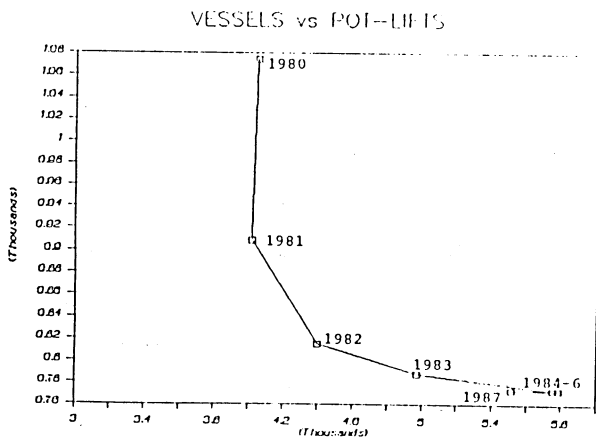### LANDINGS PER POT-LIFT
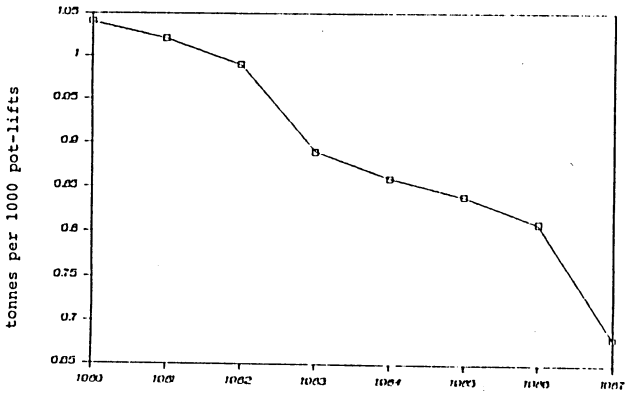
Figure 5k
LANDINGS vs POT-LIFTS

Figure 6

SUBSTITUTION IN LOBSTER PRODUCTION

Pot-lifts per Vessel per tonne

Figure 7

VESSELS vs POT-LIFTS
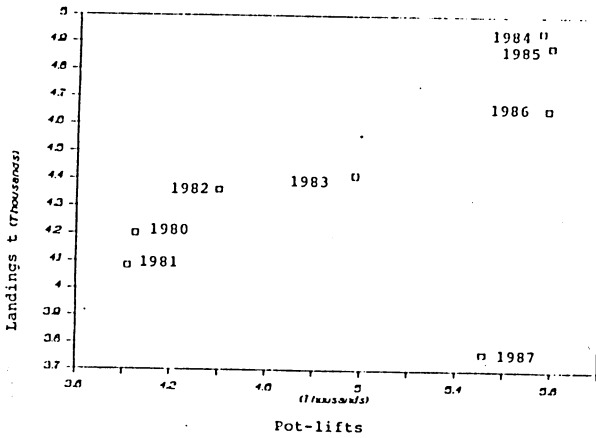
this period of costly substitution of fishing intensity for vessels. After all, the model predicts that, other things equal, an increase in costs represented by a leftward pivoting of the cost schedule should bring down the competitive fishing effort. More generally, it turns out that the profit-maximizing level of fishing effort is a decreasing linear function of the ratio of marginal cost to price (c/p). Table 2 portrays the relationship between the percentage changes in the cost/price ratio during the early 1980's and the corresponding percentage changes in the number of pot-lifts.

TABLE 2: <u>CHANGES IN COSTS, PRICES AND POT-LIFTS, 1980-85</u>

	Percentage Changes from Previous Year in	
	c/p ratio	Pot-lifts
1981	15.0	-0.5
1982	-11.1	9.5
1983	-22.8	13.0
1984	-7.6	15.6
1985	3.1	0.7

Until 1984, changes in the cost/price ratio induced the predicted sign changes in the level of fishing effort as measured by pot-lifts. Between 1982-84, there were dramatic increases in world lobster prices relative to domestic fishing costs. This raised both the profit-maximizing fishing level and the social surplus-maximizing fishing level. Over 1985, however, total pot-lifts increased in response to an increase in the cost/price ratio. To understand the reasons for this apparently non-competitive response, note that since 1984, the number of

vessels has remained constant, while the number of pot-lifts per vessel has remained nearly constant at historically high levels. The catch per pot-lift, however, has continued its march downwards, with a really dramatic fall in 1987. It may well be the case, therefore, that lobster fishermen are making substantial short-term losses while maintaining high levels of fishing effort and depleting the fishery. Inspection of Figure 6 reveals that after 1987, substantially greater vessel numbers and pot-lifts were required for each tonne of catch.

If the argument is correct, why are fishermen acting this way? Some insight is provided by examining the proposed ITQ system favoured by fisheries regulators. In NZMAF (1986a), it was clearly recognized that restrictions on vessel numbers were just not doing their job of protecting the fishery, that economic returns to fishermen were declining, and that lobster stocks had been seriously depleted in some fishing zones. After consultations with the National Rock Lobster Advisory Committee, the Government considered that four major management options were available. The first two involved the continuation of restrictions on vessel numbers, with an option of transferable licenses, and were not favoured since fishing effort was not controlled by this process. The third involved transferable pot entitlements, with a limitation on total pots. Again, it was recognized that fishing effort could only partially be controlled in this manner. Each of these proposals involves fishermen choosing other than cost-minimizing techniques for fishing. The fourth proposal, ITQ's, were strongly favoured.

The initial proposal had ITQ's "transferable at will",

while "the sum of these quotas would determine the total allowable catch (TAC) for each area " (NZMAF 1986a, p. 17). It was argued that such a proposal would encourage conservation for long term harvesting by "the use of appropriate catch quotas", and would encourage "each fisherman to improve efficiency in fishing and business practices by eliminating the economic incentives to wastefully expand fishing capacity". In addition, there was also to be a mechanism provided by which the Government could purchase quota so that "surplus fishing effort" could be removed.

The proposed ITQ involved "the right to catch a certain quantity of rock lobster each year within a certain area", and would be "allocated in perpetuity". They could be freely traded, and, once a certain amount of quota was held, the fisherman's "incentive will be to catch his quotas at the least possible cost" (NZMAF 1986a, p 18). It was observed that ITQ's would enable "new entrants into the fishery without increasing the pressure on the stock", permit each fisherman to "choose his level of involvement in the industry by trading quota", and allow each fisherman to retire by selling, amongst his other assets, his ITQ at market prices.

Aspects of this proposal can be evaluated by inspecting Figure 4. The object of the exercise is to induce the free-entry competitive fishery to choose a level of fishing effort $\bar{E}_0$ which maximizes the social surplus $R^* - C^*$. This can be achieved by two methods. First, a unit tax on lobster landings will, if chosen at an appropriate rate t^*, make fishermen face the net revenue function shown in Figure 4. Net of tax profits are

maximized at point B, and the tax revenue R* - C* is available for distribution to the "owners" of the resource. Now although the MAF did not consider this tax solution to the problem, it turns out that exactly the same outcome can be achieved by an ITQ mechanism. Suppose that the TAC is chosen so that the corresponding fishing effort level is $\bar{E}_0$. Then, whatever is the initial allocation of quotas, any fisherman will sell any quota units he does not want to use, and will buy additional quota units if the increase in net revenue is no less than the price of quota. When trade in quota is complete, and if each fisherman harvests exactly the quota held, the price of quota units will be equal to the optimal unit tax t*.

Now the interesting question arises, how did the MAF propose to distribute the initial quotas? The answer is that "All fishermen currently holding rock lobster licenses will be eligible for allocation of quota". In other words, the Government intended to assign the economic rent (net of royalties to be discussed) from the fishery to the existing fishermen, that is, to the group held responsible for the depletion of the lobster stock and for the necessity of introducing the ITQ management regime!

Given the prior introduction of ITQ's in the fin fishery, and the discussions which preceded this event, it is reasonable to suppose that lobster fishermen correctly predicted the MAF proposal subsequent to 1986, especially since unlike the fin fishery, the lobster fishery involves no problems of by-catch which bedevil the operation of the fin-fishery ITQ mechanism. Thus, although the number of licensed vessels in 1983

was less than half that of 1978; from 1984, the number of vessels has not changed at all. As long as the ITQ scheme is expected to be introduced on the proposed terms, regulators can forget about further attrition as a means of reducing fishing effort, since fishermen leaving the industry would forgo the right to receive their quota allocation if they were not current license-holders. This point is made explicitly in the revised MAF proposal (NZMAF 1986b, p 7).

It is clear that the socially optimal lobster catch decreases as the ratio of costs to price increases. Depending on cost and price conditions, the appropriate quota allocation (and quota price or tax rate) will vary over time. Independently of the issue of who gets the initial quota, presumably the initial quota size should be based on the rationally expected values of costs and prices in immediately forthcoming periods. The MAF, however, proposed that "the initial allocation to each license holder will be based on his average catch over the five fishing years from 1 October 1980 to 30 September 1985". The justification provided in the revised proposal was that the allocation procedure "should fairly reflect fishermen's recent involvement in the fishery, while not giving undue advantage to those persons who have recently increased effort in anticipation of the introduction of ITQ's". It is unclear, however, that this allocation bears any relationship whatever to the appropriate TAC.

To illustrate, consider Figure 8 which shows the catch levels associated with the competitive and socially optimal fishing levels and two different cost functions. If the cost

FIGURE 8: CATCH LEVELS ASSOCIATED WITH DIFFERENT COST FUNCTIONS
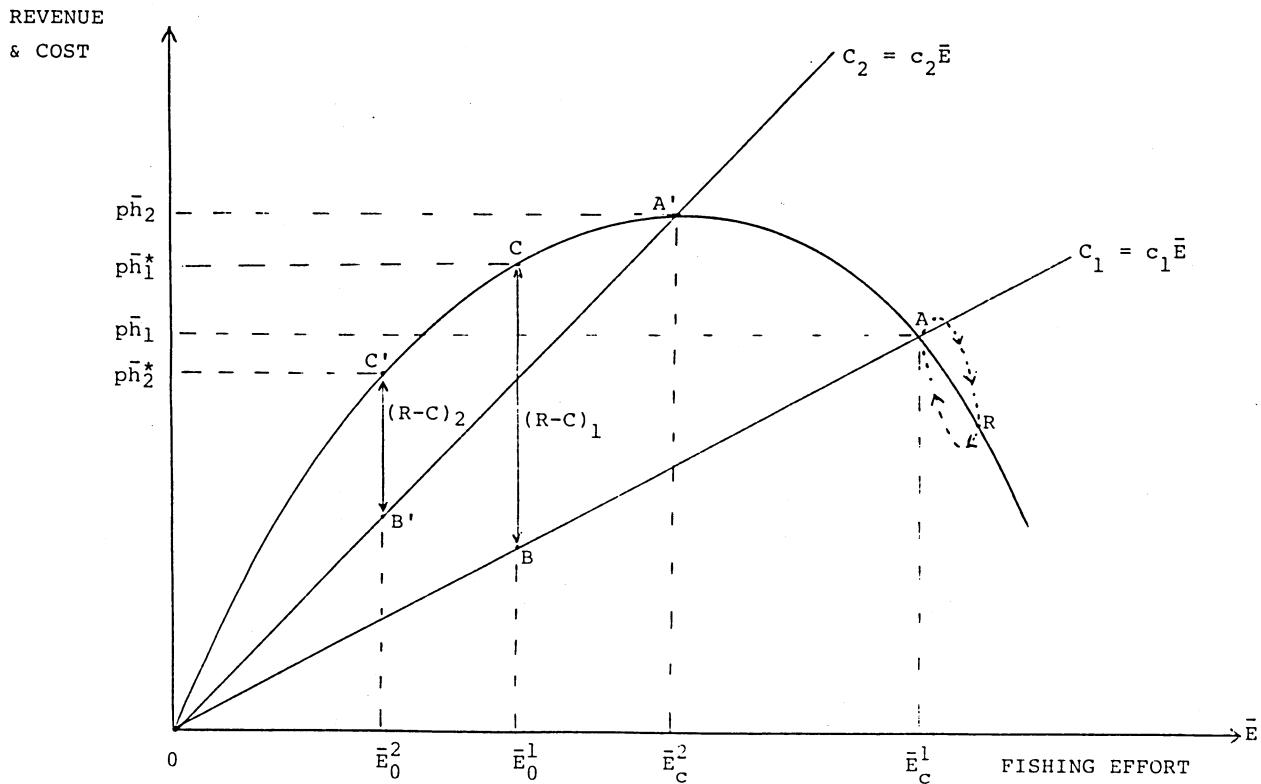
function is C_2, competitive fishing levels will be consistent with the maximum sustainable yield A', generating revenue R = $p\bar{h}_2$, implying a steady catch level of $\bar{h}_2$. At these costs and prices, the socially optimal fishing level is $\bar{E}_0{}^2$, implying a catch of $\bar{h}_2{}^* < \bar{h}_2$. If, however, the cost function is C_1, competitive fishing effort is $\bar{E}_C{}^1$, generating revenue $p\bar{h}_1$, and implying a catch of $\bar{h}_1$. The optimal fishing effort is $\bar{E}_0{}^1$, implying a catch of $\bar{h}_1{}^* > \bar{h}_1$. In each case, it pays society to reduce its fishing efforts and its fishing costs so as to generate positive resource rents. But in the latter case, the reduction in effort causes the *fish population* to expand sufficiently for the permanently lower effort level to be associated with a permanently higher catch. The moral is that although fishing levels may have been excessive, with too many resources devoted to fishing, nevertheless, the catch levels have been also been inappropriate and should not be used as a basis for setting initial quotas.

This argument is strengthened if, as has been suggested, fishermen engage in apparently unprofitable short-run fishing in order not to fall behind or maybe get a head start in what Anderson and Hill (1988) describe as "the race for property rights". If fishermen reasonably expect that their allocation of a scarce piece of property depends on their current and immediate future catch, they will take steps to increase their catch, wasting valuable resources in this process of rent-seeking. They may, in the short-run, be able to increase their landings with more fishing effort, but not in the longer run. However, even if they are aware that a collectively greater

fishing effort may reduce everybody's catch, nevertheless, it still pays any individual fisherman to increase effort in order to maintain his share of whatever total quota is finally allocated. Therefore no matter what is the response of other fishermen, it pays each fishermen to increase effort under such an incentive scheme; in the language of game theory, such behaviour is a dominant strategy.

The data seem to support this story. From 1979-84, landings per vessel increased dramatically, but declined thereafter, as Figure 5b reveals. Pot-lifts remained substantially above their 1983 levels, but, as Figure 5g shows, after an initial spurt in landings, lobster catch fell very significantly in later periods. In terms of Figure 8, suppose there is a short-term spurt in effort at A, although at an increasing short-run marginal cost. Catch and revenue both increase temporarily, then decline while costs rise. Then, at point R, say, when effort is reduced, catch declines in the short-term since there is less effort and the lobster stock is slow to recover from its recent attack.

If our interpretation is correct, the policy message is clear. As long as fishermen believe that ITQ's will be introduced and that their current catch levels will have some bearing on their allocation of quota, they will continue to overfish, deplete the lobster stock, waste resources and dissipate the rent associated with the handouts of rights to fish. The ways to beat this rent dissipation process are as follows. Instead of ITQ's, introduce the optimal tax structure described earlier. Alternatively, introduce ITQ's unannounced,

instead of laboriously negotiating with the interest groups involved, or else dispose of the initial quotas in an open competitive auction. For the case of ITQ's, for the first method, fishermen do not get time to alter their fishing behaviour. In the second, there is no incentive for fishermen to alter their behaviour. In addition, under an auction mechanism, quotas are allocated to those with the highest valuation, that is, to the lowest-cost fishermen.

Further, the longer is the process of introducing ITQ's, and if fishermen expect that their allocation will be related to their current fishing efforts, they will fish more intensively than the competitive level which itself involves overfishing. It is of interest to observe that in 1987, fishing effort in terms of the number of pot-lifts fell by 10 percent, much as expected since at that stage, fishermen would have reasonably expected the introduction of ITQ's to be imminent, in which case catch levels for that year would have been irrelevant for the allocation of quotas.

ESTIMATING THE APPROPRIATE SIZE OF THE LOBSTER FISHERY

In this section, we report results from Borren and Woodfield (1988) in which we attempted to give some quantitative estimates of the appropriate size of the lobster fishery. The steady-state fishery model was estimated in two steps. First, an equation expressing optimal effort as a function of the cost-price ratio was estimated. Then, the predicted values of effort from this equation were used as instruments in estimating the steady-state catch function.

There were several difficulties with this procedure.

First, the main data series were only available from 1963-85, so that the period of peak landings was regrettably excluded. Catch data are from Annala and Esterman (1986). Cost and price data turned out to be very scarce. The price series was basically obtained by dividing landings each year by total weight. An index of costs was constructed, using nominal wage rates by occupation group, the producers price index, and the home mortgage interest rate, along with imputed returns to labour supplied by vessel owners. Since the series for pot-lifts only begins in 1980, we were forced to use the estimated number of vessel-days from Annala and Esterman (1986). In addition, some diagnostic tests suggested that the model, even when adjusted to account for different regulatory regimes and lagged adjustment processes, may not have been the most suitable dynamic specification, and the behaviour of fishermen in the 1980's is likely to at least partly account for this.

Nevertheless, the results are quite striking. For example, in 1985, some 4886 tonnes of lobsters were caught, with a fishing effort of 72,609 vessel-days. Lobster prices were $11,250 per tonne that year, and unit cost of fishing effort was estimated at $792 per vessel-day. This implied a maximum equilibrium yield effort level of 32,989 vessel-days, and an optimal catch of 4010 tonnes. Notably, the estimated optimal effort is a mere 45 percent of observed effort in 1985, suggesting considerable recent overfishing. The optimal yield, however, is 83 percent of the 1985 yield, so that the very considerable reduction in effort required will have a rather small effect on the number of lobsters caught in the long-run.

Some biologists favour the maximum sustainable yield as the appropriate catch level. This is estimated to involve 55,882 vessel-days, and a catch of 4818 tonnes. The MEY effort is only 59 percent of the MSY effort, while the MEY catch is 83 percent of the MSY catch. Evidently, the fishing levels observed during the 1980's have been excessive relative to the estimated MEY and MSY levels.

If costs and prices in 1985 had been maintained permanently, the estimated model says the following about the size of the resource rent given up by open-access fishing. If an ITQ scheme had been introduced without warning in that year, with quotas set equal to 4010 tonnes in total, a surplus of revenue over costs of nearly $19 millions would have been available on an annual basis, in perpetuity, once the lobster stock had adjusted to its new higher long-run level. At real discount rates of 5 - 10 percent, the present value of these resource rentals turn out to be $190 - $380 millions, a hardly trivial amount to be assigned to those 'loyal' fishermen. In fact, we estimate that on an annual basis, at 1985 prices, fishermen would be willing, in the long run, to pay $4734 per tonne of lobster quota (this also measures the optimal tax rate), which represents 42 percent of the gross price of lobster.

The Government, however, does not apparently wish to dispose of property rights to fish for lobsters without some return. In NZMAF (1986a, p 23) it was argued that "The Government considers that the fishing industry should pay a royalty in recognition of its commercial gain from publicly owned resources...... In fisheries where ITQ's are implemented there is

an associated property right. The industry will be expected to pay for this privileged access to harvest the resources". And what did the Government have in mind as payment? A shrimp-size $275 per tonne, a mere 6 percent of the figure we estimate represents the fishermen's willingness to pay.

In the revised proposal, the regulators proposed to set the TAC at 4500 tonnes, approximately the average annual catch over the previous five years. It was argued that this was lower than their "estimated maximum equilibrium yield" (NZMAF 1986b, p 7) but it is not clear that this definition is the same as our MEY, or whether they are referring to MSY. Our estimates suggest that the proposed allocation is 93 percent of the MSY, and is 111 percent of MEY. Accordingly, we suggest that the MAF proposal involves overfishing and rent dissipation unless the cost/price ratio is smaller than in 1985. Notably, during 1981-85, the cost/price ratio was generally substantially higher than in 1985. At 1985 prices, a catch of 4500 tonnes would have required 41670 vessel-days, and would have yielded a resource rent of 93 percent of the corresponding MEY amount.

It must be emphasized, however, that these are long-run results. Figure 3, for instance, tells us little about the dynamic adjustment to the long-run optimum. The process is likely to be very drawn-out, since lobsters take a relatively long time to grow to maturity, and are hence slow to respond to reductions in fishing effort. Whether the MEY or the MAF catch levels had provided the basis for initial allocations, it is possible that the resulting quotas would have been non-binding in the short-run.

For example, the open-access catch of 3763 tonnes represents only 94 percent and 84 percent of the long-run optimal catch and the MAF's proposed catch, respectively. Thus,there may have to be several years of substantially reduced fishing, involving zero or small resource rents, until the long-run is achieved. In the interim, the resource royalty may turn out to be a serious burden to fishermen. This is especially so if the royalty is adjusted upward unexpectedly after the initial quota allocation has taken place. The government might, after this event, discover it has gifted a valuable property right and attempt to recoup via an increased royalty. This will be especially onerous to fishermen who have purchased quota initially allocated at a zero price to existing fishermen.

CONCLUSION

We conclude as follows. First, existing regulation of the New Zealand rock lobster industry mainly involves increased costs without having much effect on reducing fishing levels. In addition, there appear to be considerable social gains associated with the definition and enforcement of private property rights in New Zealand's rock lobster fishery. Proposed ITQ schemes, however, involve the resource rents associated with these property rights being transferred at virtually zero cost to the existing fishermen responsible for depletion of the fishery. The method of allocating quotas appears to have encouraged fishing in excess of levels agreed to be excessive. We have suggested alternative regulatory methods, possibly involving ITQ's, which avoid these results.

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