ITQ'S VS ITE'S IN THE WRLF

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INTRODUCTION

Since 1965, the Western Rock Lobster Fishery has been managed by what is essentially a license limitation scheme involving restricted entry for boats, a limited duration fishing season, and strict controls on the aggregate number of pots which can be used by the commercial fishing sector. These core policy instruments have been supported by a range of other regulations, such as prohibitions on taking berried or setose adults, controls on pot design, and other gear restrictions. Many of the additional regulations have the effect, at least in part, of reinforcing the effectiveness of the license limitation scheme in controlling fishing effort by limiting catching power of licensed pots.

By most measures, management of this fishery has been highly successful. Biological over-exploitation of the fish stock has been prevented, at least until recently. The level of compliance with fishery regulations has also improved significantly over the past twenty-five years, and has been achieved with relatively low levels of enforcement costs. However, by far the most significant achievement, and one which is still quite rare in the management of fisheries around the world, has been the generation and preservation of significant resource rents (i.e. the long run net returns to ownership of the resource stock net of all "real" catching costs other than those related to accessing the fish stock, such as pot, boat, and quota license costs). Generation of potential resource rent has been driven primarily by increases in the price of the product from subsistence to luxury levels, but it has been the management of the fishery which has been responsible for preservation of a significant proportion of the potential rent. The tangible evidence of this rent is the prices paid for pot licenses, which are freely tradeable. The aggregate capitalised value of pot licenses in the fishery now exceeds $1,000 million, which at a discount rate of 5 per cent, implies that over $50 million in resource rent is generated annually.

Notwithstanding these achievements, there is widespread concern that the future profitability, and even the viability of the industry is under threat unless the current management practices are reformed. For a number of years, there has been continuing increases in nominal fishing effort[1], and even greater increases in effective fishing effort despite continuing attempts to tighten regulations governing the level of use and effectiveness of fishing gear in the industry. As a result, exploitation rates have been higher in recent years, which in turn has led to marked decreases in the estimated size of the breeding stock. Growing concern over the level of the breeding stock has led to an emerging consensus that further changes to the methods used to manage the Western Rock Lobster Fishery will have to be made in order to protect its long term profitability and viability.

In broad terms, there are two options which could be adopted to manage the fishery on a sustainable basis. One is to continue to rely on a modified version of the current management scheme, the essence of which is a License Limitation Scheme (license limitation schemes) involving restricted use of key inputs (i.e. pots). If the primary objective of restoration of the breeding stock to a viable level (and subsequent preservation at this level) is to be achieved using this option, then the average annual catch and exploitation rate will need to be reduced by further reducing effective effort so that a higher proportion of recruits "escape" into the breeding stock. Available means of reducing nominal effort include further reductions in the number of licensed pots and/or extending the duration of the closed season. Independent reductions in effective effort also could be achieved by further restrictions to the effectiveness of pot use (e.g. by changing minimum size limits, and by banning technologies which enhance pot "catching power").

[1] Defined as aggregate number of pot lifts.

Economic theory[2] suggests that reducing catch by reducing licensed pot numbers is likely to increase th average cost of effort because it encourages increasingly inefficient combinations of licensed and unlicensed inputs. As a result, realised resource rent will be less than potential resource rent. Furthermore, any regulations which impede rationalisation of boat numbers operating in the fishery in order to meet socio-economic policy goals will exacerbate this problem of rent dissipation. Likewise, regulations which restrict the effectiveness or "catchability" of licensed fishing gear will also dissipate potential rent. Where such regulations restrict the duration or timing of fishing effort, they may reduce the average return per unit of catch as well as increasing the average cost of effort, thereby further dissipating rent. Finally, if past history repeats itself, there will be a continuing need over time to furthe reduce the number of licensed pots to offset the impact of fishermen's ingenuity in exploiting technological change to further raise the effective level of effort. Such ongoing change in the regulatio of the industry would involve additional administrative, managerial, and political costs.

The alternative approach is to abandon methods of management based on input controls for one basec on direct control of output, or level of catch. One intrinsic benefit of catch control based management methods is that their effectiveness in limiting exploitation rates and ensuring the desired level of escapement to the breeding stock is not compromised by advances in fishing technology nor by favourable changes in economic circumstances (e.g. higher prices and/or lower costs) which provide a incentive to increase effective fishing effort. Consequently, so long as the total allowable catch (TAC) introduced before the fishery is over-exploited, and is set at the correct level from the outset, there should not be any need for continual adjustments to fishery regulations as is the case with input contro based management systems.

It is widely recognised that the inevitable consequence of a management scheme which relies solely or TAC is total rent dissipation[3] due to the "rush to fish". A more sophisticated approach to output contr is to base the management system on individual transferable (catch) quotas (ITQ's). The disadvantage of ITQ based management systems have been discussed by Copes (1986). In particular, they revolve around difficulties associated with compliance and enforcement, and the consequences of actual catch exceeding the TAC. Other management costs, such as stock assessment research, are also likely to be greater than for an ITE based management system.

In theory, an ITQ based management system should foster generation of the maximum potential resource rent from the fishery. In practice, there is insufficient evidence available from the implementation of ITQ based management systems on which to base a judgement about whether there will, or will not be any rent dissipation under this type of management system.[4] Consequently, econon models have to be used to try to estimate whether possible changes in the method of fishing under ITC based management systems are likely to increase aggregate net economic returns from the fishery relative to those which could be earned under a system which controls inputs[5]. Several methodologica different procedures were employed by Lindner (1994b) in an attempt to obtain broadly consistent estimates of the relative benefits and costs of a change from an input based management system to an output based management system. Preliminary estimates derived from a simple bioeconomic model of potential resource rent dissipated under the current management regime of ITE's have been reported previously (Lindner, 1994a). This paper contains the key findings of a complementary study in which programming model of the fishery was used to directly estimate some of the main benefits of a switch from ITE's to ITQ's.

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[2] See Anderson (1985) and Campbell and Lindner (1990).

[3] i.e. net returns from the fishery are driven down to the point where catching costs at least equal gross returns.

[4] What is clear is that the likelihood and degree of rent dissipation will be greater if regulations used to reinforce a license limitation system of management are not discarded upon adoption of an ITQ based management system.

[5] For example, see Dann, T. and Pascoe, S. (1994), and Lindner (1994b).

ITE's VERSUS ITQ's IN THEORY.

Anderson (1985) has demonstrated that fishery regulation by means of license limitation may generat resource rents in a commercial fishery. While restricting the amount of a major input (e.g. pots) used i the production of effort may increase the unit cost of effort, the reduction in the total amount of effo devoted to the fishery will yield a benefit through a shift of resources to higher value uses elsewhere.

Rent dissipation is defined in this paper as the difference between the level of resource rent actuall generated under a license limitation scheme and that for the benchmark case of a sole owner generatin maximum potential rent. Dupont (1990) describes the sources of such rent dissipation as:

- capital stuffing, or input substitution, which results when fishermen attempt to increase their catches by using more unrestricted inputs in place of the restricted input;
- fleet redundancy, or excessive effort, due to the fact that the regulator permits more than the optimal number of restricted inputs to be employed in the fishery;
- heterogeneous vessels and/or catching technology which allows less efficient firms to continue to operate in the fishery.

There is a high degree of homogeneity of vessel type in the Western Rock Lobster Fishery, so the third source of rent dissipation is unlikely to be important, and it is ignored in the rest of this paper. As noted above, in theory a shift to a management system based on ITQ's from one based on ITE's ought to eliminate rent dissipation due to capital stuffing as fishermen respond to the elimination of distorted incentives to economise on the use of licensed inputs. Moreover, provided that the TAC is set at the optimal level, competitive pressures to earn a market rate of return on the capital invested in ITQ's should over time eliminate rent dissipation due to fleet redundancy.

Under an ITQ based scheme, most fishery regulations are redundant except for those relating to setting the level of the TAC so as to preclude excessive effort, and those designed to ensure protection of the breeding stock such as prohibition of high grading. Assuming all redundant regulations are in fact repealed, economic theory suggests that the main benefits of ITQ's relative to a license limitation scheme will include :

- lower cost per unit of effort (i.e. effective pot lift) due to:
  - fewer boats,
  - more cost efficient boat and gear configurations,
  - more timely fishing, and
  - more efficient fishermen.
- a higher return per unit of catch due to:
  - better matching of the seasonal distribution of catch to seasonal variations in market demand, and
  - better quality (e.g. better class size mix, more "live", more reds, etc.).

Given that both the level of compliance and the quality and reliability of stock assessment are equivalen under each method of management, the primary disadvantages of ITQ's relative to a license limitation scheme will include:

- higher enforcement and compliance costs.
- higher costs of research for stock assessment.

It is possible that the risk of stock failure also will be affected by the choice of management method, bu further research is required to determine both the direction and the magnitude of this effect.

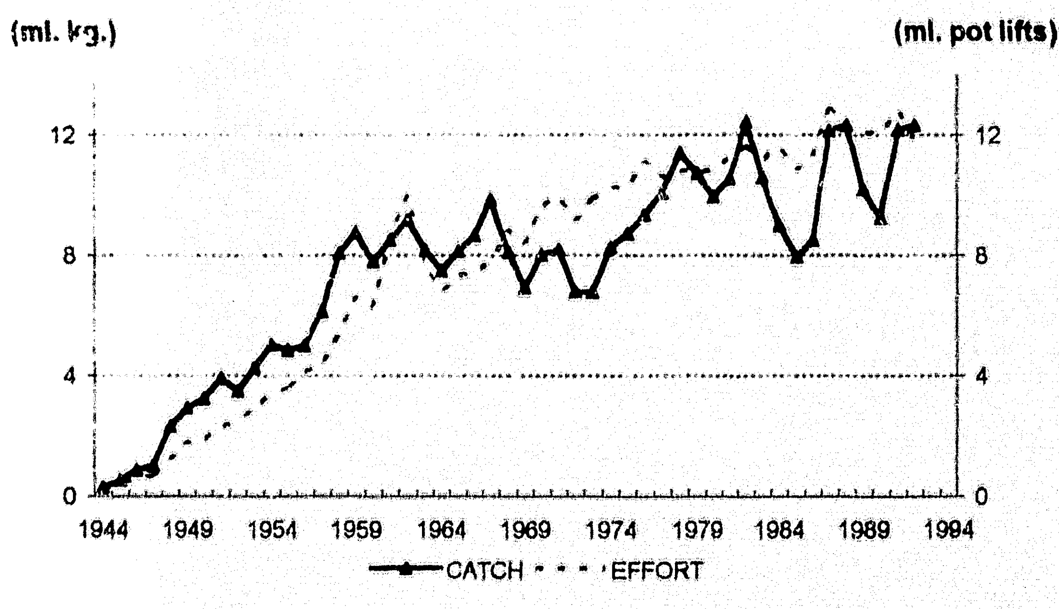
The evaluation of long run management options for the Western Rock Lobster Fishery reported here is restricted to one key issue, namely the estimated impact of the above two alternative management systems on realised resource rent from the fishery due to changes in cost per unit of effort, and in return per unit of catch. Estimates also are made of changes in net annual industry returns from the fishery du to:

- reduced boat numbers
- more or less intensive pot use
- extended fishing season

A POTTED HISTORY OF THE WRLF

Development of the Western Rock Lobster fishery took off after World War II with the opening up of national and international markets made possible by refrigerated transport. Both fishing effort and catch grew so rapidly from 1945 to 1965 that concerns arose about long term sustainability of the fishery. As a result, a policy of limited entry into the commercial fishery was introduced in 1963, and the number c boats and pots licensed to operate in the fishery have been controlled since 1965. A number of other regulations, such as a defined fishing season and restrictions on the length of replacement boats, have also been used to control fishing effort and/or achieve other government policy objectives. The high rates of growth in catch and effort prior to 1965, and the much lower growth rates since then are evident in Figure 1 below.

Figure 1: History of Catch and Fishing Effort

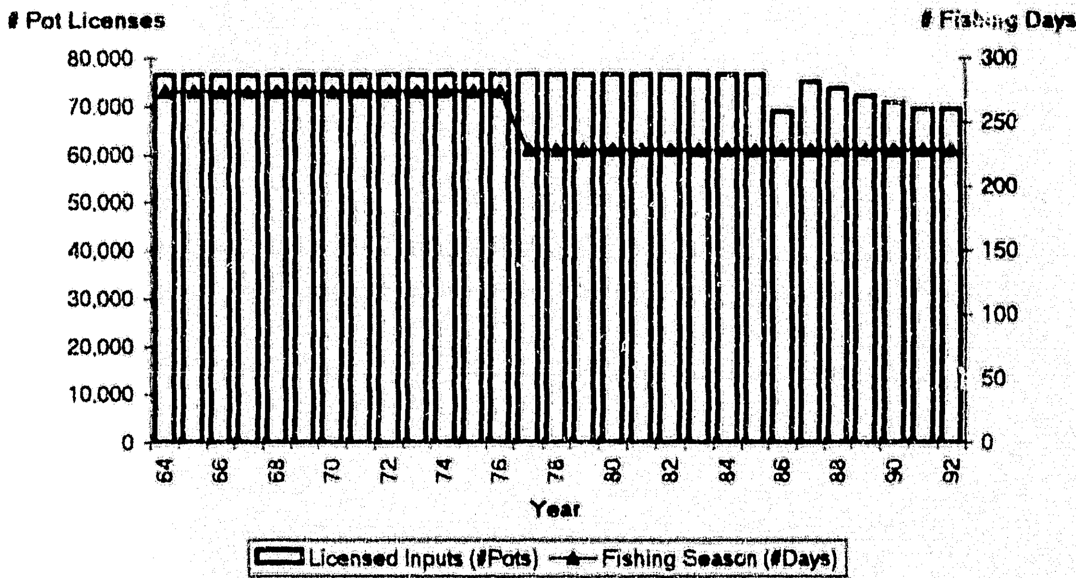


In Figure 1, fishing effort is measured in terms of number of pot lifts, which in the literature is often referred to as the level of nominal fishing effort. In recent years, fishing effort has been of the order of 12 million pot lifts per annum, which given previous levels of recruitment and catchability would result in an annual catch of nearly 11 million kg, at least in the short term. However, there is evidence that thi level of exploitation has depleted breeding stocks to levels which could not sustain current levels of recruitment.

The other determinant of aggregate catch is catch per unit of effort, or CPUE[6]. Catch per pot lift depends both on stock abundance, and on pot catching power. There is substantial evidence, even though some of it is anecdotal, that pot catching power has increased over time due to input substitution. Under a license limitation scheme, there is an economic imperative to rush to catch as many fish as quickly as possible. Otherwise they most likely will be caught by other fishermen, who seek to increase their own level of fishing effort by what ever legal means are at their disposal. Examples of input substitution which have increased pot catching power include "fish finding" aids such as depth sounders and improved navigational aids to locate productive fishing grounds. More exotic options such as remote controlled mini submarines with a TV "eye", and bigger or better pots have been banned to prevent even greater increases in pot catching power.

For the above reasons, growth in nominal fishing effort almost certainly understates the growth in *effective* fishing effort. Nevertheless, as can be seen from Figure 1, even nominal fishing effort has continued to grow, albeit at a slower rate, throughout the period of management by ITE's. This has occurred despite shortening the fishing season from 274 days to 228 days in 1977 by bringing the closing date forward from August 15 to June 30, and in recent years by reducing the number of pot licenses on issue by 10%. Arguably these instruments are the two most effective means for controlling nominal fishing effort, and changes in them are depicted below.

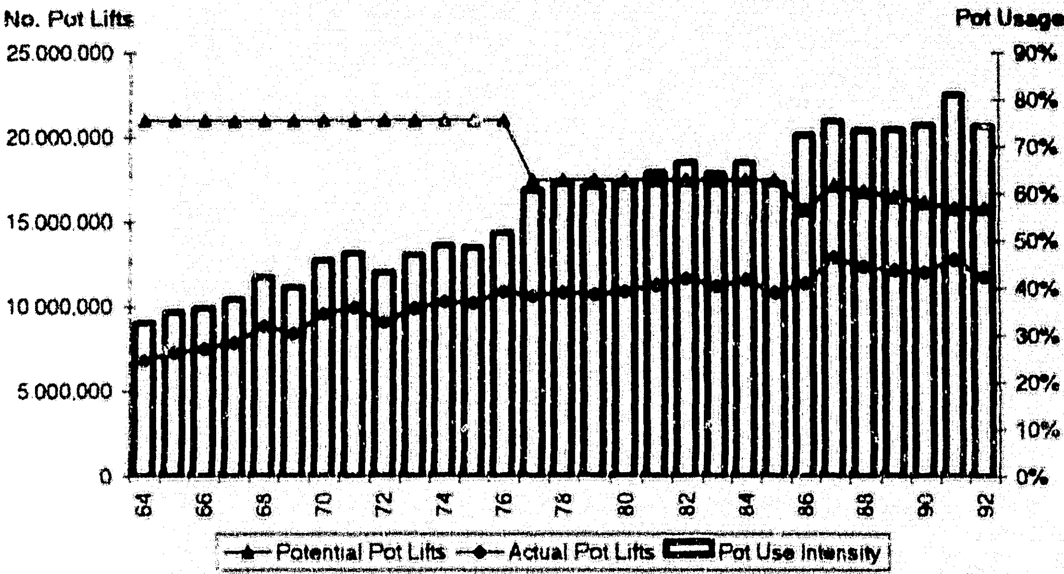
Figure 2: History of Season Duration, and Pot License Numbers



As can be seen from Figure 3 below, fishermen have been able to subvert much of the intent of a shorter fishing season and reduced pot numbers by increasing the intensity of pot use, defined as level of actual pot lifts as a percentage of potential pot lifts. Since the biology of the Western Rock Lobster severely limits the effectiveness of lifting an individual pot more than once per day, potential pot lifts is calculated as the product of number of licensed pots by number of available fishing days during the defined fishing season.

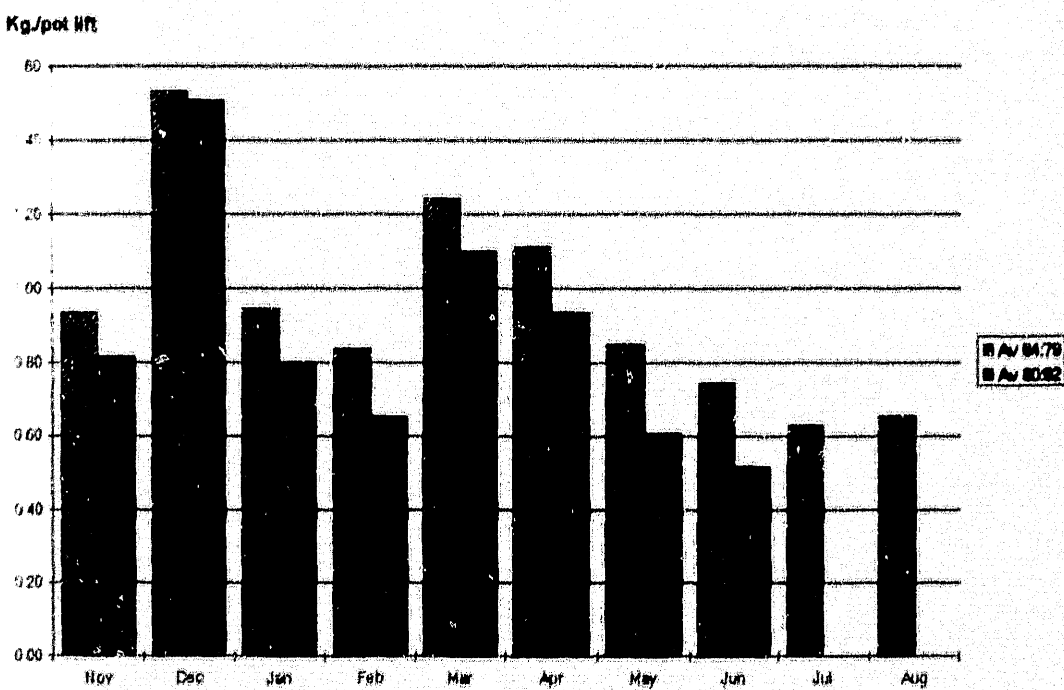
[6] Given these definitions, the unit of measurement for CPUE is kg. of catch per pot lift.

Figure 3: History of Pot Use Intensity



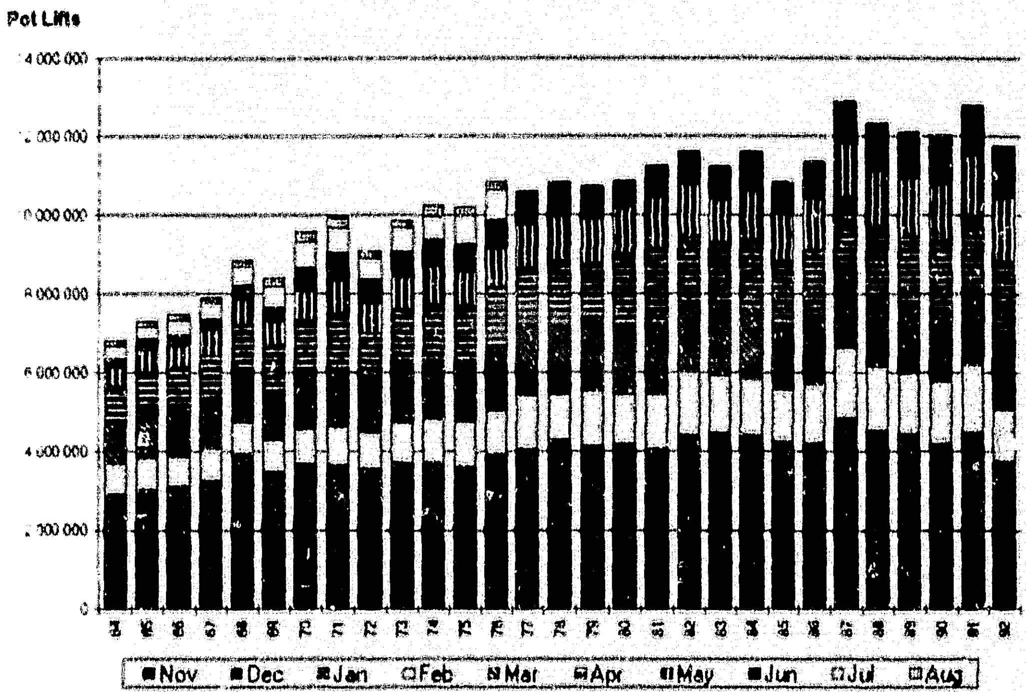
Fisherman have increased expenditure in various ways to increase pot utilisation rates, including buildin larger, faster, and more seaworthy boats so as to be able to increase the proportion of available time spent fishing. In particular, they have increased fishing effort during the main months of the "reds" season (ie March to June) which are both less productive and more prone to bad weather. Data on catc per pot lift in Figure 4 illustrates the greater catchability of lobster during the migratory "whites" season in the early part of the fishing season relative to the later months.

Figure 4: Monthly Catch/Pot Lift for Earlier and More Recent Years.



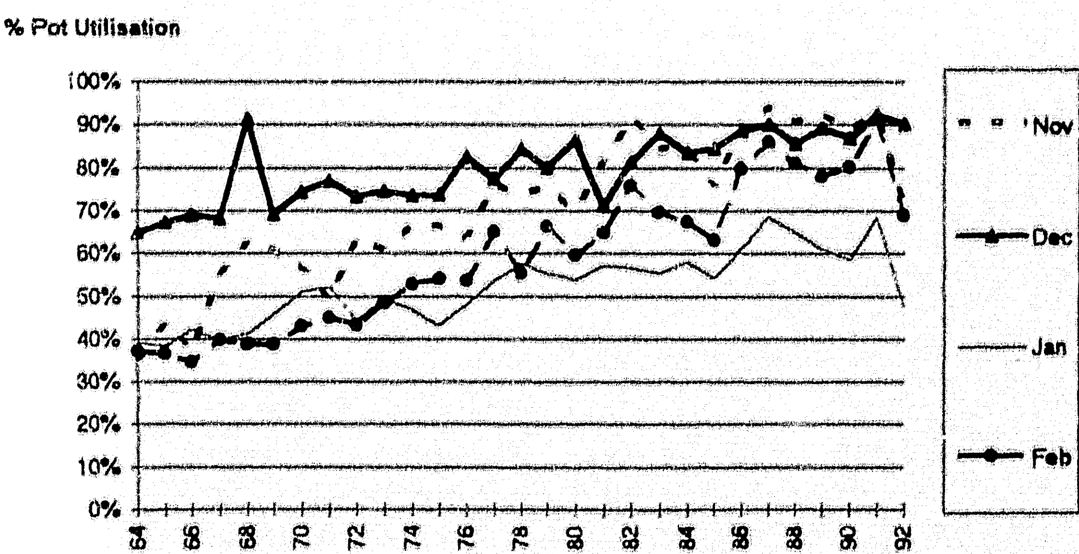
Several aspects of Figure 4 are noteworthy. CPUE is markedly higher in December, followed by March and April than it is for the remaining months. In all months, CPUE is lower in the later sub-period than in the earlier sub-period, and this difference is more marked in the later months of the fishing season than in the earlier months. This seasonal pattern of fishing productivity is reflected in the seasonal distribution of fishing effort as illustrated in Figure 5 below.

Figure 5: History of the Seasonal Pattern of Fishing Effort.



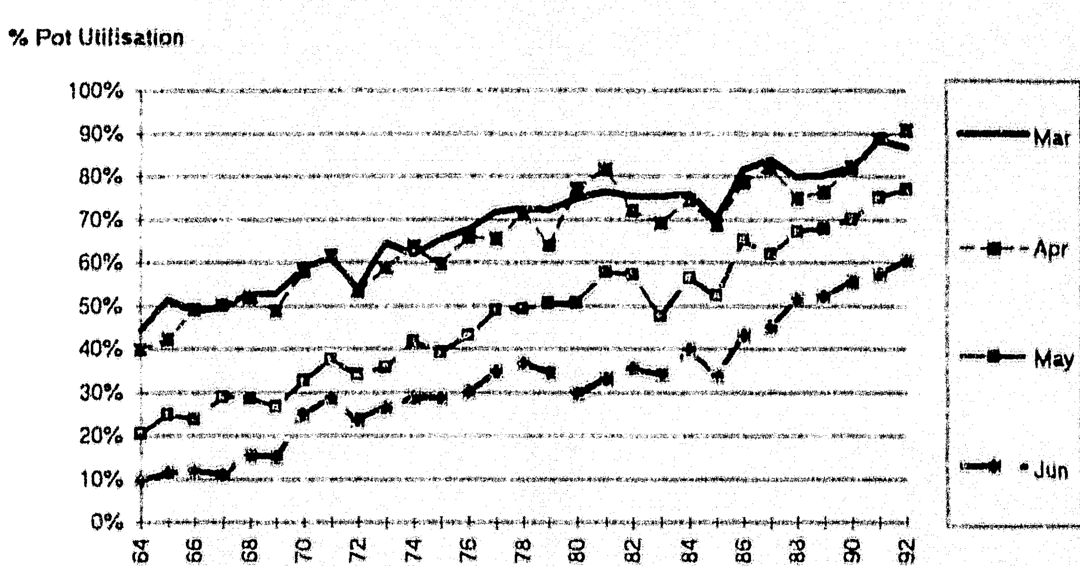
The difference in the increase in pot utilisation rates between the early and later parts of the fishing season can be seen by comparing Figure 6 with Figure 7.

Figure 6: History of Pot Utilisation in the "Whites" Season



From Figure 6 it can be seen that pot utilisation rates have always been high in December, and apparently reached a ceiling of about 90%. Given that in any given month, some "down time" will be inevitable for some boats and/or fishermen due to sickness, mechanical breakdowns, bad weather, etc., a 90% pot utilisation rate probably is close to the achievable maximum with existing technology. Initially, pot utilisation rates were lower in November and February, but in recent years have levelled out at about the 90% level. By contrast, pot utilisation rates in the last four months of the fishing season started at much lower levels than for December, but have been increasing steadily ever since, and in the case of March and April may well have reached maximum achievable rates.

Figure 7: History of Pot Utilisation in the "Reds" Season.



To sum up, because of greater catchability of lobsters during selected months, and especially in December and to a lesser extent in March and April, it has been globally optimal, *ceteris paribus*, to expend more fishing effort during these months relative to the rest of the fishing season. When there is "open access" to the resource stock, even if such access is limited to a select number of licensed fishermen, this tendency to increase effort in the early part of the fishing season will be exacerbated by the "rush to fish". Consequently, increasingly more effort is likely to be expended early in the fishing season, and due to intra-seasonal stock depletion, the fishing season is likely to reach the point of economic exhaustion sooner than it should under an optimal pattern of exploitation. In the early years of the development of the fishery, available data on pot utilisation rates suggests that the seasonal pattern of exploitation was broadly consistent with this scenario.

However, under the input based system of fishery management introduced in the mid 1960's, the evidence presented above suggests that economic pressures arising from this scheme have worked in the opposite direction. Because the opportunity to further increase pot utilisation rates in the early part of the fishing season is limited by a finite number of available fishing days, the only means to maximise returns to the scarce input of licensed pots has been to increase pot utilisation rates in previously lightly fished months, which tend to be in the latter part of the fishing season. As a result, for at least the past two decades pot utilisation rates in the latter months of the fishing season can be seen from Figure 7 above to have increased faster than equivalent rates during earlier months as illustrated in Figure 6.

The above discussion implicitly assumes a stable economic environment. One of the things that has become less equal in recent years has been the seasonal pattern of prices per kg. for live product. Because of the emerging importance of live exports to Japan, and more recently to Taiwan and China, unit prices now tend to be relatively lower during the early part of the fishing season. This has increased the economic incentive to redistribute more fishing effort into the latter part of the fishing season relative to the early part of the season. To some extent, this fact offsets the lower catching costs in the "whites" season, so that a more even seasonal distribution of fishing effort is now more economically rational than it was at previous times in the development of the fishery.

It is a moot point whether the current seasonal pattern of exploitation in this fishery which has evolved as a result of the economic forces outlined above is consistent with maximisation of fishery resource rent. This is one of the key issues addressed in the analysis using the programming model described below.

MODEL SPECIFICATION AND ANALYTICAL OVERVIEW

The mathematical programming model of the fishery developed for this study simulates both economic relationships and limited biological relationships. By incorporating constraints into the model which reflect existing industry structure in terms of boat and pot numbers, the seasonal pattern of effort, etc., it can be used to represent the current management scenario based on ITE's. For comparative purposes, the same basic model can then be run to identify the method of fishing[1] which will maximise aggregate net annual economic returns in the absence of these management specific constraints. Results from such a model run provide a prediction of aggregate fishery outcomes under an ITQ's based management scenario as well as an indication of likely economic behaviour by individual fishermen. Because the model was constructed to be able to identify the optimal monthly pattern of exploitation of the fishery which takes account of both seasonal variations in abundance and catchability on the one hand, and seasonal variations in the average worth of the catch on the other hand, it provides an indication of the potential economic benefits of switching to an ITQ based management system, although it is difficult to predict all of the ways in which such a system would evolve in the absence of any input based controls.

Specifically, the model provides estimates of maximum potential annual net economic returns which could be generated from the fishery given a defined total allowable catch (TAC), given specific assumptions about the values of key fishery parameters and constraints, and given an assumed economic structure in the catching sector of the industry. In addition, the model computes the optimal boat and pot numbers, and seasonal patterns of effort and catch which, subject to specified constraints, maximise aggregate annual net returns from the fishery.

Note that annual net returns may not equate with annual resource rents for several reasons. For instance, there is no necessary reason why maximum potential short run net returns should be biologically sustainable in the long run. For this reason, the model was designed to ensure that catch levels are consistent with stock availability, and that sufficient animals "escape" into the breeding stock to satisfy the steady state condition for biological sustainability. Specifically, the model incorporates a simple representation of steady state population dynamics in the Western Rock Lobster Fishery based on assumptions about key relationships, including both catch and natural mortality as well as growth over time in size of surviving animals. The level of resource rents being generated in a fishery also depends on industry economic structure, which is determined, *inter alia*, by the method of fishery management.

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[1] i.e. the aggregate level and configuration of boats, pots, and other fishing inputs.

In addition to a comparison of alternative management regimes, the model was used to explore the implications of changes to some aspects of the regulatory environment which impact on economic structure, including in particular the number of boats operating in the fishery. The starting point for the analysis of changes to the economic structure of the industry was historical average monthly patterns o catch, effort, and CPUE for the period from 1980 to 1992 inclusive[8]. Apart from stock abundance, CPUE will depend on "managerial" variables such as catching technology and care and time taken in p placement, as well as on various environmental factors which are imperfectly understood. It is well documented that the downward trend over time in CPUE due to declining stock levels has been ameliorated to some degree by the above "managerial" factors. The extent to which this is likely to continue in the future will depend upon the method of management used in the fishery, and in the case of a license limitation scheme, on the severity of further pot reductions. Other things being equal, CPU may be higher (i.e. decline slower) under a license limitation scheme than under an ITQ based management system. Because there is no evidence available on which to base predictions of the magnitude of such a difference, it was not built into the model.

Key parameter values assumed in the programming model are set out in Table 1, and data sources a detailed in Appendix 1.

Table 1: Key Data and Parameter Values

HISTORICAL DATA	YEAR	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	S
Avg. Catch (Kg.)	10,796,313	817,441	2,958,997	1,073,505	995,765	1,986,984	1,612,919	853,892	496,808			
% Catch	100.0%	7.57%	27.41%	9.94%	9.22%	18.40%	11.94%	7.91%	4.60%			
Max fishing days	320	16	31	31	28	31	30	31	30	31	31	
Avg. Days fished	187	15	28	22	25	27	27	25	18	15	12	
PARAMETERS USED IN MODEL	**SEASON**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**S**
Max fishing days	Current	15	29	22	25	27	27	25	18			
Max fishing days	Extended	15	29	22	25	27	27	25	18	15	12	
CPUE(kg/pl)		0.80	1.47	0.86	0.68	1.10	0.97	0.65	0.55	0.63	0.65	
Catch worth($/kg)	Current	$23.90	$19.64	$20.03	$21.75	$22.43	$22.43	$[illegible]62	$24.87			
Catch worth($/kg)	Extended	$24.51	$20.67	$20.27	$22.07	$22.50	$22.47	$23.8[illegible]	$25.21	$26.04	$26.04	$26.

Average Costs					
$ / trip	$145	$ / pot	$145	Deckhands ($/kg.)	$3.20
$ / potlift	$2.10	$ / boat	$115,000	Processor's Overheads ($/kg.	$3.50

Minimum required monthly pot numbers depend on required effort, and on assumptions about numbe of available fishing days. In any given month during the mandated fishing season, the expected numbe of "available" fishing days will be a function both of expected weather conditions for that time of the year as well of current boating and catching technology. It can be inferred from Figures 6 and 7 above that number of days fished per year has been increasing steadily since the introduction of the license limitation scheme to manage effort levels in the fishery. In recent years, this trend has continued despit significant reductions in the number of pots licensed for commercial use.

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[8] See Figure 5 above for monthly effort data, and Figure 4 for catch per pot lift data.

An analysis of data on fishing effort for a sample of individual boats revealed that while almost all boats are pulling their pots on every available day during the "productive" months, only some boats are doing so during the "unproductive" months. Consequently, it would seem that there is still considerable potential for further increases in effort under a license limitation scheme, and particularly in the latter part of the season. Subjective predictions of potentially available fishing days by month were based on the above evidence, and used to estimate pot numbers required on an annual basis to achieve specific seasonal patterns of catch and effort.

Likewise, estimates of optimal boat numbers are influenced by assumptions made about average number of pots per boat used in the industry. Based on data for recent fishing seasons, a value of 104 pots per boat was assumed for most scenarios. However, for reasons discussed above, number of pots per boat is likely to be appreciably larger under an ITQ based management system than under a license limitation scheme, so an average value of 144 pots per boat was assumed in some scenarios.

In other scenarios, the implications of adopting a policy of preventing rationalisation of boat numbers by regulating number of pots per boat was investigated by fixing boat numbers at the current[9] levels of 669 boats. Average pot numbers per boat in these scenarios was simply the ratio of minimum pot numbers required to take the specified catch to the mandated number of boats. Given the number of assumptions which had to be made in specifying the model, the results reported below provide an imperfect guide to the consequences of changing the method of management in the fishery because of the difficulty of predicting all of the ways in which economic structure will change in response to a change in the system of management.

To explore the economic consequences of changing the method of managing the Western Rock Lobster Fishery, the mathematical programming model was modified to represent a number of different scenarios. In all of the evaluated scenarios reported in this paper, the primary consideration was preservation of the fishery on a biologically sustainable basis. Expert advice is that average annual catch needs to be reduced to approximately 9 million kg so that sufficient animals can escape capture long enough to reach sexual maturity, thus maintaining the breeding stock at a sufficient level. As noted above, in recent years annual catch has been averaging nearly 11 million kg., which is most probably not sustainable.

Relative to a base case defined to approximate current organisation of the catching sector and the average aggregate net economic returns being generated from the fishery performance, the defined scenarios varied in some or all of the following respects:

- retain the License Limitation Scheme and reduce pot lifts and the average catch level (from about 10.8 million Kg. to 9 million Kg.)
- retain the license limitation schemes and adopt a variable closed season with a TAC set equal to 9 million Kg.
- adopt a management system based on ITQ's, and with a TAC set equal to 9 million Kg.
- extend the end of the fishing season from June 30 to Sept. 30 for each management method
- prevent decline in pot nos. (by appropriate regulation)
- prevent decline in boat nos. (by appropriate regulation)
- relax regulations governing catching efficiency (e.g. maximum pots/boat)

[9] At the time of initiation of this study.

RESULTS

The specific scenarios reported in this paper are summarised in Table 2 below together with reference case numbers. Results of evaluating these scenarios are summarised in Table 3 for cases involving inp based management methods, and in Table 4 for cases involving management methods based on outpu controls. A comparison of otherwise equivalent cases differing only in the basis for fishery manageme is presented in Table 5.

Table 2: Alternative Management Scenarios Evaluated with Programming Mod

Case No.	Catch (m. kg.)	Management Method	Boat Nos.	Pot Nos.	Avg. Pots/Boat	Season End Date
0	10.8	TAE/ITE	669	69,576	104	June 30
1	9.0	TAE/ITE	Opt. No.	Opt. No.	104	June 30
2	9.0	TAE/ITE	669	Opt. No.	104	June 30
3	9.0	TAC only	669	69,576	104	Variable
4	9.0	TAC/ITQ	Opt. No.	Opt. No.	104	June 30
5		TAC/ITQ	669	Opt. No.	104	June 30
11	9.0	TAE/ITE	Opt. No.	Opt. No.	144	June 30
14	9.0	TAC/ITQ	Opt. No.	Opt. No.	144	June 30
21	9.0	TAE/ITE	Opt. No.	Opt. No.	104	Sept 30
24	9.0	TAC/ITQ	Opt. No.	Opt. No.	104	Sept 30

Scenarios 1, 2, 11, and 21 all simulate variations on the current ITE/TAE based management scheme (case 0), and are summarised in Table 3.

It can be seen that reducing catch from current to more sustainable levels under this system by reduci pot and boat numbers (case 1 relative to case 0) reduces aggregate net returns by about $5.7 million p.a., while the minimalist approach of reducing pot numbers only, but preventing any decline in boat numbers, (case 2 relative to case 0) reduces aggregate net returns by over $18.5 million p.a.. These estimates do not account for any offsetting losses due to additional rent dissipation likely to accompan attempts to reduce effort and catch while retaining the ITE/TAE system. Clearly there is a large opportunity cost of about $13 million (case 1 - case 2)involved in failing to allow rationalisation of bo numbers when the catch is reduced to sustainable levels.

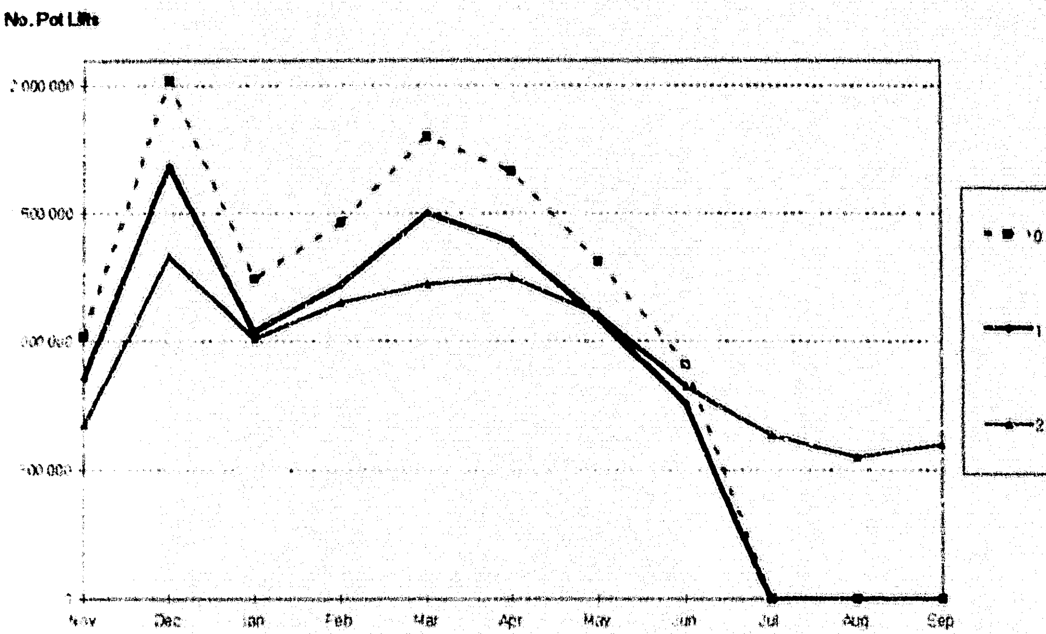
Pot and boat numbers are both treated as freely variable (up to current levels) in cases 1, 11, and 21. comparison of cases 1 with 21, which differ only in the length of the fishing season, indicates that the potential gain from an extra three months fishing under an ITE/TAE based system is likely to be substantial, and of the order of $21 million per annum. However, if boat numbers were constrained to equal current numbers, then the potential gain would be much smaller. Note that an ITE/TAE system may inhibit rationalisation of boat numbers.

Table 3: Summary of Results for TAE/ITE Based Management

Case	0	1	2	11	21
Management	TAE/ITE	TAE/ITE	TAE/ITE	TAE/ITE	TAE/ITE
Catch Level	Unsustainable	Sustainable	Sustainable	Sustainable	Sustainable
Boat Nos	Constant	Variable	Constant	Variable	Variabl
Pot Nos	Constant	Variable	Variable	Variable	Variabl
Avg Pots/boat	<=104	<=104	<=104	<=144	<=10
Season ends	June 30	June 30	June 30	June 30	Sept. 3
Catch	10,795,339	8,999,188	8,999,188	8,999,188	9,000,00
Boats	669	558	669	403	44
Pots	69,576	58,000	58,000	58,000	46,23
Pot Lifts					
Nov	1,020,278	850,522	850,522	850,522	676,63
Dec	2,018,782	1,682,893	1,682,893	1,682,893	1,331,64
Jan	1,243,343	1,036,473	1,036,473	1,036,473	1,011,11
Feb	1,464,628	1,220,940	1,220,940	1,220,940	1,151,68
Mar	1,801,387	1,501,668	1,501,668	1,501,668	1,223,90
Apr	1,663,190	1,386,465	1,386,465	1,386,465	1,248,22
May	1,310,311	1,092,298	1,092,298	1,092,298	1,104,85
Jun	908,661	757,476	757,476	757,476	823,04
Jul	0	0	0	0	636,46
Aug	0	0	0	0	551,02
Sep	0	0	0	0	600,00
Total Pot Lifts	11,430,579	9,528,735	9,528,735	9,528,735	10,358,59
CPUE	0.94	0.94	0.94	0.94	0.8
Total Revenue ($m)	$196.3	$163.6	$163.6	$163.6	$172.5
Total Cost ($m)	$162.0	$135.0	$147.8	$117.2	$123.2
Net Return ($m)	$34.3	$28.6	$15.8	$46.4	$49.3
Net Return/pot ($)	$493	$493	$272	$800	$1,066
Net Return/boat ($)	$51,244	$51,244	$23,584	$115,184	$110,869

The difference in the seasonal pattern of fishing effort between the various cases in Table 3 are illustrated in Figure 8. Simply reducing catch to sustainable levels by reducing pot numbers (case 0 - 1) does not alter the distribution but merely lowers fishing effort in each month by a proportionate amoun Moreover, it can be seen from a comparison of case 1 with case 3 that within the range evaluated, this result is independent of boat numbers. If the length of the fishing season is extended, then there is som flattening of the distribution, with proportionately less effort expended prior to May, and more thereafter.

Figure 8: Seasonal Pattern of Fishing Effort under Input Based Management



It has been suggested that a sustainable fishery could be achieved by setting a Total Allowable Catch (TAC), and closing the fishery as soon as the TAC was reached. In scenario 3, the consequences of reducing average catch levels to 9 million kg. using this traditional approach to stock preservation of imposing a TAC together with a variable closed season while maintaining both pot and boat numbers estimated assuming current technology and economic structure. It can be seen from Table 4 that even the short run, this scenario involves a greater loss of economic efficiency than either cases 1 or 2, and on average will result in closure of the fishery sometime in April. Such an outcome is clearly wasteful and reduces industry net returns by about $21 million relative to the base case. In the long run, these efficiency losses would almost certainly swell to the point where catching costs at least matched gross revenue as fishermen invested more and more heavily in boats, gear, and equipment in order to catch much of the TAC as possible before the season closed.

Table 4 also summarises the results for scenarios 4, 5, 14, and 24, each of which simulates an ITQ based management system by allowing monthly levels of effort to be constrained only by available numbers of fishing days and pots, and to be selected so as to maximise industry net returns. Both pot and boat numbers are allowed to vary freely up to maxima equal to current levels in cases 4, 14, and while boat numbers are constrained to equal current numbers in case 5. In cases 4 and 5, the fishing season ends on June 30, while it is extended to September 30 in cases 6 and 7.

In the main, the findings from the results in Table 4 simply reinforce the points made above, but there are some important differences. By switching to an ITQ/TAC based system while reducing catch to 9 million kg., it is quite possible that aggregate net returns might actually increase by about $4.3 million (relative to base case 0) so long as both pot and boat numbers (case 4) are permitted to reduce to the most efficient level.

Moreover, the actual gains realised might even be larger than this estimate if rent dissipation due to capital stuffing also declines in importance under an ITQ/TAC based system. Some idea of the importance of this consideration is provided by the difference in annual net returns of $15.2 million between cases 4 and 14. The starting point for these two cases differed only in the economic structure implicit in the model (average pots per boat assumed was 104 for case 4, and 144 for case 14). The latter value is probably best treated as an upper bound, but it does illustrate that under an ITQ/TAC based system, it might be possible to reduce catch to sustainable levels and increase annual net returns by up to $19.5 million at the same time even if the season is not extended.

Since introduction of ITQ's should make it easier to extend the season, the upper bound on increase in annual net returns could exceed $30 million. However, it needs to be stressed that the possibility of such large gains materialising depends on very large reductions in boat numbers (i.e. down to less than 300 boats). If rationalisation of boat numbers is prevented, increases in net returns will be much more modest because of the large opportunity cost of preserving boat numbers.

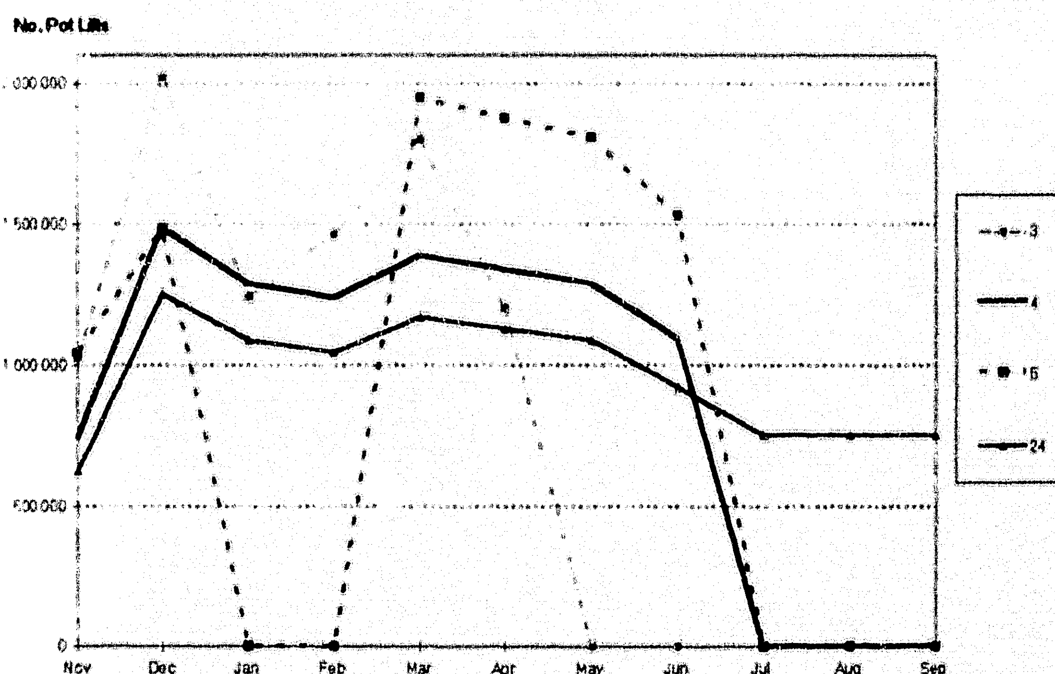
Table 4: Summary of Results for TAC/ITQ Based Management

Case	3	4	5	14	24
Management	TAC only	TAC/ITQ	TAC/ITQ	TAC/ITQ	TAC/ITQ
Catch Level	Sustainable	Sustainable	Sustainable	Sustainable	Sustainable
Boat Nos.	Constant	Variable	Constant	Variable *	Variable
Pot Nos.	Constant	Variable	Variable	Variable	Variable
Avg. Pots/boat	<=104	<=104	<=104	<=144	<=104
Season ends	Variable	June 30	June 30	June 30	Sept. 30
Catch	8,996,809	9,000,000	9,000,000	9,000,000	9,000,000
Boats	669	477	669	344	402
Pots	69,576	49,600	69,576	49,600	41,804
Pot Lifts					
Nov	1,020,278	744,007	1,043,640	744,007	627,061
Dec	2,018,782	1,488,013	1,484,522	1,488,013	1,254,122
Jan	1,243,343	1,289,611	0	1,289,611	1,086,906
Feb	1,464,628	1,240,011	0	1,240,011	1,045,102
Mar	1,801,387	1,388,812	1,948,128	1,388,812	1,170,514
Apr	1,202,299	1,339,212	1,878,552	1,339,212	1,128,710
May	0	1,289,611	1,808,976	1,289,611	1,086,906
Jun	0	1,091,210	1,530,672	1,091,210	919,690
Jul	0	0	0	0	752,473
Aug	0	0	0	0	752,473
Sep	0	0	0	0	752,473
Total Pot Lifts	8,750,716	9,870,488	9,694,490	9,870,488	10,576,432
CPUE	1.03	0.91	0.93	0.91	0.85
Total Revenue ($m)	$160.0	$164.4	$169.0	$164.4	$173.8
Total Cost ($m)	$146.8	$125.7	$150.1	$110.5	$118.5
Net Return ($m)	$13.2	$38.6	$18.9	$53.9	$55.3
Net Return/pot ($)	$190	$779	$271	$1,086	$1,323
Net Return/boat ($)	$19,781	$81,001	$28,195	$156,386	$137,611

An appreciation of the possible gains from extending the fishing season under an ITQ based system can be gained by comparing case 4 with 24. In these two cases, pot and boat numbers are both allowed to vary freely (up to current levels). Aggregate annual net returns are estimated to increase by about $17 million due solely to differences in the length of the fishing season. This estimate is slightly less than the estimated potential gain from an extra three months fishing under an ITE/TAE based system.

The impact on the seasonal distribution of fishing effort of alternative scenarios under an output based management system are illustrated in Figure 9. Predictably, as much effort as possible is employed as quickly as possible under the scenario of a variable closed season, so that the season closes in late April. As was the case for input based management systems, the impact of an extended fishing season is the reduce effort in the early months of the season, and to compensate with more effort in the tail end of the season. Case 5 which represents an ITQ's based management system, but constrains boat numbers to current levels, provides the most intriguing finding, as it predicts that maximum net economic returns would be generated by shutting down the fishery for the months of January and February, and then deploying more effort in the months of March to June than were applied in the traditional peak month of December. This finding is almost certainly sensitive to the assumptions made about the seasonal pattern of variation in the landed net value of the catch.

Figure 9: Seasonal Pattern of Fishing Effort under Output Based Management



Key parts of the results presented above are rearranged in Table 5 to facilitate a comparison of industry net returns from an ITE/TAE based system with those possible under a system of ITQ's. In particular, this table highlights the pivotal role of policy towards rationalisation of boat numbers, and the corresponding importance of the impact of type of management system on number of pots per boat.

Table 5: A Comparison of TAE/ITE vs TAC/ITQ Based Management Systems.

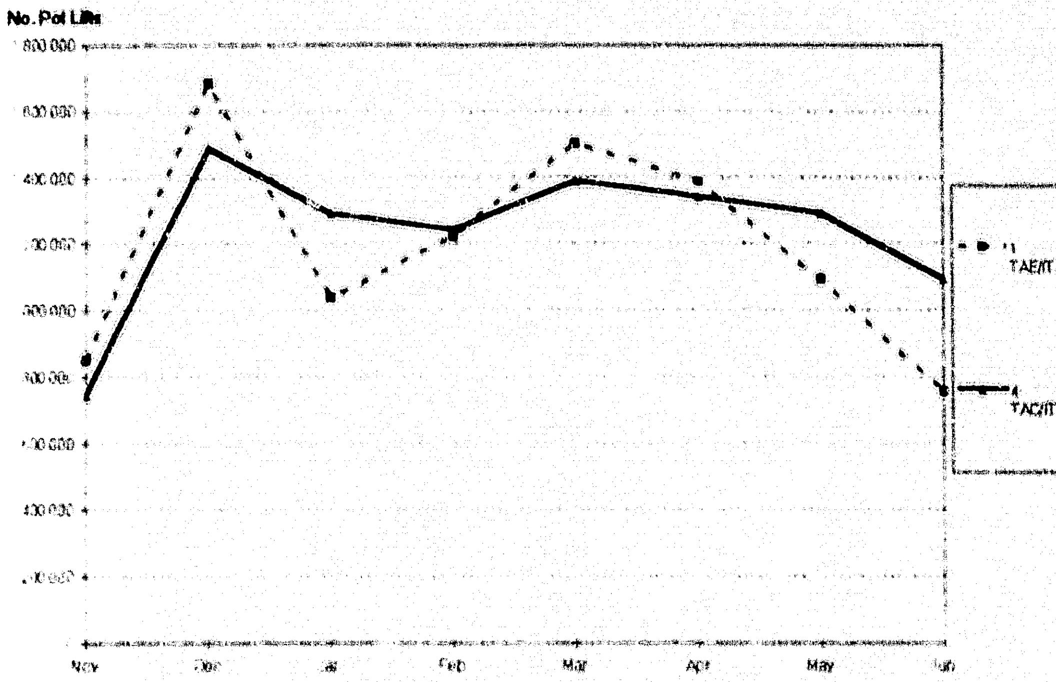
	LOWER BOUND ESTIMATES - No Minimum Boat Nos.		UPPER BOUND ESTIMATES No Minimum Boat Nos.		LOWER BOUND ESTIMATES - Constant Boat Nos.	
Boat Nos	Variable	Variable	Variable	Variable	Constant	Constant
Pot Nos	Variable	Variable	Variable	Variable	Variable	Variable
Avg Pots/boat	=104	=104	<145	<145	<104	<104
Season ends	June 30	Sept. 30	June 30	Sept. 30	June 30	Sept. 30
Days fished	188	230	188	230	188	230
ITE/TAE Case	1	21	1	21	2	22
Boat Nos	558	445	558	445	669	669
Pot Nos	58,000	46,231	58,000	46,231	58,000	69,576
Pot Lifts (m.)	10	10	10	10	10	10
Industry Returns ($m)	$163.6	$172.5	$163.6	$172.5	$163.6	$172.5
Industry Costs ($m)	$135.0	$123.2	$135.0	$123.2	$147.8	$152.4
Net Returns ($m)	$28.6	$49.3	$28.6	$49.3	$15.8	$20.1
ITQ/TAC Case	4	24	14	34	5	25
Boat Nos	477	402	344	290	669	669
Pot Nos	49,600	41,804	49,600	41,804	69,576	69,576
Pot Lifts (m.)	10	11	10	11	10	12
Industry Returns ($m)	$164.4	$173.8	$164.4	$173.8	$169.0	$185.0
Industry Costs ($m)	$125.7	$118.5	$110.5	$105.6	$150.1	$157.2
Net Returns ($m)	$38.6	$55.3	$53.9	$68.2	$18.9	$27.8
Extra Net Returns ($m)	$10.1	$6.0	$25.3	$18.9	$3.1	$7.7
Extra Enforcement Costs ($m)	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7
Extra Research Costs ($m)	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0
Net Gain ($m)	$7.4	$3.4	$22.6	$16.2	$0.4	$5.1

Consider first the case depicted in the first column of Table 5 where boat and pot numbers are permitted to be rationalised, and the duration of the fishing season is unchanged. Changing the management system from one based on ITE/TAE's to one based on ITQ/TAC's is estimated to increase net returns by about $10 million (from $28.6 million for case 1 to $38.6 million for case 4). While this gain would be partly offset by additional costs of research and enforcement, which were deemed to be $1 million and $1.7 million respectively, the bottom line still involves an increase in aggregate annual net economic returns of more than $7 million.

Making the same assumptions about boat rationalisation and numbers of pots per boat, this analysis suggests that extending the season by three months actually reduces the advantages of a switch in the basis of fishery management. If as assumed in the second column the season were extended to September 30, which should be biologically viable under a system of ITQ's, and boat numbers were again permitted to decline, then the increase in industry annual net returns from adopting ITQ's of $6 million would be largely offset by additional research and enforcement costs, leaving a net gain of perhaps $3 million.

Most of the gains from swapping from ITE's to ITQ's in the above pairs of cases derive from the direct and indirect benefits of a more efficient seasonal pattern of fishing effort. The direct effects flow from more efficient pot utilisation if seasonal effort patterns are less cyclical, and from distributing more of the catch to the latter part of the season when prices are higher. The impact of fishery management method on the seasonal pattern of effort illustrated in Figure , which depicts monthly pot lifts for case 1(ITE's) and case 4 (ITQ's).

Figure 10: Monthly Pot Lifts under ITE's and ITQ's.



An indirect consequence of less month to month fluctuations in pot lifts and consequential better pot utilisation is that the same total catch can be caught with fewer boats. It can be seen from the first two columns of Table 5 that boat numbers under ITQ's are markedly lower, at 447 for the "short" season, and 402 for the "long" season, compared to 558 and 445 respectively under ITE's. The importance of allowing boat numbers to rationalise can be seen by comparing findings for cases in the first two columns of Table 5 with the respective cases depicted in the last two columns where boat numbers are held constant at 669 boats, which was the level in 1994. For a fishing season finishing on June 30, the gains in net returns from moving to ITQ's is only $3 million, which is almost entirely offset by greater research and compliance costs. For the "longer" fishing season cases, holding boat numbers constant under ITE's imposes extra costs under both systems, but under ITQ's it also provides greater opportunity to offset these higher costs with extra revenue from catching more product late in the season when prices are higher, so paradoxically net gains in the last column are actually larger than in the second column.

There is little doubt that the estimates of potential gain from adopting ITQ's in the first two columns of Table 5 are conservative, because they make no allowance for fishermen finding more efficient ways to combine boats and pots if they were not constrained by fishery regulations. As noted above, an ITE/TAE system is likely to inhibit rationalisation of boat numbers, and thus result in rather fewer pots/boat on average than would pertain under an ITQ/TAC based system, which would not threaten biological sustainability if catch is limited to safe levels by the TAC. As noted above, the ratio of pots to boats has been increasing steadily in recent years, and the current level of approximately 104 pots/boat would almost certainly be higher in a deregulated ITQ's managed fishery. As total catch levels are reduced, the economic incentives to increase number of pots/boat is likely to intensify. Just how large the difference in number of pots per boat would be under the alternative management systems has to be a matter for conjecture because of a lack of hard empirical evidence on which to base a realistic assumption.

The third and fourth columns in Table 5 are based on an assumption that the current industry average o 104 pots per boat will continue under any ITE/TAE system, but over time would rise to 144 pots per boat under an ITQ/TAC based system . If the introduction of ITQ's increases average numbers of pots per boat by this degree, then depending on length of season, the net efficiency gains of switching systems are estimated to lie between $16 and $22 million. These estimates of potential net gains may overestimate the gains actually realisable by switching systems if the above assumption exaggerates the efficiency gains from better input combinations and/or more effective fishing gear likely to be fostered under an ITQ based management system. Hence these columns are best regarded as providing upper bound estimates of potential efficiency gains for the current, and an extended season respectively.

To sum up, there is a very strong interaction between policy on boat numbers and changes in industry net returns resulting from changes in other aspects of management in the Western Rock Lobster Fishery, and one of the most striking features of the results is the sensitivity of the estimated increase in industry net returns to policies indirectly controlling minimum boat numbers by regulating number of pots per boat.

CONCLUSIONS

There are several conclusions to be drawn from the analysis reported above. Some relate to changing one or other aspect of the method of managing the Western Rock Lobster fishery, so not all of the estimated benefits are independent and additive. Specific conclusions are:

- up to $22 million of potential resource rents are being dissipated under the license limitation system of management. Even without a longer fishing season, and without "better" designed pots to enhance catching power, some or all of this potential rent might be realised if an ITQ/TAC based system of management were adopted.
- reducing the catch to sustainable levels under an ITE/TAE based management system closing on June 30 is most unlikely to increase realised resource rents even if rationalisation of boat number is allowed to proceed unimpeded by policy regulations.
- if boat numbers are held at current levels by policy measures under an ITE/TAE based management system, measures adopted to reduce catch levels to sustainable levels will almost certainly result in large losses in industry annual net returns. With the current fishing season, thes losses could up to $20 million (40%), and of the order of $14 million (28%) if the season is extended.
- there are potentially large economic gains in terms of industry net returns to be gained from allowing market forces to reduce the number of boats operating in the industry to economically efficient levels. For a fishing season of the current duration, it has been estimated to be of the order of $13 million (26%) of current income collectively being earned in the industry. This amount could be as large as $30 million (60%) for an extended season lasting until September 30 However, it needs to be stressed that the possibility of such large gains materialising depends on very large reductions in boat numbers (i.e. down to less than 300 boats).
- there are potentially large economic gains in terms of industry net returns to be gained from extending the duration of the fishing season. Estimates range from $16 million to $21 million so long as boat numbers are permitted to fall to economically efficient levels, but otherwise will be comparatively small.
- there may be potentially large economic gains to be gained from changing the system of managin the Western Rock Lobster fishery from one based on ITE's/TAE to one based on ITQ's/TAC. Depending on length of season, potential gains in industry net returns of switching systems could range from negligible to $22 million (44%) for a June 30 closure, and from $2 million (4%) to $16 million (32%) for a September 30 closure.

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APPENDIX 1: Data Sources for the Programming Model

ABS (or Fishery returns) (1964-1992)

Aggregate Catch (Kg.): by Month and by Zone

Aggregate Effort (pot lifts): by Month and by Zone

Aggregate Licensed pots (nos.): by Year and by Zone

Fremantle Fishing Cooperative (1992/93 fishing season):

(individual boat data for an anonymous sample of 59 boats for the)

No. pot licenses: by Month

Catch (Kg.): by Month, Zone, and by Size Grade

Expenses for Bait, Fuel, Gear and Other: by Month

Department of Fishery Returns (1991/92 & 1992/93 fishing seasons)

(individual boat data for the same anonymous sample of 59 boats above
- matched using double blind coding procedure to preserve anonymity of boat licensees)

No. days fished: by Month and by Zone

Crew Nos.: by Month

Location (block) fished: by Month

Landing port: by Month

No. pots used: by Month

Catch (Kg.): by Month and by Zone

Jurien fishermen informal survey - (1992/93) fishing seasons

No. pots used and Crew Nos.

No. days fished: by Month

Distance travelled to fishing ground: by Month

Catch (Kg.): by Month

Capital Value: (by type of asset)

All expenses: (by month and by type of expense)

Economic study of S.A. Rock Lobster industry - Edwards & Presser