Fisheries management report

Long term management strategies for the Western Rock Lobster Industry

(4 Volumes)

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Volume 2

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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, 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 a closed season for several months, 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 limiting fishing effort by limiting pot numbers..

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 these 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 primarily 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 tradable. The aggregate capitalised value of pot licenses in the fishery now exceeds $1,000 million, which, at a discount rate of 3 per cent, implies that over $30 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, 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. This increasing effort is linked to higher exploitation rates which in turn has led to marked decreases in the estimated size of the breeding stock. In particular, 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 and boats). 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 effort so that a higher proportion of recruits "escape" into the breeding stock. Available means of reducing effort include further reductions in the number of licensed pots, and/or further restrictions to the effectiveness of their use (e.g. by reducing the length of the fishing season, by changing minimum size limits, and by banning technologies which enhance gear "catchability").

Economic theory[1] suggests that reducing catch by reducing licensed pot numbers is likely to increase the average cost of effort because it encourages increasingly inefficient combinations of licensed and unlicensed inputs. As a result, realized resource rent will be less than potential resource rent, a phenomena known in the literature as "rent dissipation". 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 inefficient input combinations and consequential 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 further 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 regulation 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 based on direct control of output, or level of catch. One intrinsic benefit of catch control based management methods vis-à-vis input control based management methods is that the effectiveness of the former 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 an incentive to increase effective fishing effort. Consequently, so long as the total allowable catch is 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 control based management systems.

Historically, the most common method of managing a fishery by controlling output has been to rely on a variable closed season, whereby the season is closed as soon as the total allowable catch (TAC) is reached. Under such a system, no attempt is made to limit level of catch by individual fishing firms. It is widely recognised that the inevitable consequence of a management scheme which relies solely on a TAC is total rent dissipation (i.e. net returns from the fishery are driven down to the point where catching costs at least equal gross returns). For this reason, an hybrid system comprising both elements of a License Limitation Scheme and a TAC with variable closed season has been suggested. At least in the short run, such an hybrid system might support positive aggregate net economic returns, but there is still likely to be significant economic waste incurred in the "rush to fish".

A more sophisticated approach to output control is to base the management system on individual transferable (catch) quotas (ITQ's). The disadvantages 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 catches exceeding the TAC. Other management costs, such as stock assessment research, are also likely to be greater than is currently the case. These two aspects are addressed in detail elsewhere in the main report, and in special attachments by McLaughlan, and by Penn et. al. .

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[1] See Anderson 1985 and Campbell and Lindner (1989).

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.[2] Consequently, economic models have to be used to try to estimate whether possible changes in the method of fishing under ITQ based management systems are likely increase aggregate net economic returns from the fishery relative to those which could be earned under a modified version of the current system.

Given that regulations are set so as to ensure equivalent protection of the breeding stock under both systems, economic theory suggests that the main benefits of an ITQ based scheme 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 fishers.
- 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 equivalent 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 likely that the risk of stock failure also will be affected by the choice of management method, but further research is required to determine both the direction and the magnitude of this effect. The evaluation below of long run management options for the Western Rock Lobster Fishery reported is restricted to one key issue, namely the impact of the two principal alternative management systems on expected resource rent from the fishery due to changes in cost per unit of effort, and in return per unit of catch. In particular, estimates are made of the magnitude of rent dissipation under License Limitation associated with current regulations in the Western Rock Lobster Fishery, as well as the level of rent dissipation consequential on further reductions in the level of licensed inputs (pots) needed to reduce the exploitation rate to levels required to protect the breeding stock. Estimates also are made, *inter alia*, of changes in catching costs, in catch returns, and in resource rent from the fishery due to:

- reduced boat numbers
- less intensive pot use
- more intensive pot use
- extended fishing season
- altered seasonal catch distribution

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[2] 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.

ANALYTICAL OVERVIEW

Alternatives Analytical Approaches

Because of the complexity and intrinsic uncertainty of evaluating counter-factual situations, the approach adopted in this study was to employ several methodologically different procedures 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. Specifically, the following three methods were used:

- Bioeconomic Model
- Accounting Model
- Programming Model

In all three approaches, the primary consideration was the need to achieve the pre-eminent objective of preserving the fishery on a sustainable basis. To do so, it is essential that the breeding stock be maintained at a sufficient level, and this will only be possible if catch is constrained so as to allow sufficient animals to escape capture long enough to reach sexual maturity. In recent years, fishing effort has been of the order of 12 million pot lifts per annum, which given average seasonal conditions affecting recruitment and catchability will result in an annual catch of nearly 11 million kg. in the short term, and probably a significantly lower catch on a sustainable basis. Expert advice is that average annual catch needs to be reduced to approximately 9 million kg. if the breeding stock is to be maintained at sustainable levels. In all three models, the first estimate to be made was the consequence of reducing average annual catch to this sustainable level.

Relative to a base case defined to approximate current organization of the catching sector and the average aggregate net economic returns being generated from the fishery performance, the models described above were used to explore the economic consequences of changing the method of managing the Western Rock Lobster Fishery 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)

The bioeconomic model

The bioeconomic model was used to undertake steady state analysis of the economic efficiency of alternative management systems (broadly defined) using a modified form of the Schaefer bioeconomic model, which is a classical bioeconomic model incorporating both biological stock-dynamics relationships and economic relationships. Because the focus in the model is exclusively on sustainable levels of exploitation of the fishery, this approach provides the best guide to the long run economic consequences (e.g. degree of rent generation/dissipation) from retaining the current License Limitation Scheme and relying on reductions in pot numbers to reduce the catch and the exploitation rate in order to protect the breeding stock. Given constant average catch value, the model also can be used to predict the theoretical maximum level of resource rent which potentially would be generated under an ideal management system. It is not possible to use the model to determine whether actual aggregate net economic returns from the fishery under an ITQ based management system would approximate this theoretical target.

On the other hand, this approach relies more on abstract theory than the other two approaches, and for that reason the results need to be viewed with some skepticism. Moreover, some results may depend critically on the value assumed for the elasticity of constrained supply when one or more inputs are limited by a License Limitation Scheme. In the absence of research to determine the value of this key parameter, estimation of the impact on rent dissipation of changes in the level of fishing effort had to be based on "best guess" estimates together with sensitivity analysis to determine the range of possible outcomes for all likely values of the elasticity of constrained supply.

Another disadvantage is the highly aggregated nature of the analysis, which precludes allowing for changes in the duration of the fishing season, or in the monthly distribution of the catch (and in consequential changes in the average value, or worth, of the catch). This approach also does not provide any detailed insights into how reductions in fishing effort might be achieved. For instance, it is not possible to predict the impact of a reduction in licensed pot numbers on number of boats operating in the fishery from results obtained from this model.

The accounting model

The accounting model is a simple simulation model of the fishery incorporating primarily economic relationships, and can be used to investigate specified sub-problems in more detail. For instance, it is used to predict the impact on resource rents (i.e. net returns to the fishery) of introducing regulations to maintain boat numbers when pot numbers are reduced.

There are severe limitations on the questions which can be addressed in an accounting model, but because of its simplicity, it does have the virtue of being relatively easy to understand, and can highlight some of the key issues in a comprehensible way. Like all models, the utility of the results depends above all else on the validity of the values assumed for the parameters in the model.

The programming model

The mathematical programming model of the fishery developed for this study incorporates both economic relationships and limited biological relationships. It can be used to investigate optimal economic behaviour by individual fishermen.

Given specified management regulations, it also can be used to determine the aggregate configuration of inputs which will maximize aggregate net economic returns from the fishery (i.e. the method of fishing which is collectively optimal for the hypothetical scenario of management by a sole owner). Because the model incorporates limited biological relationships, there is some capacity to test the extent to which particular scenarios enhance long run viability of the breeding stock.

This model also is ideally suited 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 average catch worth on the other hand. For this reason, it provides the best available 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.

BIOECONOMIC MODELLING OF RENT DISSIPATION FROM LICENSE LIMITATION

Background

Anderson (1985) has demonstrated that fishery regulation by means of license limitation may generate resource rents in a commercial fishery. While restricting the amount of a major input (e.g. pots) used in the production of effort may increase the unit cost of effort, the reduction in the total amount of effort 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 actually generated under a license limitation scheme and that for the benchmark case of a sole owner generating 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.

As there is a high degree of homogeneity of vessel type in the Western Rock Lobster Fishery, the judgement was made that the third source of rent dissipation was unlikely to be important, and it is ignored in the rest of this paper. The other two types of rent dissipation were estimated from the following analytical model, which is based on that in Campbell and Lindner (1990).

Analytical Framework

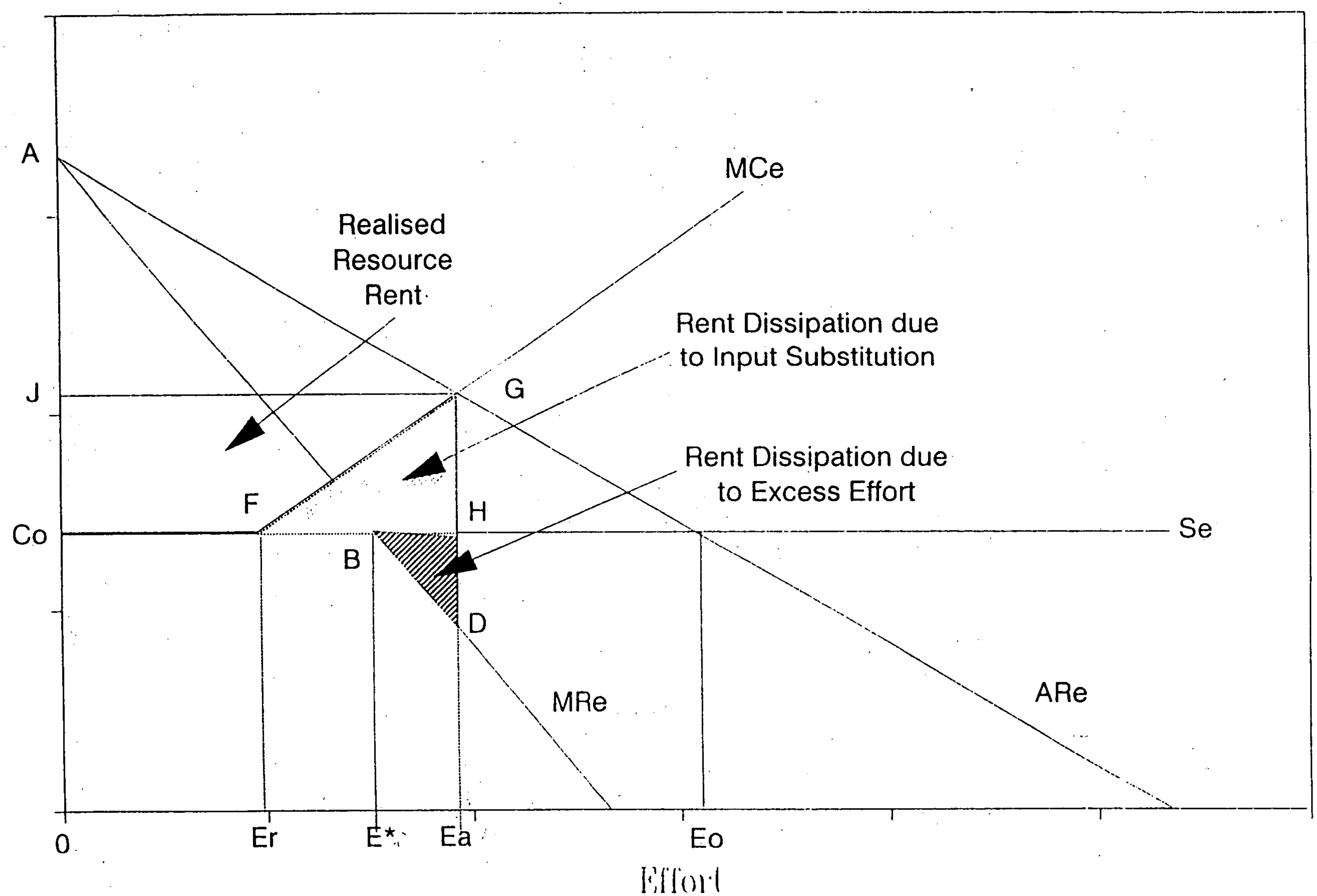
The basic model for the analysis is illustrated in Figure 1 of the present paper. Note that this model is a static model, but that conclusions drawn from it about the optimal level of effort are good approximations if the intrinsic growth rate for rock lobster is large relative to the discount rate. Figure 1 shows a linear schedule for the average revenue of effort, AR_e, such as that which can be derived from the Schaefer model (Schaefer 1967), and a perfectly elastic long-run supply curve of effort, S_e. It should be noted that the Schaefer model is based two contentious assumptions, one being the use of a logistic growth function to represent biomass/stock dynamics, and the second being that catch per unit of effort is always a constant proportion of the size of the fish stock. In the absence of regulation, long-run steady-state equilibrium is at the effort level E_0 at which the value of average product of effort equals the long-run average cost of effort, C_0. Because inputs are combined in the least cost manner at all points on S_e, it will be referred to below as the efficient average/marginal cost curve.

When one or a range of inputs is restricted in supply by license limitation to a level significantly less than that which would prevail in an open access fishery, the marginal cost curve for the industry is coincident with S_e up to level of effort E_r, defined as the level of effort at which the limited supply of the restricted input becomes binding. Beyond E_r, the constrained industry marginal cost curve diverges from the most efficient cost path because increases in effort beyond E_r can only be achieved by substituting unrestricted inputs for the restricted input. This somewhat inelastic section of the industry's constrained marginal cost curve is labelled MC_e . Note that it is equivalent to the short-run marginal cost curve for an industry which can only increase the use of some factors in the short-run.

Equilibrium effort in such an industry will be determined by the intersection of the constrained MC_e curve with the average revenue of effort curve (AR_e). This point of intersection is labelled G in Figure 1, and determines both the actual level of effort (E_a) and the actual value of average revenue of effort. Because E_a of effort could have been generated at total cost of $OCHE_a$, the efficiency loss from excessively costly effort (i.e. rent dissipation due to input substitution, or capital stuffing) is measured by the area of the triangle FGH.

Optimal effort in Figure 1 is depicted by E^*, as this level of effort equates efficient marginal cost with the marginal revenue of effort (MR_e), thus maximizing potential rent which is represented by area ABC in Figure 1. As actual effort exceeds optimal effort, there is a further amount of rent dissipation due to excessive effort, or fleet redundancy, which is represented by the area of the triangle BDH.

FIGURE 1: RENT DISSIPATION FROM LICENSE LIMITATION



Given that the fishery is to be managed by a license limitation scheme, the second best solution is to minimize the combined value of rent dissipation due to input substitution and to fleet redundancy. This is equivalent to maximizing the realized rent, represented by the area *CFGJ*. Campbell and Lindner (1990) have derived an analytical result for this second best solution given particular assumptions about the form of the key relationships, and the derivation is reproduced as Appendix 1.

The key determinant of the degree of rent dissipation is the form and slope of the industry constrained marginal cost curve, MC_e. A license limitation scheme will be successful in minimizing rent dissipation if this marginal cost curve is highly inelastic. Campbell and Lindner (1990) show that the necessary conditions are:

- The elasticity of substitution between restricted and unrestricted inputs should be very low so that there is very limited scope to increase effort indefinitely by using more and more unrestricted inputs.
- The restricted input(s) should be a major component of total factor costs.

On the face of it, the Western Rock Lobster fishery meets the critical conditions for successful management by an appropriately designed license limitation scheme. While level of usage of both boats and pots is restricted to the number of licenses issued, it is clear that the restriction on the number of pots that can be used is the effective policy instrument for controlling level of effort and generating rent. Because of the biology of the Western Rock Lobster, lifting pots more than once every 24 hours is subject to severe diminishing returns. With complete diminishing returns, the absolute limit on the number of pot lifts would simply be the product of the number of licensed pots in the fishery multiplied by the potential number of fishing days in the fishing season. Since most other types of fishing gear and methods are banned by regulation, it should be difficult to substitute other inputs for pots. On the other hand, the cost of boats and pots do not represent a major part of catching costs, so the marginal cost curve will be less than completely inelastic.

This theoretically derived conclusion is supported by empirical evidence from the history of the fishery. Fishermen have shown remarkable ingenuity in finding ways to work their pots harder. For most of the duration of the license limitation scheme, there has been a steady increase in the ratio of the actual number of pot lifts to potential number of pot lifts. Fishermen also have devised means to increase the catchability per pot lift, mainly by more careful pot placement. New technologies such as colour depth sounders, GPS, mechanised pot lifters, and even remote controlled mini-submarines with video cameras and transmitters have been tried, and where succesful have materially assisted fishermen to increase "effective pot lifts" without increasing nominal pot lifts.

Parameter Values

Despite a degree of input substitution, tangible evidence of rent generation in this fishery is provided by the prices at which pot licenses are traded. For the past two years, advertisements asking $14,000 or more per pot license have not been uncommon. Of course, prices actually paid may be lower than asking prices, but even at a price of $12,000 per pot license, the total capital value of the fishery exceeds $800 million. It is not easy to decide on an appropriate discount rate to amortise these capital values to obtain an estimate of annual rent generated in the fishery. In a study of the market for ITQ's in New Zealand where data was available on prices paid both for annual lease of quota as well as for quota in perpetuity, a figure of 3% was suggested as a reasonable average. This figure is not inconsistent with the long term real rate of return on farm land, although it may be too low if the industry believes that there is a significant degree of sovereign risk associated with holding pot licenses. Because the regulations governing this fishery have been changed fairly frequently in recent years, discount rates of 3%, 5% and 7% could be justified, yielding estimates of current annual fishery rent ranging from $24 million to $56 million.

The data necessary to estimate the magnitude of the two types of rent dissipation identified above differs in the extent to which it is "available" by way of direct observation. For example, the actual level of effort in the fishery in any given year (E_a) is directly observable, because the Fisheries Department collects detailed data on both catch and effort (as measured by number of pot lifts). Currently there are approximately 12 million pot lifts per annum of effort being applied in the Western Rock Lobster fishery. Average priced paid to the fishermen per kilogram of catch is also fairly easy to obtain, although it does fluctuate markedly, both intra-seasonally, and between fishing seasons. Some judgement is required in choosing a value likely to prevail in the future. In the analysis below, a value of $18.18 per kilogram was used as an estimate of likely "beach price" in the foreseeable future. This reflects a view that the real price of rock lobster is likely to continue to rise in the future.

Catch per unit of effort is also quite volatile on a year to year basis due to significant annual fluctuations in the level of recruitment to the fishery. For the purpose of estimating the average level of rent dissipation under alternative management regimes, what is really required is the relationship between level of effort and the *sustainable* catch per unit of effort. To derive this relationship, a simple simulation model was constructed which could be used to predict a time series of annual catches based on data on the actual annual levels of effort applied in the fishery from 1945 to 1992. The parameters of this model are the three coefficients of the logistic growth curve, namely the intrinsic growth rate (r), ceiling stock size (K), and a catchability coefficient (A). Values for these parameters were obtained by visually fitting the predicted time series of catches derived from the simulation model to the actual series of catches in the fishery for the period from 1945 to 1992. The plot of these two time series of annual catches is illustrated in Figure 2. There are significant differences between the predicted and actual catch in many years, largely due to year to year environmentally determined fluctuations in recruitment to the fishery which could not be taken account of in the simulation model.

Estimated parameter values derived by this method were:

- unexploited stock size (K): = 50 million kg
- catchability coefficient (A): = .03
- intrinsic growth rate (r): = 0.8

These parameter values were then used in the logistic growth function to predict sustainable catch per unit of effort for various levels of effort required in the analysis below.

The actual level of rent currently being generated in the fishery also needs to be estimated. In Figure 1, the amount of annual rent being generated from E_a of effort is depicted by the area C_0FGJ. As noted above, this annual amount of rent cannot be observed directly, but it can be estimated from the prices paid by fishermen for pot licenses, which are freely tradable. The current selling price for pot licenses is about $14,000, so with 69,000 licensed pots in the fishery, the capitalised value of the industry's expectations about future rent total $966 million. Using a discount rate of three per cent to amortise this value, yields an estimate of annual resource rent being generated in the fishery of about $28 million. If the prices being paid by fishermen for pot licenses are based on expectations about continuing increases in product prices, and/or efficiency gains in catching rock lobster, then this value might over-estimate the annual resource rent currently being generated in the fishery, but will still approximate the average annual resource rent expected for the foreseeable future.

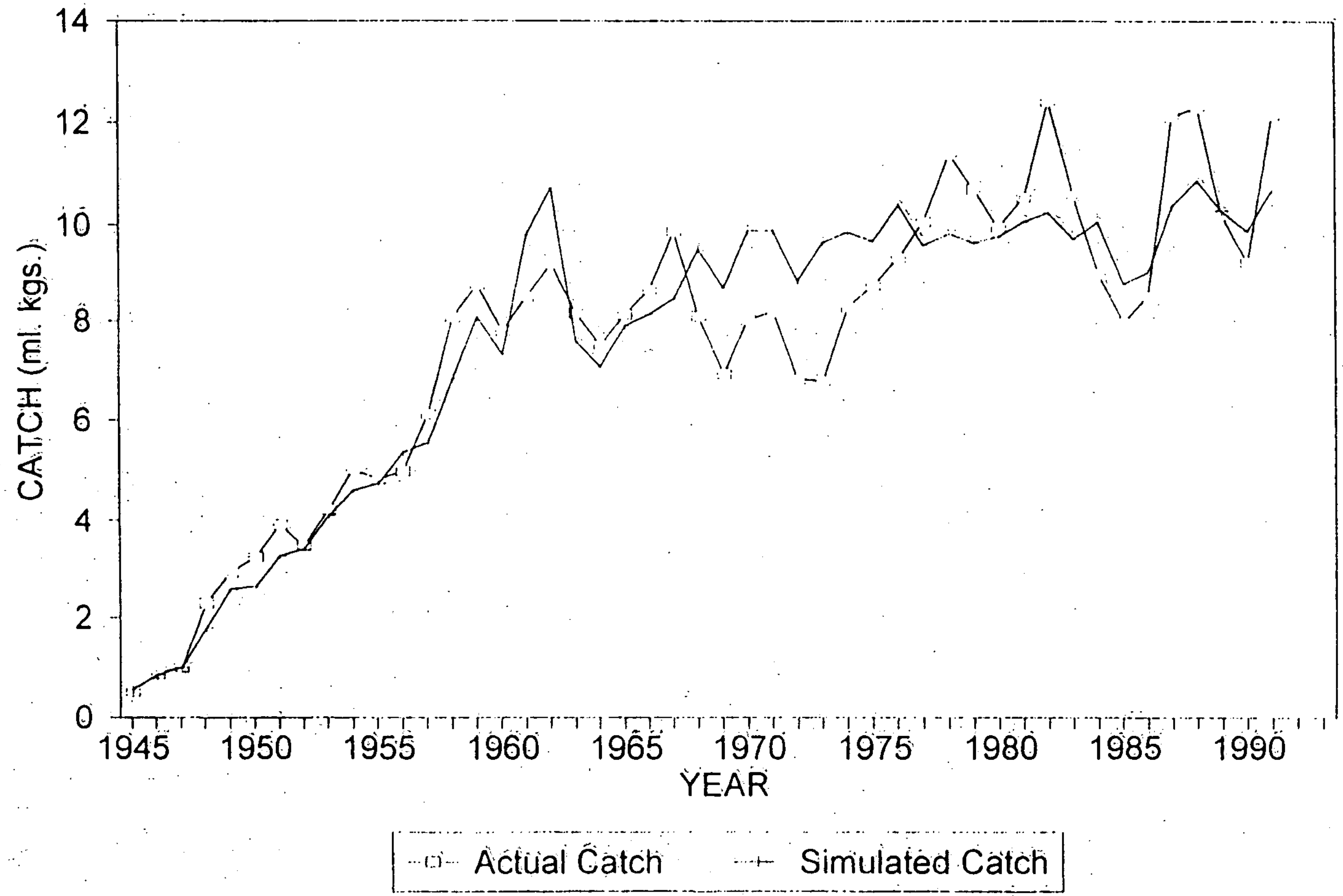
The other three values required to estimate the level of rent dissipation in the fishery are:

- the average cost of effort using minimum cost combinations of inputs (i.e. C_0)
- the efficient level of restricted effort (i.e. the point at which the constrained marginal cost curve for the industry diverges from the efficient marginal cost curve - depicted by E_r in Figure 1)
- the slope of the constrained marginal cost curve (g).

Only one of the above values is needed in order to estimate the other two given that all of the more directly observable information discussed above is available. Campbell (1991) in an analysis of the Tasmanian Rock Lobster Fishery has estimated that the elasticity of substitution is less than unity, and has an expected value 0.75. The biology of the Southern Rock Lobster in Tasmanian waters differs in some respects from that of the Western Rock Lobster, and there also are some differences between the Tasmanian and West Australian fisheries in terms of regulations and catching technology. Nevertheless, the degree of substitution between pots and other inputs is likely to be similar in both fisheries.

FIGURE 2: WRL ANNUAL CATCH

Simulated vs Actual Catch History



In order to carry out the analysis, it was assumed that the constrained marginal cost curve is linear, and that it shifts in a parallel manner when fishery managers alter the number of licensed pots in the fishery. Because of uncertainty about the slope of the constrained marginal cost curve (g), and about trading prices for pot licenses, sensitivity analysis was carried out using the following ranges of values for:

- at 12 million pot lifts, the constrained level of effort, E_r, varied over the range from 65% to 95% of E_a.. (NB this determines the slope of the restricted marginal cost curve.)
- pot license trading prices varied over the range from $12,000 to $16,000 per pot (NB there have been substantial further increases since the analysis commenced).

Results

The relationships set out in the Appendix 2 were used to generate a range of estimates for:

- the minimal average cost, C_0,
- the optimal level of effort, E^*, and
- the maximum potential rent which could be generated under sole ownership.

The results of estimating these variables are set out in the top part of Table 1. "Minimum" average cost (i.e. based on least cost input combinations) of effort was estimated to range from $12.17 up to $12.49 per pot lift, and with an average (or "best guess") value of $12.32 per pot lift. The corresponding range of values for optimal effort is 7.2 to 7.4 million pot lifts (average =7.3 million pot lifts), which should yield a sustainable catch of 7.9 million to 8.0 million kg. (average =7.96 million kg.). If this catch were caught in the least cost manner, then it should generate a resource rent of $53.4 million to $55.8 million (average =$54.7 million) *per annum*.

Note that the expected value of $54.7 million is the expected maximum potential resource rent which could be generated from the fishery *given current regulations on such things as duration of the fishing season, pot design, and other regulations designed to preserve the breeding stock*[3]. Because bioeconomic models of this type cannot analyse the effect of changes to such regulations, all of the results derived using this model presumes no change in the regulations which reinforce the effectiveness of the basic license limitation scheme. With a longer fishing season, with "better" designed pots to enhance catching power, and like changes, the potential resource rent could be considerably larger than $54.7 million.

For reasons already discussed, effective license limitation schemes generally increase average and marginal cost of effort to some degree, and so involve some degree of rent dissipation. Hence maximum realisable resource rent under an ITE/TAE system of management will be considerably less than the maximum expected value of resource rent of $54.7 million no matter what the level of fishing effort and the size of the catch. Moreover, because the degree of rent dissipation is sensitive to the severity of the license limitation scheme and the consequential level of effort actually applied in the fishery, the "second best" level of effort under an ITE/TAE system of management will almost certainly exceed the "first best" estimate of 7.3 million pot lifts.

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[3] Such as the prohibition on taking setose or tar-spot animals.

TABLE 1: IMPACT OF LICENSE LIMITATION SCHEMES

Sensitivity Analysis for Various Equilibrium Effort Levels

Parameter Values	License Price ($/pot)	#pots	r/i=	Realised Rent ($m)	Efficient Effort (% of actual)	Minimum Avg. Cost ($/pot lift)	Optimal Effort (m. lifts)	Optimal Rent ($ m.)
Lower Bound=	$12,000	69,000	3%	$24.84	65%	$12.49	7.23	$53.41
Mean=	$14,000	69,000	3%	$28.98	80%	$12.32	7.31	$54.67
Upper Bound=	$16,000	69,000	3%	$33.12	95%	$12.17	7.38	$55.76

Product Price ($/kg.) = $18.18

	Efficiency Loss due to:		Total Efficiency Loss				
Output Range:	Capital Stuffing ($ m.)	Excess Effort ($ m.)	($ m.)	(as % of Optimal Rent)	% pot reduction	Realised Rent ($m)	% rent incr.
Effort = 8 m. pot lifts (Sustainable catch = 8.4 m. kg.)							
Lower Bound=	na	na	na	na	*	**	***
Mean=	$20.52	$0.48	$21.00	38%	80%	$33.67	16%
Upper Bound=	$5.08	$0.39	$5.46	10%	43%	$50.29	52%
Effort = 9 m. pot lifts (Sustainable catch = 8.9 m. kg.)							
Lower Bound=	na	na	na	na	*	**	***
Mean=	$14.79	$2.91	$17.71	32%	60%	$36.97	28%
Upper Bound=	$3.69	$2.67	$6.36	11%	32%	$49.40	49%
Effort = 10 m. pot lifts (Sustainable catch = 9.4 m. kg.)							
Lower Bound=	$17.36	$7.86	$25.22	47%	70%	$28.18	13%
Mean=	$10.00	$7.39	$17.39	32%	40%	$37.29	29%
Upper Bound=	$2.52	$7.00	$9.52	17%	21%	$46.24	40%
Effort = 11 m. pot lifts (Sustainable catch = 9.7 m. kg.)							
Lower Bound=	$10.44	$14.56	$25.00	47%	35%	$28.41	14%
Mean=	$6.14	$13.91	$20.05	37%	20%	$34.62	19%
Upper Bound=	$1.57	$13.37	$14.94	27%	11%	$40.81	23%
Effort = 12 m. pot lifts (Sustainable catch = 9.9 m. kg.)							
Lower Bound=	$5.27	$23.30	$28.57	53%	0%	$24.84	0%
Mean=	$3.22	$22.47	$25.69	47%	0%	$28.98	0%
Upper Bound=	$0.85	$21.79	$22.64	41%	0%	$33.12	0%

* > 100%

** < $24.84

*** < 0%

Hence, the bottom part of Table 1 contains estimates of the impact of scenarios ranging from the *status quo* level of effort of 12 million pot lifts down to a reduced level of actual effort of only 8 million pot lifts (i.e. a 33% reduction in actual effort bought about by the retirement of licensed pots). The results presented include estimates of the impact on the following measures of rent dissipation (i.e. efficiency loss) plus associated measures:

- efficiency loss (rent dissipation) due to input substitution (area FGH in Figure 1).
- efficiency loss (rent dissipation) due to excess effort (area BDH in Figure 1).
- total efficiency loss (total rent dissipation due to both input substitution and to excess effort).
- percentage total efficiency loss (relative to potential maximum rent).
- percentage reduction in number of licensed pots relative to status quo required to achieve assumed level of effort.
- estimated actual level of aggregate annual resource rent to be realised given specified levels of fishing effort.
- percentage change in possible realised aggregate annual resource rent relative to the best guess estimate of current realised aggregate annual resource rent.

At current effort levels of 12 million pot lifts, the **sustainable** catch predicted by the model is only 9.90 million kg., which is significantly lower than average annual catches for recent years of about 10.8 million kg.. It can be seen from Table 1 that given current effort levels, on average, approximately $29.0 million of sustainable resource rent is likely to be realised from the fishery, while $3.2 million plus $22.5 million will be dissipated due to capital stuffing and excess effort respectively. Total efficiency loss (or degree of rent dissipation) of $25.7 million p.a. is the difference between maximum potential sustainable resource rent ($54.7 million p.a.) and sustainable annual rent given current effort in the fishery ($29.0 million p.a.). Note that short run net returns currently being earned in the industry, which are estimated below to be at least $32.4 million per annum, are not sustainable because recent catch levels exceed estimated maximum sustainable yield (catch) for the fishery of 10 million kg.. These excessive catches are the source of the efficiency loss of $22.5 million due to excess effort. However, adjusting the level of effort applied to the fish stock within the framework of the existing license limitation management system will have relatively minor effects on the degree of rent dissipation and realised resource rent.

Among the various scenarios presented in Table 1, reducing effort to 10 million pot lifts, and sustainable catch to 9.4 million kg., comes closest to maximizing the mean value of realized annual resource rent (i.e. minimizing mean aggregate annual rent dissipation). Using best guess parameter values, it is estimated that a 35% reduction in the current number of 69,613 licensed pots in the fishery is likely to be required to achieve a long run reduction in fishing effort to 10 million pot lifts. However, note that depending on the true value of the elasticity of the constrained industry marginal cost curve, the required reduction in licensed pot numbers could be as low as 13%, or as high as 40%. Politically, it may be difficult to achieve the required reduction, whatever its magnitude.

Even if the required pot reduction could be achieved, annual resource rents would only increase by about $8.31 million (29%), and rent dissipation, totalling between $9.5 million and $25.2 million, would still remain, with a value of $17.4 million being most likely. Hence maximum sustainable rent is unlikely to exceed $37.5 million, (69% of potential) if a license limitation scheme is retained. Aggregate realised sustainable resource rent under a license limitation scheme is relatively insensitive to reductions in licensed pot numbers (and consequential reductions in the equilibrium level of effort) because even though achievable reductions in rent dissipation due to fleet redundancy can be substantial, they will be more or less offset by large increases in rent dissipation due to input substitution (i.e. capital stuffing).

The estimate of expected aggregate level of annual resource rent dissipation of $17.4 million associated with the second best level of fishing effort under a license limitation scheme also provides an estimate of the potential gain in economic efficiency from switching to a management system based on ITQ's. On the one hand, this could be regarded as an upper bound estimate because, as noted above, there may well be other unanticipated sources of rent dissipation under an ITQ based management system which will partly, or even totally offset the potential gains identified in this analysis. On the other hand, the above estimate does not include any allowance for gains in efficiency which might be possible due to relaxation of regulations which reinforce the effectiveness of the basic license limitation scheme, such as limits to the duration of the fishing season , and/or controls on pot design which reduce possible catching power. While at least some such regulations also could be relaxed if the license limitation scheme was retained, to do so while reducing the size of the catch to sustainable levels would require even greater reductions in pot numbers, and much larger associated amounts of rent dissipation due to capital stuffing than those estimated above.

With fishery management changes such as a longer fishing season, and with a "better" distribution of effort throughout the season, the potential resource rent from the fishery could be considerably larger than $54.7 million. For reasons to be discussed below, much of the potential increase in annual resource rent which might be generated under either management system will only be realised if substantial rationalisation of boat numbers in the fishery is allowed to proceed. Under a license limitation scheme, this gain in efficiency is unlikely to be fully realised because the use of pots will become increasingly expensive relative to boats[4] as the number of pot licenses is reduced in order to reduce effort. This distortion in the cost of pot use relative to boat use will both inhibit existing pressures for rationalisation of boat numbers, and increasingly will provide the incentive for more intensive and uneconomic use of pots, such as pulling each pot more than once per day. In fact, further investment in expensive electronic navigation equipment, further expenditure on travel to the "hot spot" fishing grounds, and more time spent on pot placement, together with more intensive pot use are likely to be the main sources of ever increasing rent dissipation under a license limitation scheme.

To sum up, under a License Limitation Scheme, protection of the breeding stock will require increasingly drastic reductions in pot numbers or equivalent changes in other regulations, either of which will incur substantial efficiency losses in the form of rent dissipation. Any changes in regulations, such as an extended season, which might improve industry returns, will require even more drastic reductions in pot numbers. Hence, there is only limited potential to improve the level of realised aggregate net economic returns from the fishery under this form of management.

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[4] And to other inputs as well.

ACCOUNTING MODEL ANALYSIS

The aim of the analysis reported in this section was to derive estimates of the annual net (economic) returns being generated in the fishery *in the short run* given defined levels and seasonal patterns of effort and catch, given specified assumptions about the values of a few key parameters, and given existing economic structure in the catching sector of the industry. Short run annual net returns may not equate with annual resource rents for several reasons. For instance, there is no necessary reason why short run net returns should be sustainable in the long run, and therefore they can give a very misleading impression of the level of resource rents.

The level of resource rents being generated in a fishery also depends on the economic structure in that fishery. As noted above, the economic structure of the industry is determined, *inter alia*, by the method of fishery management. Consequently, the accounting model was used to explore the consequences of changes to some aspects of the economic structure of the industry, and for reasons discussed above including in particular the average number of pots per boat. Nevertheless, 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.

The starting point for the analysis of changes to the economic structure of the industry is a base case scenario embodying actual average monthly patterns of effort and catch for the period from 1980 to 1992 inclusive. Figure 3 presents an overview of this data, while Appendix 5 contains more detail for each zone. All of the alternative scenarios are based on assumed monthly shares of a defined total allowable catch (TAC), which in each case was set equal to a safe sustainable level of 9 million kg. These catch scenarios for the fishery were combined with the estimated current economic structure in the catching sector of the industry, which were derived from a combination of survey data and other sources. More details on these data sources are provided in Appendix 3, and the key economic parameters derived from them are set out in Table 2.

A detailed outline of the computational method used to calculate annual economic net returns to the catching sector of the industry is provided in Appendix 4. In brief, historical averages, or assumed parameters for catch per unit effort, number of days fished, and pots per boat were used to calculate corresponding monthly levels of effort, and minimum required pot and boat numbers. These structural variables were then combined with the economic parameters (average costs and monthly catch worth) as set out in Table 2 to derive estimates of short run aggregate industry catching costs, revenue, and net economic returns. Definition of some of the key variables is set out below.

Net Return = **Total Revenue - Total Costs**

Total Revenue = **∑(monthly beach price/kg. of catch* monthly catch)**

N.B. Beach price is based on "worth/kg" as estimated by P. Monaghan

Total Costs = **∑(boat costs; pot costs; trip costs; pot lift costs; catch costs)**

Boat Costs = cost/boat* Required boat nos.

Pot Costs = cost/pot* Required pot nos.

Trip Costs = cost/trip* Required boat nos.*No. days fished

Pot Lift Costs = cost/pot lift* Number of pot lifts

Catch Costs = cost/kg. of catch* annual catch

FIGURE 3: AVERGE CATCH by MONTH - 1980:1992

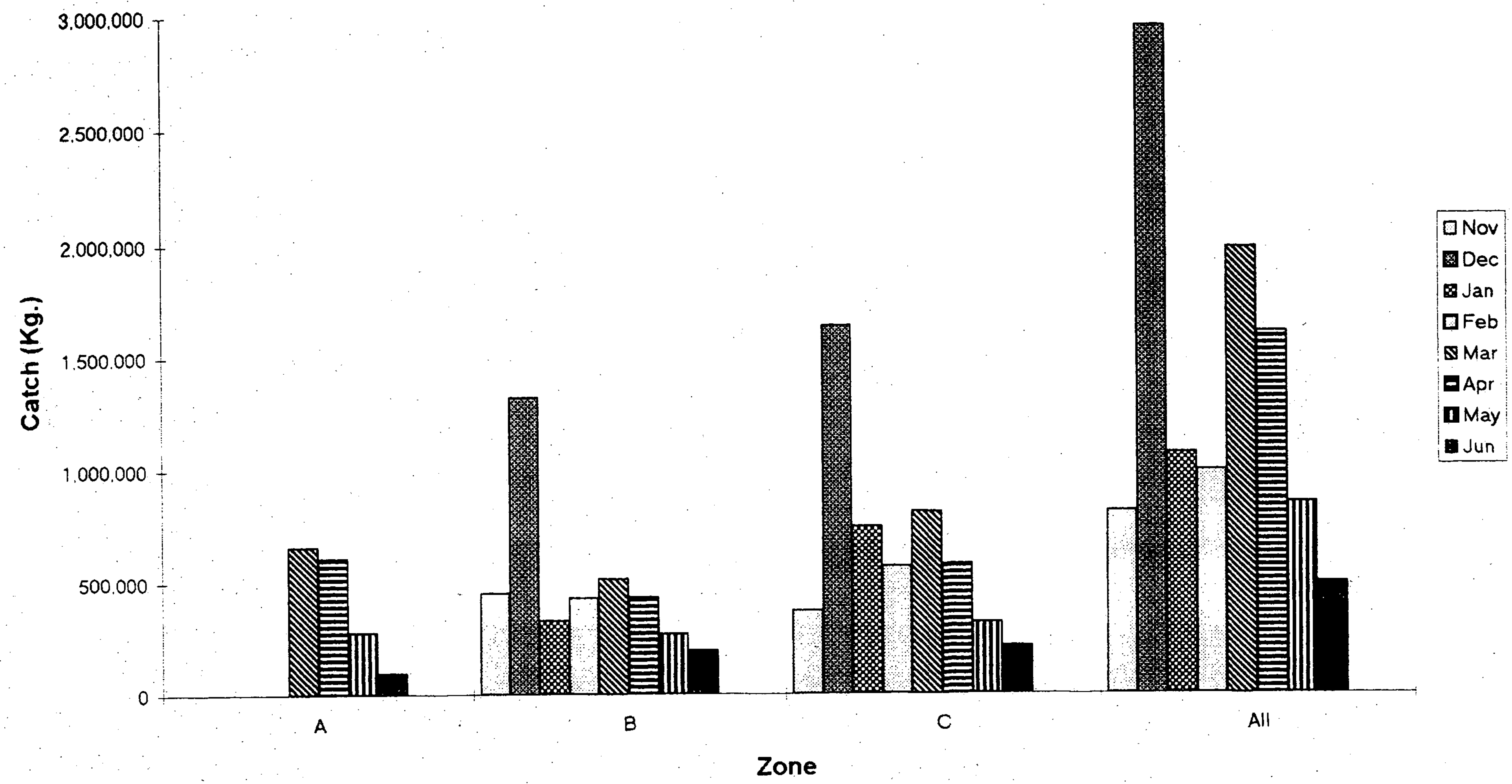

TABLE 2: DATA & KEY PARAMETERS - ACCOUNTING & PROGRAMMING MODELS

HISTORICAL DATA	YEAR	Nov.	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average 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%	14.94%	7.91%	4.60%			
Available fishing days	320	16	31	31	28	31	30	31	30	31	31	30
Avg. Days fished	187	15	28	22	25	27	27	25	18	15	12	15
PARAMETERS USED IN MODEL	**SEASON**	**Nov.**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Current Days fished	188	15	29	22	25	27	27	25	18			
Extended Days fished	230	15	29	22	25	27	27	25	18	15	12	15
CPUE(kg/pl)		0.80	1.47	0.86	0.68	1.10	0.97	0.65	0.55	0.63	0.65	0.5
Catch worth($/kg)	Current	$23.90	$19.64	$20.03	$21.75	$22.43	$22.43	$23.62	$24.87			
Catch worth($/kg)	Extended	$24.51	$20.67	$20.27	$22.07	$22.50	$22.47	$23.82	$25.21	$26.04	$26.04	$26.68

Average Costs

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

Number of pot lifts by month required to achieve a specified seasonal catch pattern can be calculated simply provided that catch per unit of effort (CPUE) is known. Historical average monthly patterns of catch per pot lift are depicted in Figures 4 and 5. Apart from stock abundance, CPUE will depend on "managerial" variables such as catching technology and care and time taken in pot 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, CPUE is likely to 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 calculations in the accounting model.

Monthly minimum required pot numbers was calculated from the corresponding levels of required effort, and from an assumption about number of days fished. In any given month during the mandated fishing season, the expected number 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 seen from Figure 6 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 despite significant reductions in the number of pots licensed for commercial use.

Appendix 6 presents historical patterns of number of days fished per month for each month of the fishing season. In the more "productive" months, such as December, March and April, it can be seen that number of days fished is at, or closely approaching the maximum number of available "days" so long as pots are only pulled once daily. In other months, historically the number of days fished has been much lower than the theoretical maximum, and is still trending upwards. Moreover, an analysis of data on fishing effort for a sample of individual boats (see Appendix 7 for histograms for selected months) 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. Subjective predictions of potentially available fishing days by month were based on the above evidence, and used in the accounting model to estimate pot numbers required on an annual basis to achieve the specified seasonal pattern of catch and effort.

To estimate required boat numbers, an assumption had to be 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[5] 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.

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

FIGURE 4: AVERGE CATCH PER POT LIFT by MONTH - 1980:1992

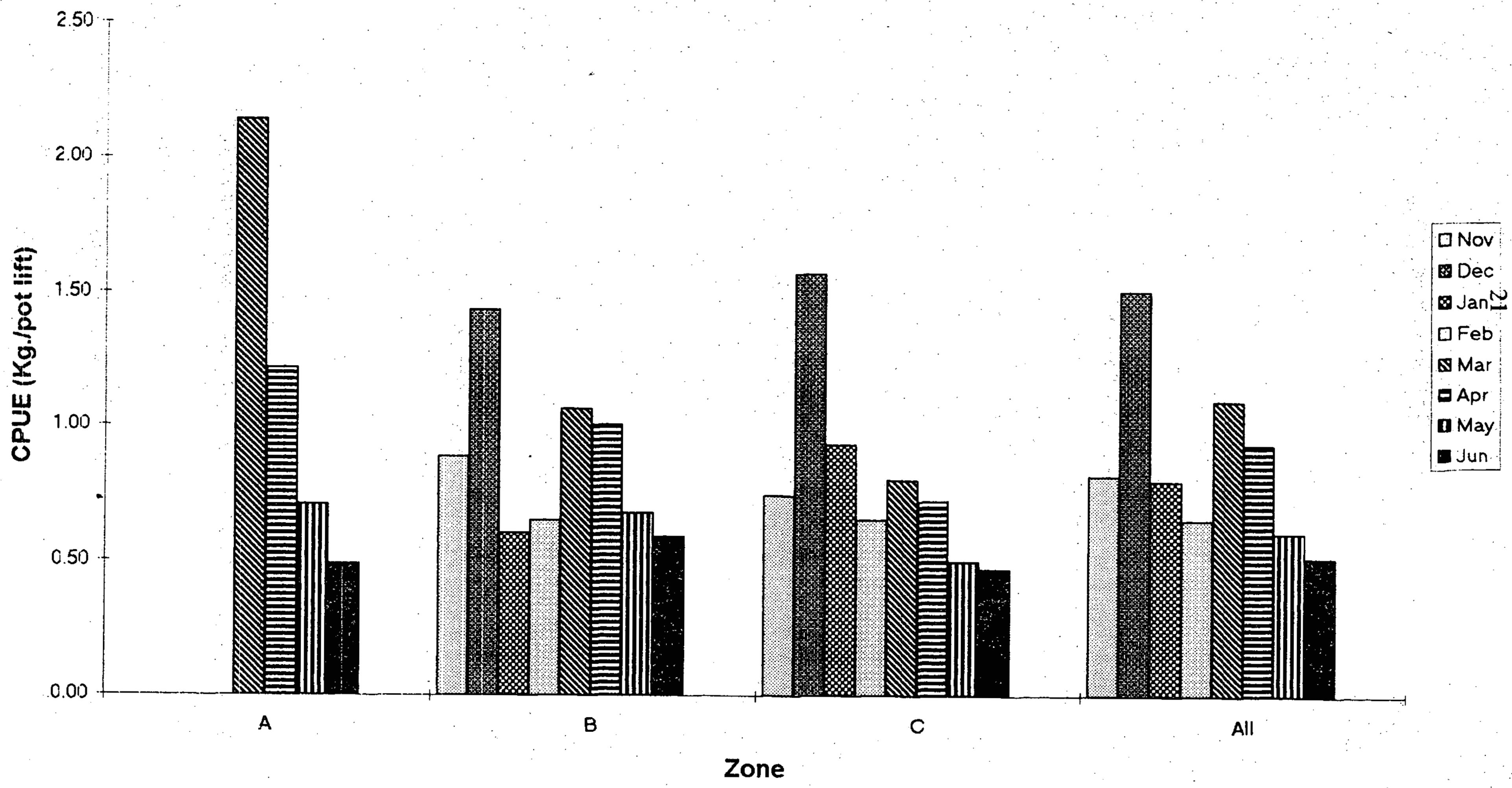

FIGURE 5: AVERAGE CATCH PER POT LIFT
- by Month & by Zone

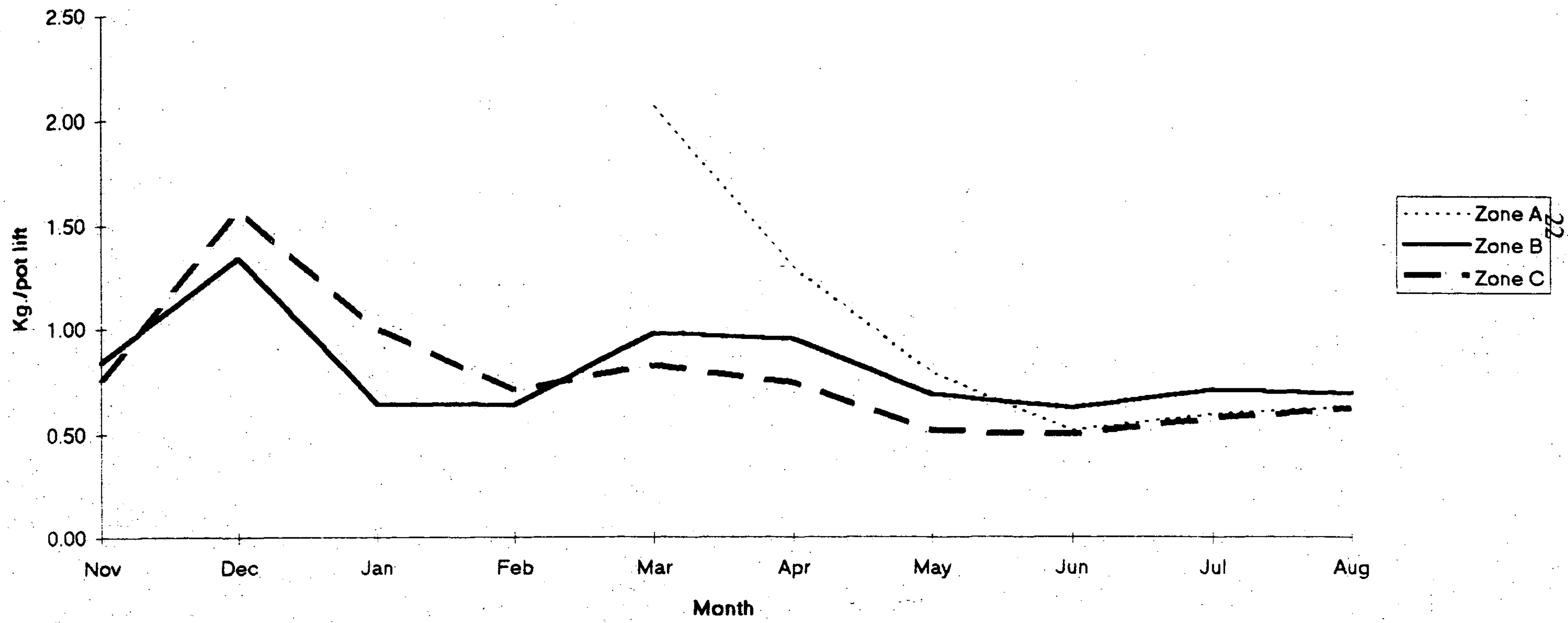

FIGURE 6: FISHING CAPACITY & INTENSITY

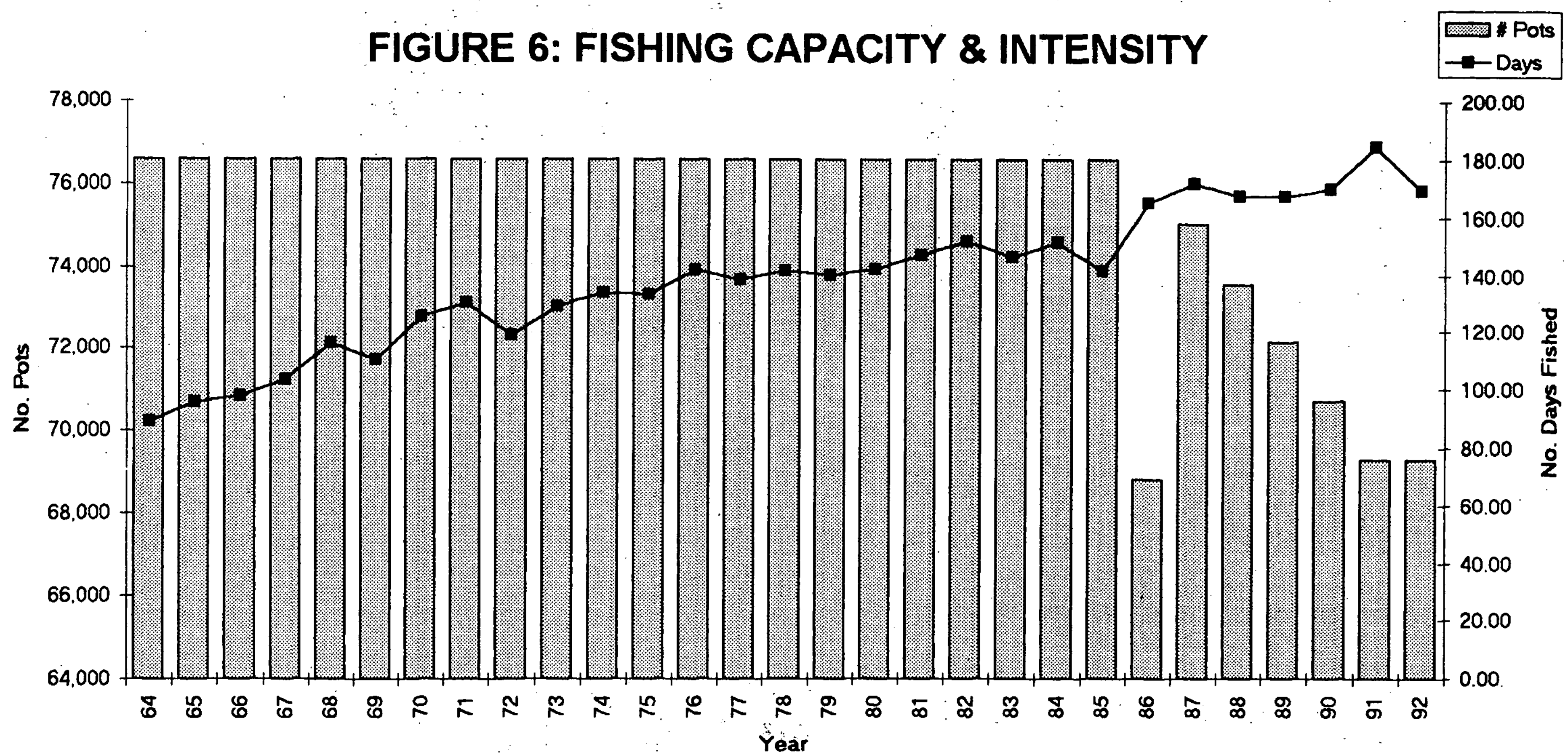

Table 3 summarises the results of using this model to evaluate the following scenarios[6]:

- 0. the base case involving *status quo* management, including:
  an unsustainable catch of about 10.8 million kg.,
  no change in boats (669) or pot nos. (69,613), and
  a close to the fishing season on June 30.
- 1. the first case involving:
  a sustainable catch of about 9 million kg.,
  reduced nos. of boats (558) and pots (58,031), and
  a close to the fishing season on June 30.
- 2. the second case involving:
  a sustainable catch of about 9 million kg.,
  reduced nos. of pots (58,031), but boat nos. constant (669) by regulating pots/boat, and
  a close to the fishing season on June 30.
- 3. the third case involving:
  a sustainable catch of about 9 million kg.,
  reduced nos. of pots (58,031), but even fewer boats (403) by permitting more pots/boat,
  and a close to the fishing season on June 30.
- 4. the fourth case involving:
  a sustainable catch of about 9 million kg.,
  reduced nos. of boats (445) and pots (46,264), and
  a close to the fishing season on September 30.
- 5. the fifth case involving:
  a sustainable catch of about 9 million kg.,
  reduced nos. of pots (46,264), but boat nos. constant (669) by regulating pots/boat, and
  a close to the fishing season on September 30.
- 6. the sixth case involving:
  a sustainable catch of about 9 million kg.,
  reduced nos. of pots (46,264), but even fewer boats (321) by permitting more pots/boat,
  and a close to the fishing season on September 30.

As note above, because this model does not incorporate any biological relationships, it is best suited to estimating short run economic impacts. Thus achieving a reduction in catch by *pro rata* reductions in boat and pot numbers in order to protect the breeding stock (scenario 1) has no effect on net returns per pot or per boat, at least in the short run, but does reduce aggregate net returns to the industry in proportion to the reduction in catch. In the longer run, this lower exploitation rate should improve stock abundance, and lead to higher catch rates and the need for even fewer pots and boats to take the defined catch. If this outcome eventuates, aggregate net returns as well as net returns per pot and per boat will increase above those estimated from the model.

[6] The spreadsheets used to compute these results are reproduced in Appendix 8.

TABLE 3: SUMMARY of RESULTS - ACCOUNTING MODEL

Scenario	0 = Base Case	1	2	3	4	5	6
	Constant boat & pot Nos.	Reduced boat & pot nos.	Reduced pots constant boats	Reduced pots more pots/boat	Reduced boat & pot nos.	Reduced pots constant boats	Reduced pots more pots/boat
Fishing season	Limited	Limited	Limited	Limited	Extended	Extended	Extended
Catch (m. Kg.)	10.796	9.000	9.000	9.000	9.000	9.000	9.000
Pots/boat	104	104	87	144	104	69	144
Days fished	188	188	188	188	230	230	230
Pot Lifts (m.)	11.435	9.532	9.532	9.532	10.449	10.449	10.449
CPUE	0.94	0.94	0.94	0.94	0.86	0.86	0.86
Pot nos.	69,613	58,031	58,031	58,031	46,264	46,264	46,264
Boat nos.	669	558	667	403	445	669	321
pot costs ($m)	$10.094	$8.414	$8.414	$8.414	$6.708	$6.708	$6.708
boat costs ($m)	$76.976	$64.169	$76.707	$46.344	$51.157	$76.883	$36.947
trip costs ($m)	$18.247	$15.211	$18.183	$10.986	$14.836	$22.296	$10.715
potlift costs ($m)	$24.013	$20.017	$20.017	$20.017	$21.942	$21.942	$21.942
catch costs($m)	$34.548	$28.800	$28.800	$28.800	$28.800	$28.800	$28.800
Total costs($m)	$163.877	$136.611	$152.122	$114.561	$123.443	$156.630	$105.112
Revenue($m)	$196.295	$163.635	$163.635	$163.635	$172.457	$172.457	$172.457
Net Return ($m)	$32.418	$27.024	$11.513	$49.074	$49.014	$15.827	$67.346
Net Return/pot	$466	$466	$198	$846	$1,059	$342	$1,456
Net Return/boat	$48,431	$48,431	$17,260	$121,774	$110,183	$23,674	$209,619

A comparison between scenarios 1,2, and 3 highlights the pivotal importance of the number of pots per boat to the economic performance of the industry, and the corresponding implications for rationalisation of boat numbers. This parameter value has been increasing steadily in recent years, and the current level of approximately 104 pots/boat would almost certainly be higher in the absence of regulations limiting maximum number of pots/boat. As steps are taken to reduce catch levels, the economic incentives to increase number of pots/boat is likely to intensify.

Cases 1,2, and 3 all depict scenarios where catch is reduced to 9 million kg. by reducing pot numbers to 58,031 pots. If boat numbers are permitted to decline so as to maintain an industry average of 104 pots per boat, then the impact of reducing catch to a safe sustainable level can be achieved with only a modest reduction in industry net returns from $32.4 million to $27.0 million. Scenario 3 represents a situation where the average value of this parameter increases to 144 pots/boat while reducing the catch to 9 million kg.. Despite the lower catch and fewer pots, net returns to the industry are some $16.5 million greater than for the base case. Net returns per pot are nearly double, and net returns per boat nearly treble those for the base case scenario. While introduction of an ITQ based management system is likely to lead to an increase in pots per boat for reasons already discussed, the magnitude of the change may not be as large as that assumed in scenario 3. Conversely, if rationalisation of boat numbers is prevented by even tighter regulations on numbers of pots per boat, then scenario 2 indicates that net returns per pot and per boat are likely to be less than half that for the base case, while industry net returns will be reduced by about $20 million.

Possible short run economic impacts of extending the close of the fishing season to September 30 are depicted in scenarios 4, 5, and 6, which in all other respects correspond to scenarios 1, 2, and 3 respectively. Note that these estimated impacts reflect both changes in the monthly levels of catch worth as estimated in the attached marketing report, as well as changes in the average cost of effort and the average catch per unit of effort due to extending the fishing season.

The most striking feature of the result is the sensitivity of the estimated increase in industry net returns to policies on boat numbers. Depending on the assumptions made about numbers of pots per boat, this analysis suggests that extending the season by three months may or may not have a significant impact on industry net returns. If boat numbers are not permitted to fall below current levels, then the gains in net returns from spreading the defined catch over more of the year are unlikely to be much larger than $4.3 million. However, if boat numbers are allowed to vary in proportion to pot numbers (cases 1 and 4), so as to maintain constant numbers of pots per boat, then extending the fishing season may increase industry net returns by up to $22 million. However, this increase in net returns due to a longer season reduces to $18.3 million if additional rationalisation of boat numbers occurs (cases 3 and 6) so as to increase pots per boat to 144.

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.

PROGRAMMING MODEL ANALYSIS

In many respects, the structure of the mathematical programming model, and the assumptions on which it is based are similar to those of the less sophisticated accounting model. Like the accounting model, the programming model provides estimates of the net (economic) returns being generated in the fishery *in the short run* given a defined total allowable catch (TAC), given specified assumptions about the values of a key parameters and constraints, and given an assumed economic structure in the catching sector of the industry. Unlike the accounting model, the programming model identifies the optimal seasonal patterns of effort and catch which maximise net returns subject to specified constraints. So far as possible, the same parameter values as set out in Table 2 for the accounting model have been assumed in the programming model.

The principal ways in which the programming model differs from the accounting model are as follows:

- boat and pot numbers, and monthly effort levels are determined simultaneously rather than sequentially
- subject to defined constraints on, *inter alia*, the level of total catch, the monthly distribution of effort is optimised so as to maximise net economic returns to the industry
- the mathematical programming model incorporates some simple representations of steady state population dynamics in the Western Rock Lobster Fishery which allow for natural mortality and for animals to grow in size over time (if they are not caught). In addition, the model ensures that monthly catch levels are consistent with stock availability, and can estimate whether sufficient animals "escape" into the breeding stock
- the results from appropriately defined scenarios provide a guide to behaviour of fishermen under an ITQ based management system

The scenarios evaluated using the programming model were as follows:

- 0. the base case involving *status quo* License Limitation Scheme management, including:
  an unsustainable catch of about 10.8 million kg.,
  no change in boats (669) or pot nos. (69,576), and
  a close to the fishing season on June 30.
- 1. the first case involving License Limitation Scheme management, and including:
  a sustainable catch of about 9 million kg.,
  reduced nos. of boats and pots, and
  a close to the fishing season on June 30.
- 2. the second case involving License Limitation Scheme management, and including:
  a sustainable catch of about 9 million kg.,
  reduced pot nos., but boat nos. held constant (669) by regulating pots/boat, and
  a close to the fishing season on June 30.
- 3. the third case involving a TAC with variable closed season management, and including:
  a sustainable catch of about 9 million kg.,
  constant nos. of pots (69,576), and constant nos. of boats (669) and
  a close to the fishing season as soon as the TAC is reached
- 4. the fourth case simulating aspects of an ITQ based management system, and including:
  a sustainable catch of about 9 million kg.,
  reduced nos. of boats and pots, and
  a close to the fishing season on June 30.

- 5. the fifth case simulating aspects of an ITQ based management system, and including:
  a sustainable catch of about 9 million kg.,
  reduced pot nos., but boat nos. held constant (669) by regulating pots/boat, and
  a close to the fishing season on June 30.
- 11. the eleventh case involving License Limitation Scheme management, and including:
  a sustainable catch of about 9 million kg.,
  reduced nos. of boats and pots, with more pots/boat (144), and
  a close to the fishing season on June 30.
- 14. the fourteenth case simulating aspects of an ITQ based management system, and including:
  a sustainable catch of about 9 million kg.,
  reduced nos. of boats and pots, with more pots/boat (144), and
  a close to the fishing season on June 30.
- 21. the twenty first case involving License Limitation Scheme management, and including:
  a sustainable catch of about 9 million kg.,
  reduced nos. of boats and pots, and
  an extended fishing season closing on September 30.
- 22. the twenty second case involving License Limitation Scheme management, and including:
  a sustainable catch of about 9 million kg.,
  reduced pot nos., but constant boat nos. (669) by regulating pots/boat, and
  an extended fishing season closing on September 30.
- 24. the twenty fourth case simulating aspects of an ITQ based management system, and including:
  a sustainable catch of about 9 million kg.,
  reduced nos. of boats and pots, and
  an extended fishing season closing on September 30.
- 25. the twenty fifth case simulating aspects of an ITQ based management system, and including:
  a sustainable catch of about 9 million kg.,
  reduced pot nos., but boat nos. held constant (669) by regulating pots/boat, and
  an extended fishing season closing on September 30.
- 31. the thirty first case involving License Limitation Scheme management, and including:
  a sustainable catch of about 9 million kg.,
  reduced nos. of boats and pots, with increased nos. of pots/boat (144), and
  an extended fishing season closing on September 30.
- 34. the thirty fourth case simulating aspects of an ITQ based management system, and including:
  a sustainable catch of about 9 million kg.,
  reduced nos. of boats and pots, with increased nos. of pots/boat (144), and
  an extended fishing season closing on September 30.

The results of evaluating the above scenarios are presented in Appendix 9, and summarised in Tables 4 and 5. While considerable trouble was taken to try to make this model directly comparable with the accounting model, structural differences between the two models inevitably resulted in some differences in estimated industry net returns. However, these differences are relatively minor, and the differences between the respective base case results and those of alternative scenarios are even smaller. For instance, the base case as well as scenarios 1 and 2 are defined equivalently in both models.

TABLE 4: SUMMARY of ITE/TAE RESULTS : PROGRAMMING MODEL

Case	Base	1	2	11	21	22	31
Management	TAE/ITE	TAE/ITE	TAE/ITE	TAE/ITE	TAE/ITE	TAE/ITE	TAE/ITE
Catch Level	Unsustainable	Sustainable	Sustainable	Sustainable	Sustainable	Sustainable	Sustainable
Boat Nos.	Constant	Variable	Constant	Variable	Variable	Constant	Variable
Pot Nos.	Constant	Variable	Variable	Variable	Variable	Variable	Variable
Avg. Pots/boat	<=104	<=104	<=104	<=144	<=104	<=104	<=144
Season ends	June 30	June 30	June 30	June 30	Sept. 30	Sept. 30	Sept. 30
Catch	10,795,339	8,999,188	8,999,188	8,999,188	9,000,000	9,000,000	9,000,000
Boats	669	558	669	403	445	669	321
Pots	69,576	58,000	58,000	58,000	46,231	69,576	46,231
Nov Pot Lifts	1,020,278	850,522	850,522	850,522	676,636	676,636	676,636
Dec Pot Lifts	2,018,782	1,682,893	1,682,893	1,682,893	1,331,648	1,331,648	1,331,648
Jan Pot Lifts	1,243,343	1,036,473	1,036,473	1,036,473	1,011,116	1,011,116	1,011,116
Feb Pot Lifts	1,464,628	1,220,940	1,220,940	1,220,940	1,151,680	1,151,680	1,151,680
Mar Pot Lifts	1,801,387	1,501,668	1,501,668	1,501,668	1,223,901	1,223,901	1,223,901
Apr Pot Lifts	1,663,190	1,386,465	1,386,465	1,386,465	1,248,228	1,248,228	1,248,228
May Pot Lifts	1,310,311	1,092,298	1,092,298	1,092,298	1,104,851	1,104,851	1,104,851
Jun Pot Lifts	908,661	757,476	757,476	757,476	823,049	823,049	823,049
Jul Pot Lifts	0	0	0	0	636,466	636,466	636,466
Aug Pot Lifts	0	0	0	0	551,020	551,020	551,020
Sep Pot Lifts	0	0	0	0	600,000	600,000	600,000
Total Pot Lifts	11,430,579	9,528,735	9,528,735	9,528,735	10,358,597	10,358,597	10,358,597
CPUE	0.94	0.94	0.94	0.94	0.87	0.87	0.87
Total Revenue ($m)	$196.3	$163.6	$163.6	$163.6	$172.5	$172.5	$172.5
Total Cost ($m)	$162.0	$135.0	$147.8	$117.2	$123.2	$152.4	$109.0
Net Return ($m)	$34.3	$28.6	$15.8	$46.4	$49.3	$20.1	$63.5
Net Return/pot ($)	$493	$493	$272	$800	$1,066	$289	$1,373
Net Return/boat ($)	$51,244	$51,244	$23,584	$115,184	$110,869	$30,021	$197,741

In Appendix 9, there is a separate table of results for each scenario. *Answer Report 1* presents results for both the base case scenario, in the column headed "Original Value", and for scenario 1 in the column headed "Final Value". In all other *Answer Reports*, it is the "Final Value" column which contains the results for that scenario. The row titled "Profit Total" contains the estimated value for annual industry net return, and the following rows contain estimates of the level of (constrained) catch, numbers of boats, pots, and potlifts by month. The final set of rows contain values for "transfer activities" designed to ensure that enough animals remain at the end of the fishing season to maintain a sustainable breeding stock .

Scenarios 1, 2, 11, 21, 22, and 31 are all intended to simulate variations on the current license limitation scheme of management, and are summarised in Table 4. It can be seen that reducing catch under an ITE/TAE based system by reducing pot and boat numbers (case 1) reduces aggregate net returns by about $5.7 million p.a., while reducing pot numbers only but preventing any decline in boat numbers (case 2) reduces aggregate net returns by over $18.5 million p.a.. These estimates approximate those obtained from the accounting model, but neither accounts for any offsetting losses due to additional rent dissipation likely to accompany attempts to reduce effort and catch while retaining the ITE/TAE system. Again, the results clearly demonstrate that failing to allow rationalisation of boat numbers when the catch is reduced to sustainable levels involves a large opportunity cost. For the current length fishing season, the cost is estimated at about $13 million (case 1 - case 2), but with an extended season up to $30 million (case 21 - case 22) could be involved.

Pot and boat numbers are both treated as freely variable (up to current levels) in cases 1, 11, 21, and 31. A comparison of cases 1 with 21, and of 11 with 31, 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 $17 million to $21 million. However, where boat numbers are constrained to equal current numbers, the potential gain is much smaller. A comparison of cases 2 and 22 yields an estimate of only $4.3 million. Note that an ITE/TAE system is likely to inhibit rationalisation of boat numbers.

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. Scenario 3 estimates the consequences, given current technology and economic structure, of reducing average catch levels to 9 million kg. while maintaining both pot and boat numbers by means of a TAC and a variable closed season. It can be seen from Table 5 that even in 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 as much of the TAC as possible before the season closed.

Table 5 summarises the results for scenarios 4, 5, 14, 24, 25, and 34, 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 maximize industry net returns. Both pot and boat numbers are allowed to vary freely up to maxima equal to current levels in cases 4, 14, 24, and 34, while boat numbers are constrained to equal current numbers in cases 5 and 25. In cases 4 and 5, the fishing season ends on June 30, while it is extended to September 30 in cases 6 and 7.

TABLE 5: SUMMARY of ITQ/TAC RESULTS : PROGRAMMING MODEL

Case	3	4	5	14	24	25	34
Management	TAC only	TAC/ITQ	TAC/ITQ	TAC/ITQ	TAC/ITQ	TAC/ITQ	TAC/ITQ
Catch Level	Sustainable	Sustainable	Sustainable	Sustainable	Sustainable	Sustainable	Sustainable
Boat Nos.	Constant	Variable	Constant	Variable *	Variable	Constant	Variable *
Pot Nos.	Constant	Variable	Variable	Variable	Variable	Variable	Variable
Avg. Pots/boat	<=104	<=104	<=104	<=144	<=104	<=104	<=144
Season ends	Variable	June 30	June 30	June 30	Sept. 30	Sept. 30	Sept. 30
Catch	8,996,809	9,000,000	9,000,000	9,000,000	9,000,000	9,000,000	9,000,000
Boats	669	477	669	344	402	669	290
Pots	69,576	49,600	69,576	49,600	41,804	69,576	41,804
Nov Pot Lifts	1,020,278	744,007	1,043,640	744,007	627,061	1,043,640	627,061
Dec Pot Lifts	2,018,782	1,488,013	1,484,522	1,488,013	1,254,122	0	1,254,122
Jan Pot Lifts	1,243,343	1,289,611	0	1,289,611	1,086,906	0	1,086,906
Feb Pot Lifts	1,464,628	1,240,011	0	1,240,011	1,045,102	0	1,045,102
Mar Pot Lifts	1,801,387	1,388,812	1,948,128	1,388,812	1,170,514	1,948,128	1,170,514
Apr Pot Lifts	1,202,299	1,339,212	1,878,552	1,339,212	1,128,710	1,878,552	1,128,710
May Pot Lifts	0	1,289,611	1,808,976	1,289,611	1,086,906	1,544,047	1,086,906
Jun Pot Lifts	0	1,091,210	1,530,672	1,091,210	919,690	1,530,672	919,690
Jul Pot Lifts	0	0	0	0	752,473	1,252,368	752,473
Aug Pot Lifts	0	0	0	0	752,473	1,252,368	752,473
Sep Pot Lifts	0	0	0	0	752,473	1,252,368	752,473
Total Pot Lifts	8,750,716	9,870,488	9,694,490	9,870,488	10,576,432	11,702,143	10,576,432
CPUE	1.03	0.91	0.93	0.91	0.85	0.77	0.85
Total Revenue ($m)	$160.0	$164.4	$169.0	$164.4	$173.8	$185.0	$173.8
Total Cost ($m)	$146.8	$125.7	$150.1	$110.5	$118.5	$157.2	$105.6
Net Return ($m)	$13.2	$38.6	$18.9	$53.9	$55.3	$27.8	$68.2
Net Return/pot ($)	$190	$779	$271	$1,086	$1,323	$400	$1,630
Net Return/boat ($)	$19,781	$81,001	$28,195	$156,386	$137,611	$41,591	$234,769

In the main, the findings from the results in Table 5 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 the base case) 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, which could range from nearly $20 million (case 4 - case 5) if the length of the fishing season is not extended, and up to $27.5 million (case 24 - case 25) if it is extended by three months.

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, and case 14 with 34. In all these cases, both pot and boat numbers are allowed to vary freely (up to current levels). Aggregate annual net returns are estimated to increase by about $16 million to $17 million due solely to differences in the length of the fishing season. These estimates are slightly less than the estimated potential gain from an extra three months fishing under an ITE/TAE based system. Where boat numbers are held constant, the gain is only of the order of $4.3 million, again similar to but smaller than the figure for a license limitation scheme.

Key parts of the results presented above are rearranged in Table 6 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. Consider first the case depicted in column one where boat numbers are held constant, 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 from $15.8 million to $18.9 million. However, this gain is almost totally offset by additional costs of research and enforcement, which were deemed to be $1 million and $1.7 million respectively. If the season is extended to September 30, but boat numbers are still held constant, the increase in industry annual net returns from adopting ITQ's of $7.7 million is still largely offset by additional research and enforcement costs.

If rationalisation of boat numbers is permitted, prediction of the consequences of a change to the management system is rather more difficult. 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. Just how large this difference would be has to be a matter for conjecture because of a lack of hard empirical evidence on which to base a realistic assumption.

TABLE 6: ITE/TAE vs. ITQ/TAC COMPARISON : PROGRAMMING MODEL

							UPPER BOUND ESTIMATES	
Boat Nos.	Constant	Variable	Variable	Constant	Variable	Variable		
Pot Nos.	Variable	Variable	Variable	Variable	Variable	Variable		
Avg. Pots/boat	<104	=104	=144	<104	=104	=144		
Season ends	June 30	June 30	June 30	Sept. 30	Sept. 30	Sept. 30	June 30	Sept. 30
Days fished	188	188	188	230	230	230	188	230
ITE/TAE Case	2	1	11	22	21	31	1	21
Boat Nos.	669	558	403	669	445	321	558	445
Pot Nos.	58,000	58,000	58,000	69,576	46,231	46,231	58,000	46,231
Pot Lifts (m.)	9.529	9.529	9.529	10.359	10.359	10.359	9.529	10.359
Industry Returns ($m)	$ 163.6	$ 163.6	$ 163.6	$ 172.5	$ 172.5	$ 172.5	$ 163.6	$ 172.5
Industry Costs ($m)	$ 147.8	$ 135.0	$ 117.2	$ 152.4	$ 123.2	$ 109.0	$ 135.0	$ 123.2
Net Returns ($m)	$ 15.8	$ 28.6	$ 46.4	$ 20.1	$ 49.3	$ 63.5	$ 28.6	$ 49.3
ITQ/TAC Case	5	4	14	25	24	34	14	34
Boat Nos.	669	477	344	669	402	290	344	290
Pot Nos.	69,576	49,600	49,600	69,576	41,804	41,804	49,600	41,804
Pot Lifts (m.)	9.694	9.870	9.870	11.702	10.576	10.576	9.870	10.576
Industry Returns ($m)	$ 169.0	$ 164.4	$ 164.4	$ 185.0	$ 173.8	$ 173.8	$ 164.4	$ 173.8
Industry Costs ($m)	$ 150.1	$ 125.7	$ 110.5	$ 157.2	$ 118.5	$ 105.6	$ 110.5	$ 105.6
Net Returns ($m)	$ 18.9	$ 38.6	$ 53.9	$ 27.8	$ 55.3	$ 68.2	$ 53.9	$ 68.2
Extra Net Returns ($m)	$ 3.1	$ 10.1	$ 7.8	$ 7.7	$ 6.0	$ 4.7	$ 25.3	$ 18.9
Extra Enforcement Costs ($m)	$ 1.7	$ 1.7	$ 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	$ 1.0	$ 1.0
Net Gain ($m)	$ 0.4	$ 7.4	$ 4.8	$ 5.1	$ 3.4	$ 2.0	$ 22.6	$ 16.2

The second and fifth columns in Table 6 are based on an assumption that the current industry average of 104 pots per boat will continue under a restructured ITE/TAE system as well as under an ITQ/TAC based system. These net gains in these columns probably underestimate the potential gains of switching systems by a significant margin, because they take no account of 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 lower bound estimates of potential efficiency gains for the current, and an extended season respectively. If the introduction of ITQ's increases average numbers of pots per boat, then the relevant parts of the third and sixth columns arguably provide a better estimate of industry net returns for this system of management. The last two columns in Table 6 provide such a comparison, namely between cases 1 and 14 for a season closing on June 30, and between cases 21 and 34 for an extended season. Depending on length of season, this comparison suggests potential efficiency gains of switching systems of either $22.6 million or $16.2 million, which should be treated as upper bound estimates of net gains if rationalisation of boat numbers is permitted.

CONCLUSIONS

To judge the significance of estimates of the impact of any particular change in the system of management in the Western Rock Lobster fishery on aggregate annual net returns, it is necessary to establish a numeraire or benchmark against which any predicted changes can be measured. In the section on the bioeconomic model, sustainable annual resource rents currently being generated in the fishery were estimated at about $28 million. This estimate is somewhat lower than that of short run annual net economic returns estimated at $32.4 million in the accounting model, or at $34.3 million in the programming model. $50 million has been adopted in the discussion that follows as a broad estimate of current gross income collectively being earned in the industry as a return to management, as a return on "real" capital invested in the fishery, and as a (resource) rent on the fish stock. Various estimates of gains and losses are expressed in the discussion below as a percentage of this measure of current aggregate annual gross income.

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:

- given current regulations on such things as duration of the fishing season, pot design, and other regulations designed to preserve the breeding stock, the *first best* optimal level of fishing effort is 7.3 million pot lifts, which should on average yield a sustainable catch of about 8.0 million kg. If this catch were caught in the least cost manner, then it could generate resource rents of up to $53 million per annum.
- currently some $25 million (50%) of potential resource rents are being dissipated under the license limitation system of management. Even without a longer fishing season, without "better" designed pots to enhance catching power, and without adjusting the seasonal catch pattern to better match market conditions, 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 numbers 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, these 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 managing 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 **A Model of Rent Dissipation and Second Best Effort Under License Limitation (from Campbell and Lindner (1990))**

We need to specify functional forms for the average product of effort schedule and the supply or marginal cost of effort schedule consistent with the assumptions we have made so far:

$AR_e = a - bE$ subject to $a, b > 0$; [1]

$MC_e = C_0 + C_1(E - E_B)$ subject to $C_0, C_1 > 0, E \_ E_B$. [2]

The equilibrium condition for the fishery is $AR_e = MC_e$, and so it follows that:
$E_B = [(C_1 + b)E - (a - C_0)]C_1^{-1}$. [3]

The fishery rent can be defined as:
$\_F = (a - C_0 - bE)E$ [4]

and the level of effort which gives a first-best optimum can be calculated as:
$E^* - 0.5(a - C_0)b^{-1}$. [5]

The efficiency loss resulting from the input restriction can be expressed as:
$L = 0.5(MC_e - C_0)(E - E_B)$, [6]

which, on substituting for MC_e and E_B, simplifies to:
$L = 0.5[(a - C_0) - bE]^2 C_1^{-1}$. [7]

The second-best optimum level of effort, $\hat{E}$, is obtained by choosing E to maximise:
$W = \_F -- L$. The solution value is:

$\hat{E} = 0.5(a - C_0)b^{--1}[(C_1 + b)/(C_1 + b/2)]$
$= E^* [(C_1 + b)/(C_1 + b/2)]$. [8]

Given our assumptions about the production of effort, the proportion of the restricted input excluded from the fishery by the limitation program is defined as: $B = 1 - (E_B/E_0)$. Substituting for E_B and E_0 and setting E and $\hat{E}$ gives the level of the second-best optimum licence limitation program:
$\hat{B} = 0.5[(C_1 + b)/(C_1 + b/2)]$.

APPENDIX 2: Derivation of Formulae to Estimate Key Parameter Values and Measures of Rent Dissipation Under License Limitation

In Figure 1, CFGJ depicts realised aggregate annual resource rent from E_a of effort and associated average revenue of effort, $AR(E_a)$

$$CFGJ = CHGJ - FGH$$
$$= (AR(E_a) - C_o) * (E_a + E_r)$$
$$= (g / 2) * (E_a\text{^}2 - E_r\text{^}2)$$

where $g = (AR(E_a) - C_o) / (E_a - E_r)$

Hence :

$$E_r = (E_a\text{^}2 - (CFGJ / 2))\text{^}0.5$$

$$C_o = AR(E_a) - g * (E_a - E_r)$$

Rent dissipation due to input substitution :

$$FGH = (AR(E_a) - C_o) * (E_a - E_r) / 2$$
$$= (g / 2) * (E_a - E_r)\text{^}2$$

In the Schaefer model, sustainable average revenue of effort:

$$AR_e = P * A * K * (1 - (2 * E * A) / r)$$

where P = price of catch
A = catchability coefficient
K = unexploited stock size
E = sustained level of effort
r = intrinsic growth rate
A =

Optimal effort,

$$Eopt. , = (1 - C_o / (P * A * K)) * (r / (2 * A)) ;$$

and corresponding maximum potential sustainable annual resource rent is:

$$Opt.\ rent = (P * A * K * (1 - Eopt * A / r) - C_o) * Eopt$$

Rent dissipation due to fleet redundancy :

$$BDH = (E_a - Eopt) * (C_o - AR(E_a))$$

APPENDIX 3: Data Sources for the Accounting and Programming Models

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

APPENDIX 4: Details of Computational Procedures for the Accounting Model

The model contained the following variables, which were either derived from specified data sources or calculated as according to the equations below:

% catch by month- (based on average for recent fishing seasons)

Aggregate Annual TAC- (based on average for recent fishing seasons, or assumed)

Monthly catch

```
= TAC * monthly % share
```

CPUE by month - (based on average for recent fishing seasons)

Number of pot lifts

```
= monthly catch/(CPUE)
```

Potential no. days fished by month - (based on projection of trends for recent years)

Required pot nos.

```
pot nos./mo.          = # pot lifts/potential # days fished
required pot nos.     = max.( pot nos./mo.)
```

pots/boat - (based on average for recent fishing seasons)

Required boat nos.

```
= Required pot nos./( pots/boat)
```

$ cost/pot (e.g. replacement of old pots) - based on survey data & SA study

$ cost/boat (e.g. fixed overheads including anti-fouling insurance, storage, etc.)
- based on survey data & SA study

$ cost/trip (mainly fuel) - based on survey data & SA study

$ cost/pot lift (bait, pot maintenance, etc.) - based on survey data & SA study

$ cost/kg. catch (deck labour) - based on survey data & SA study

Total Costs =

```
(cost/kg. of catch* annual catch) +
(cost/pot lift* Number of pot lifts) +
(cost/trip* Required boat nos.*No. days fished) +
(cost/pot* Required pot nos.) +
(cost/boat* Required boat nos.)
```

Beach price

```
(based on estimated "worth/kg" -by P. Monaghan)
```

Total Revenue

```
= Sum of (monthly beach price/kg. of catch* monthly catch)
```

Net Return

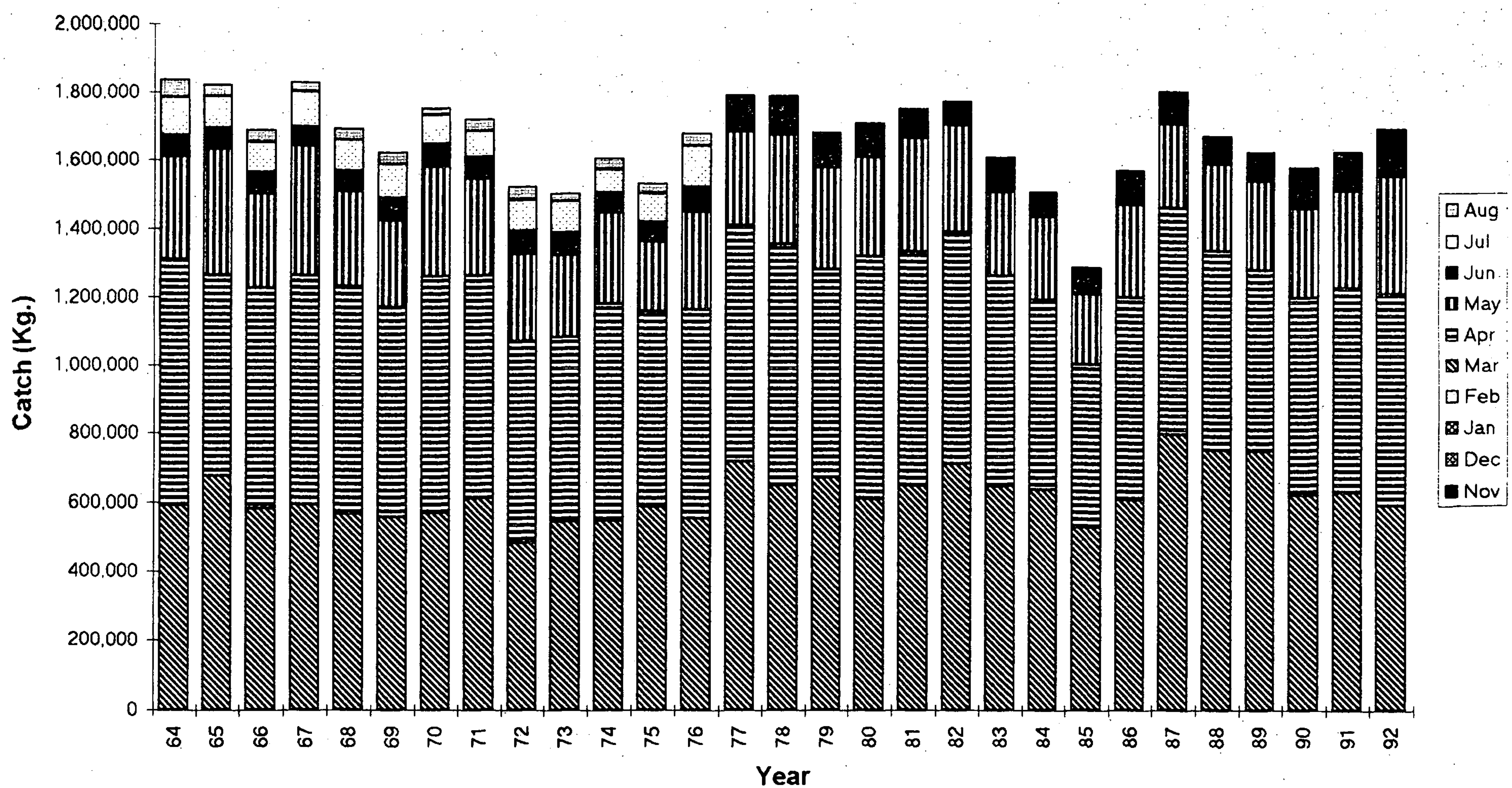
```
= Total Revenue - Total Costs
```

APPENDIX 5:

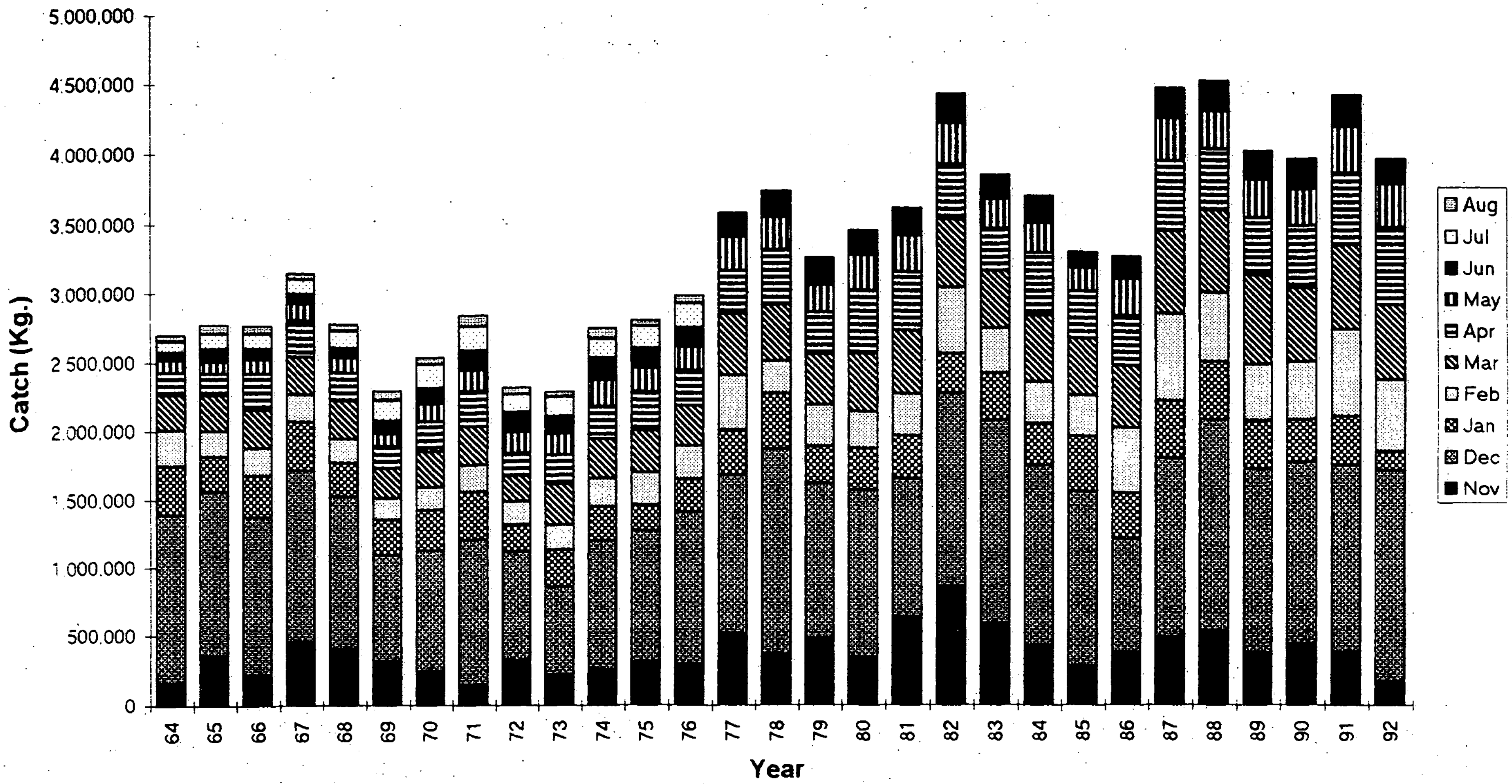
Historical Catch Patterns

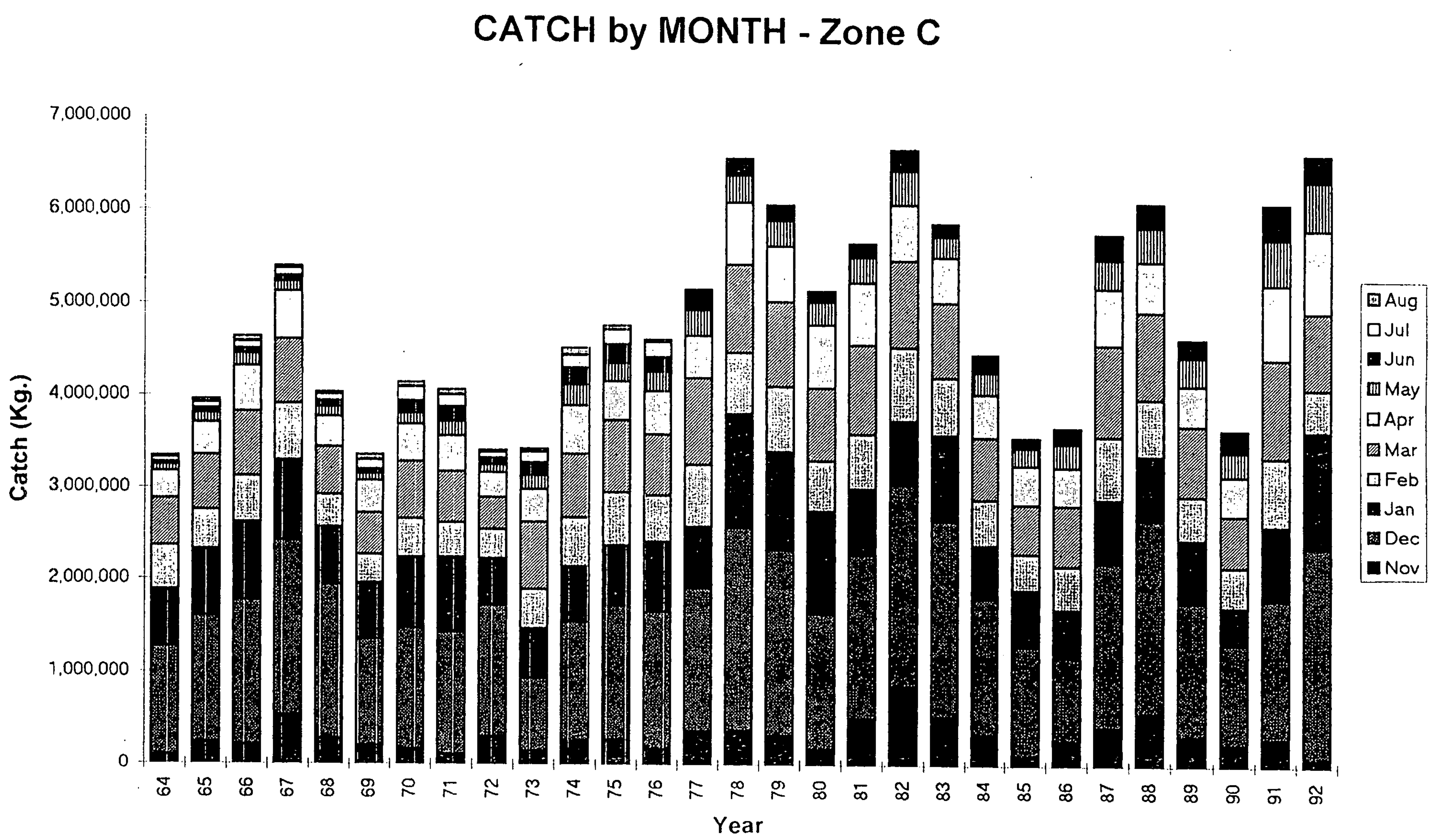
by Zone and Month

CATCH by MONTH - Zone A



CATCH by MONTH - Zone B





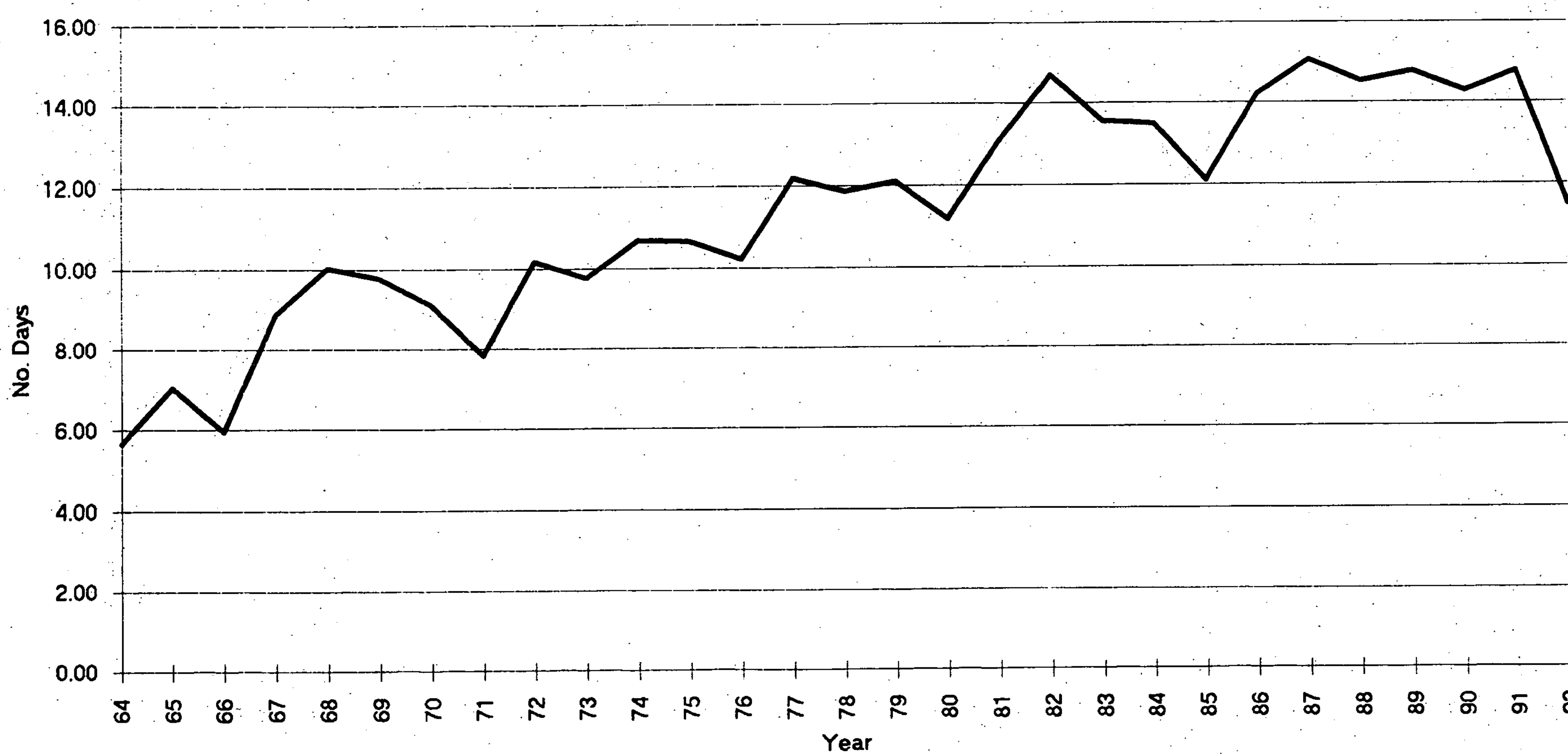
CATCH by MONTH - Zone C
Catch (Kg.)
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
Year
Aug
Jul
Jun
May
Apr
Mar
Feb
Jan
Dec
Nov

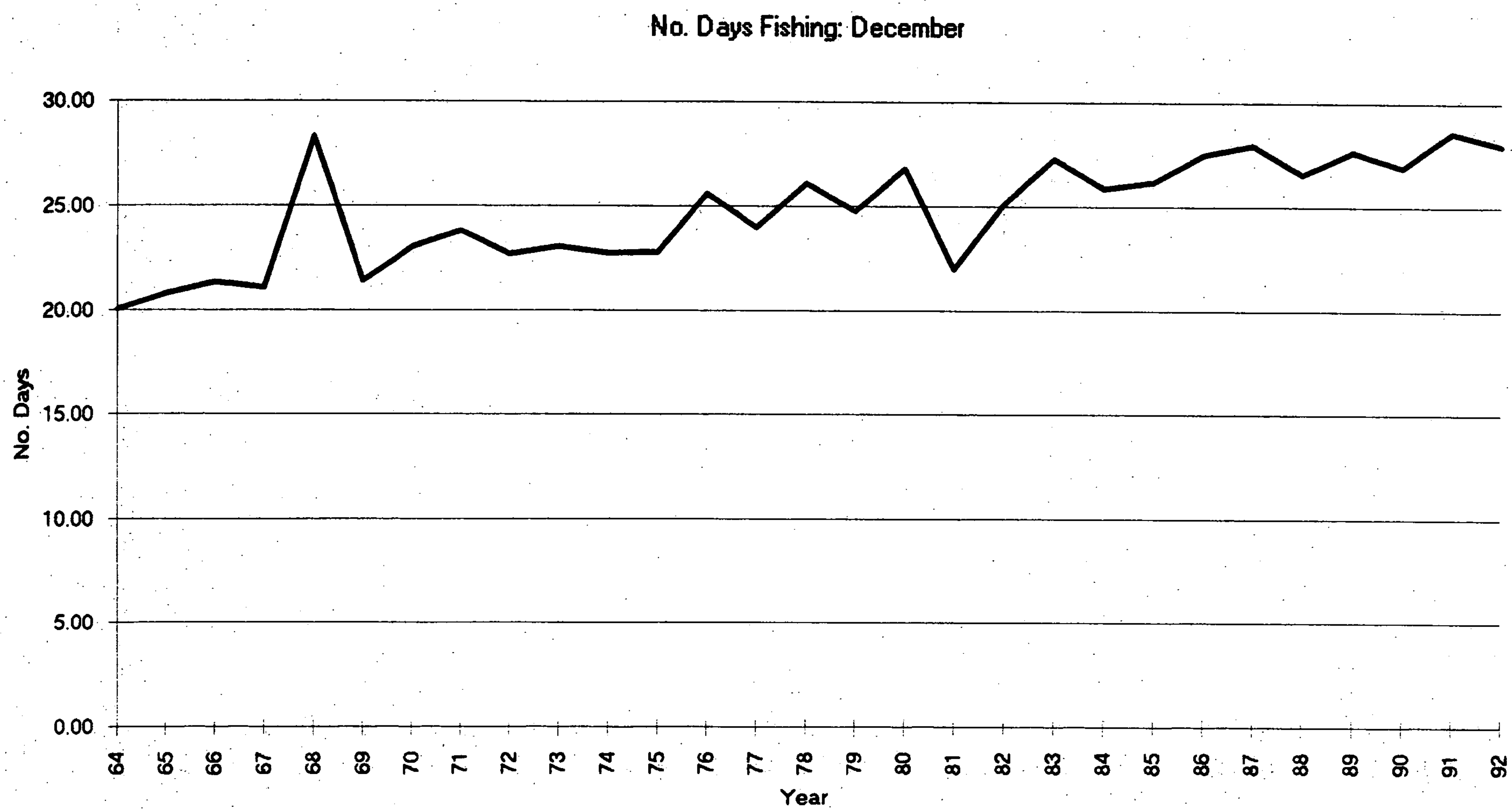
APPENDIX 6:

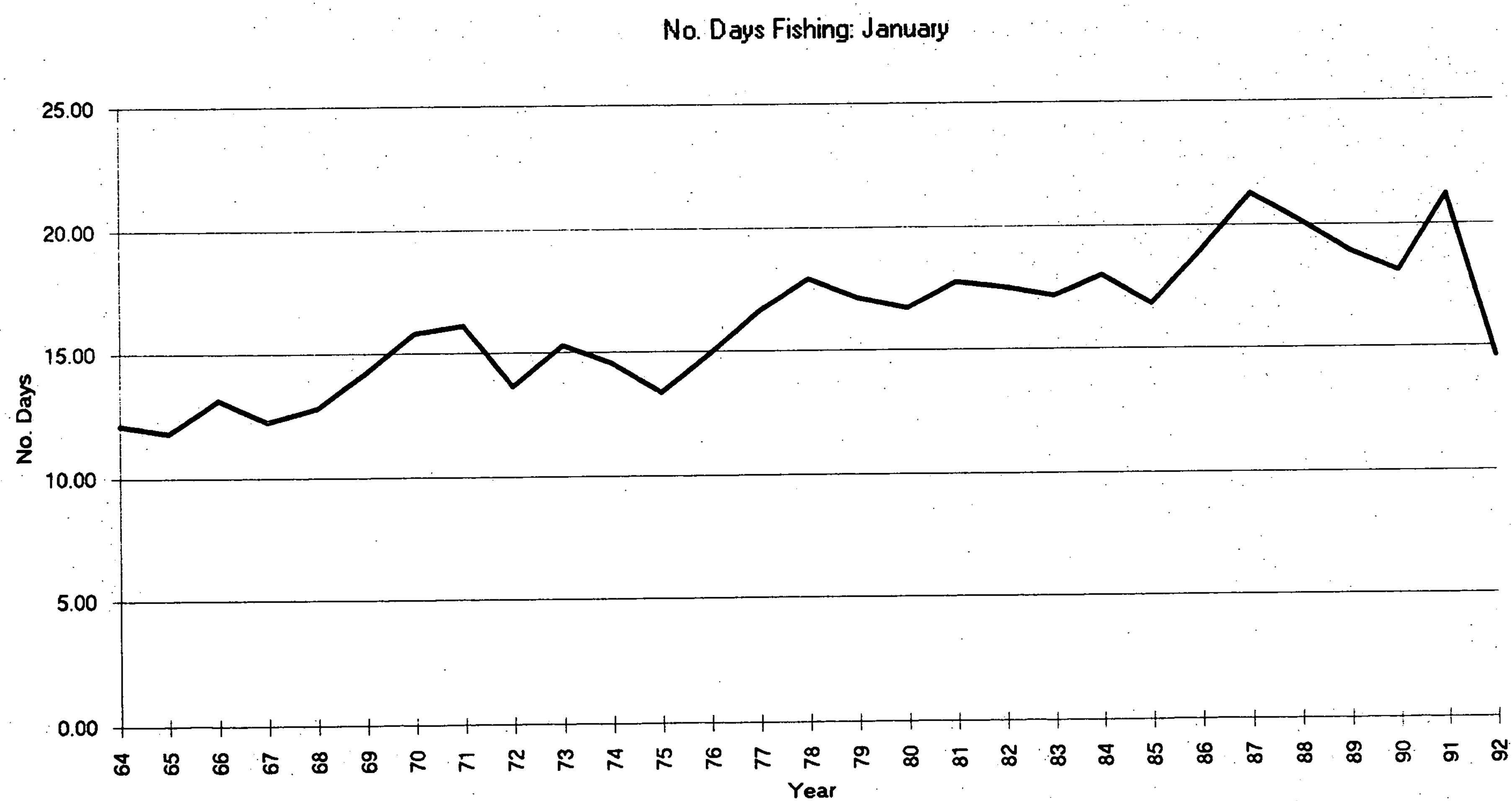
Historical Fishing Patterns

by Selected Months

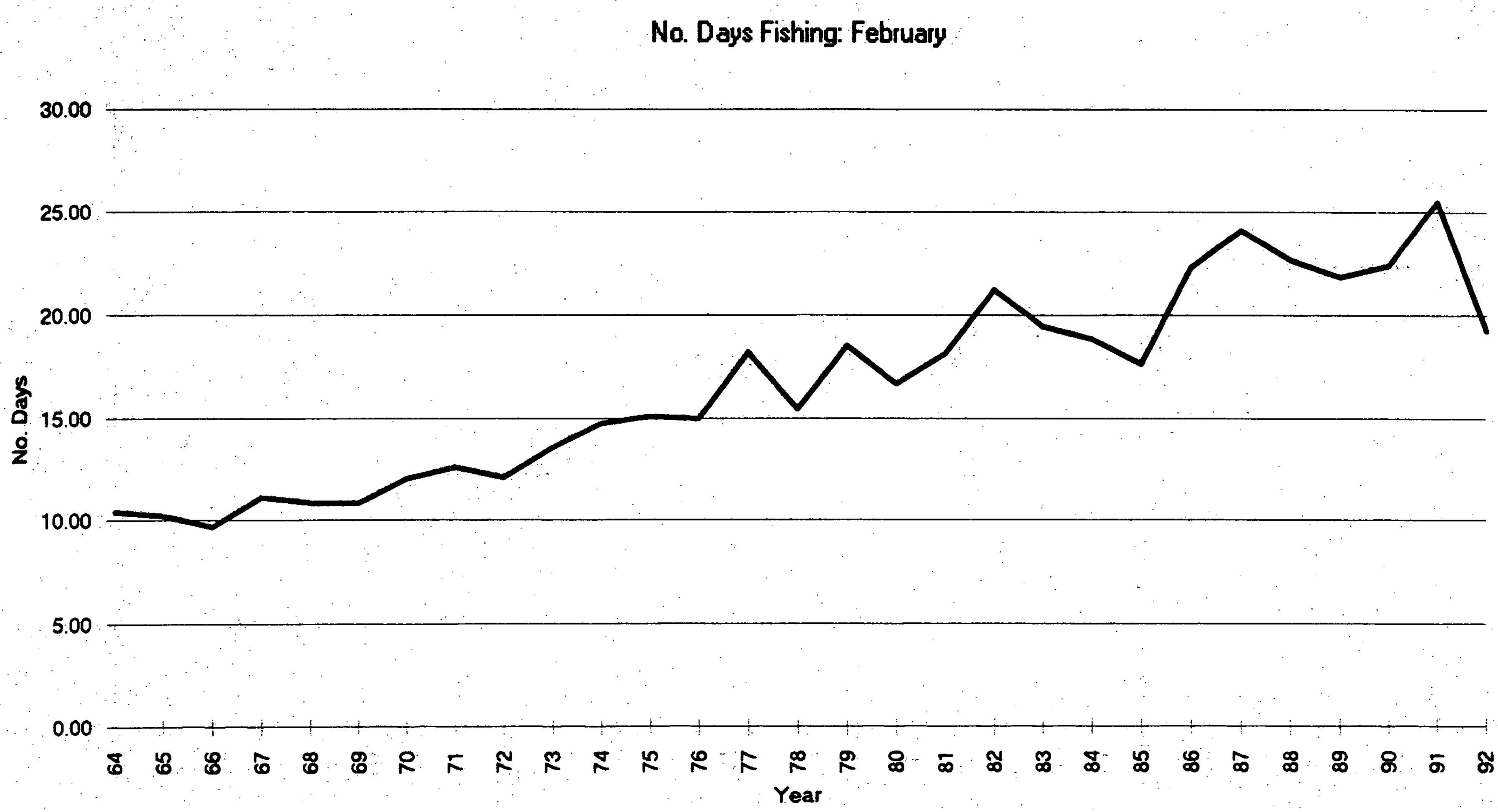
No. Days Fishing: November



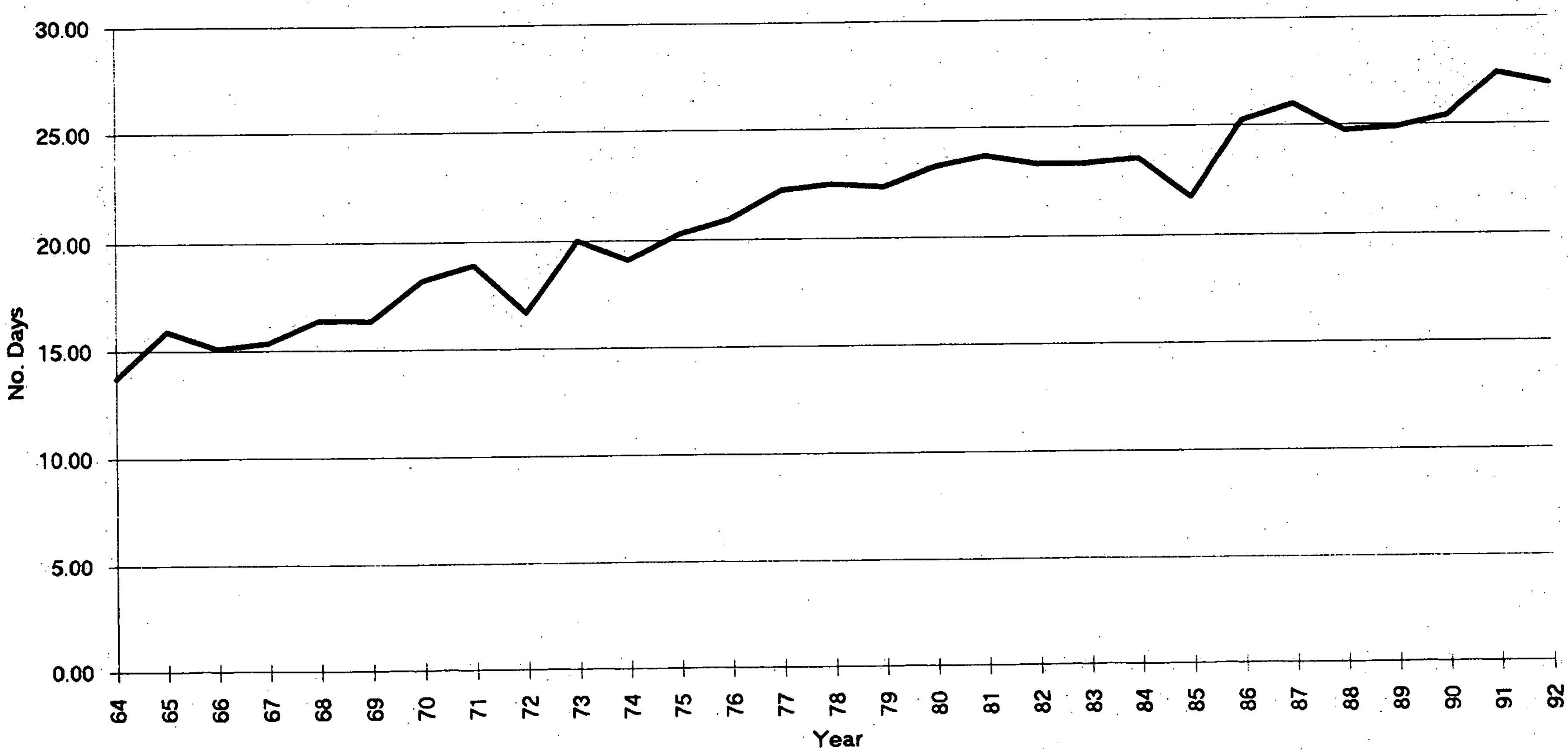

No. Days Fishing: December
No. Days
30.00
25.00
20.00
15.00
10.00
5.00
0.00
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
Year

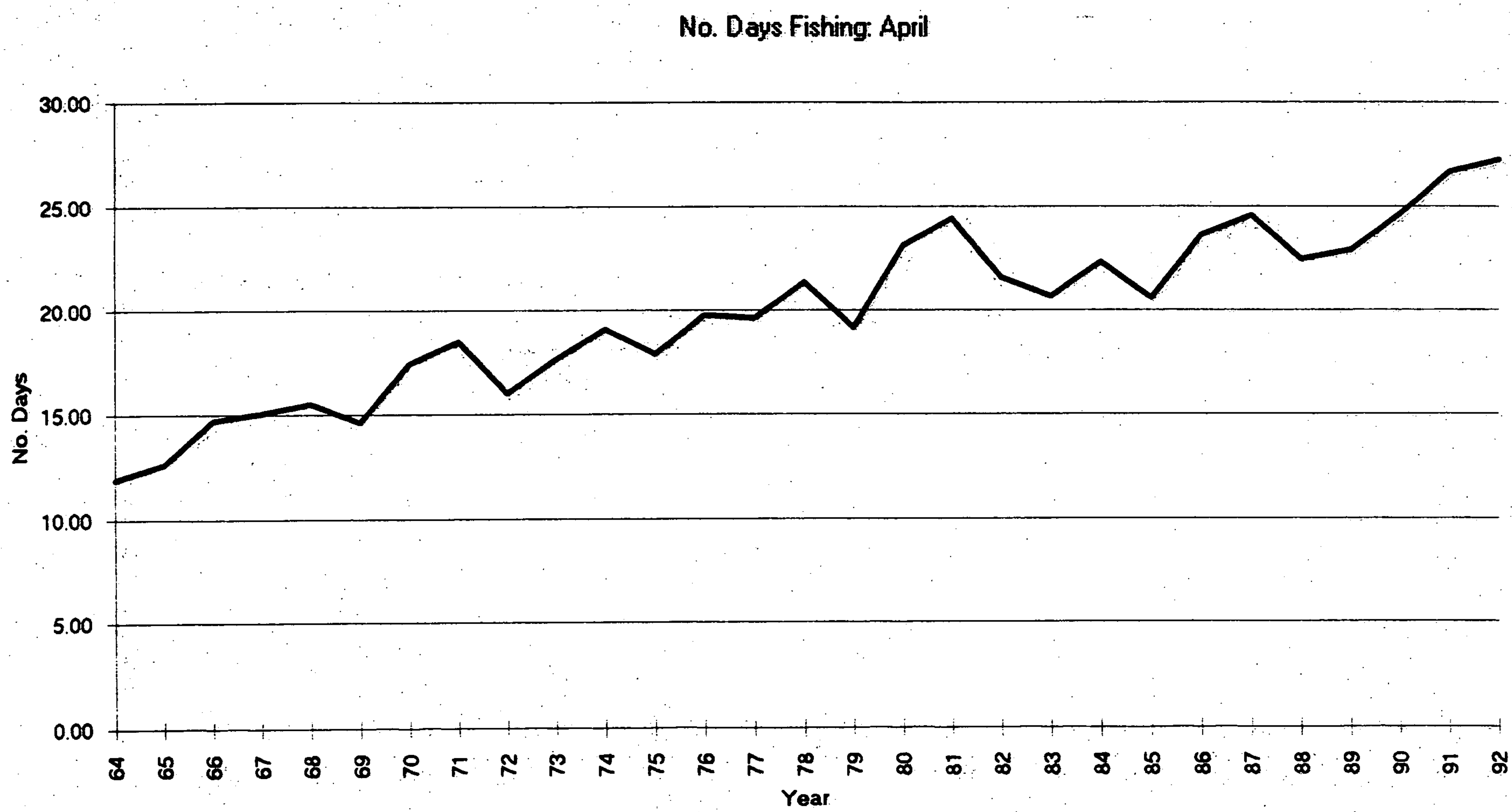


No. Days Fishing: January
No. Days
25.00
20.00
15.00
10.00
5.00
0.00
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
Year

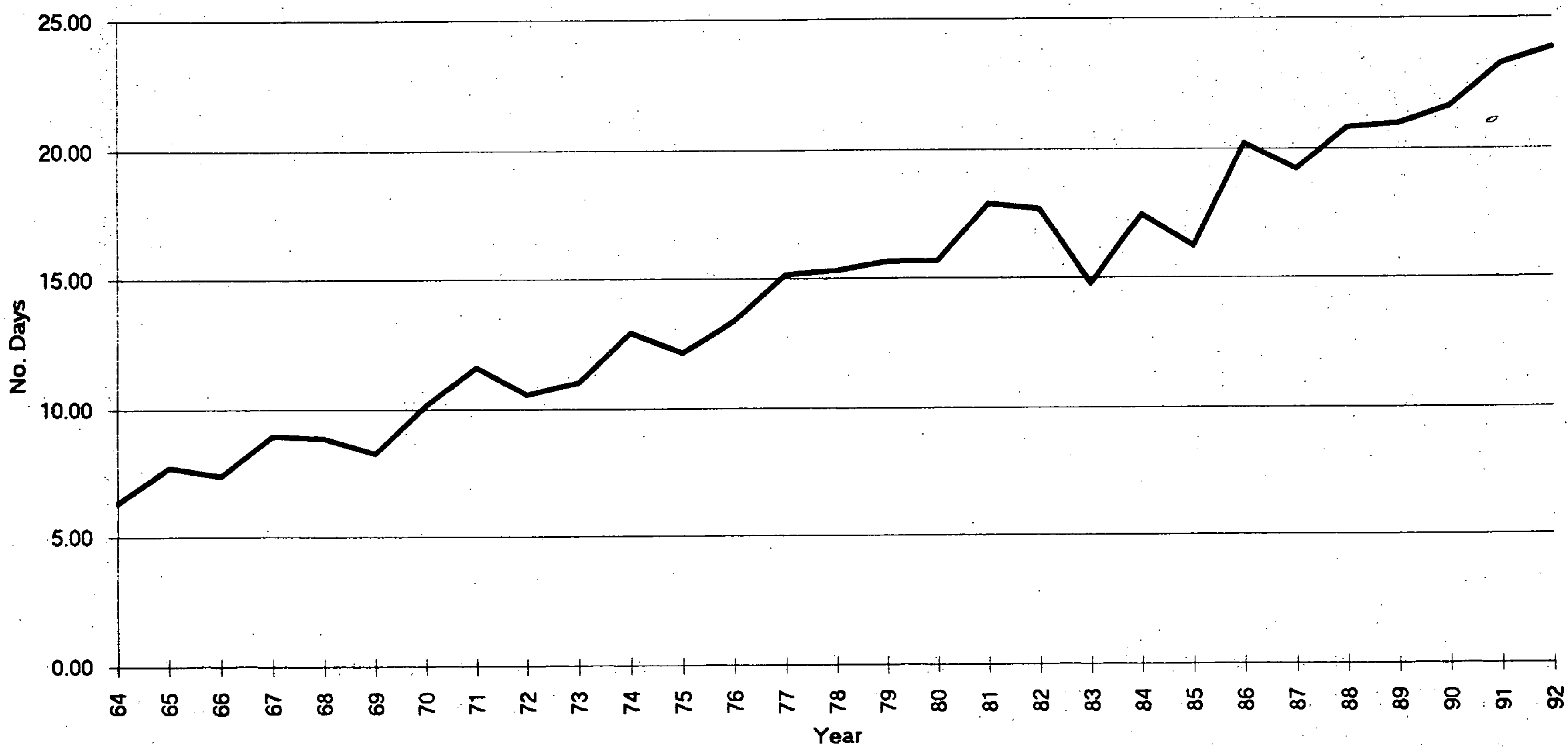

No. Days Fishing: February
No. Days
30.00
25.00
20.00
15.00
10.00
5.00
0.00
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
Year

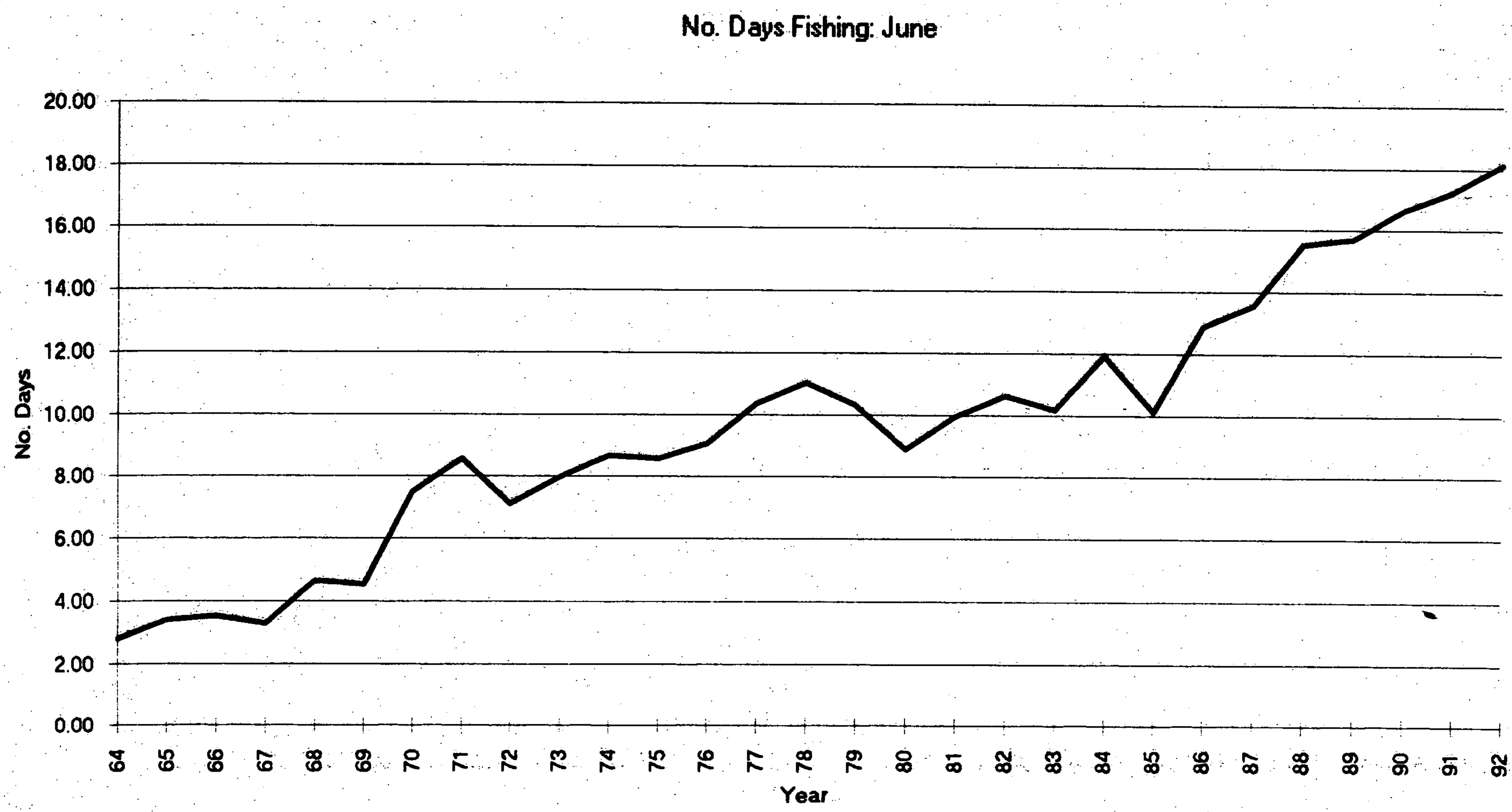
No. Days Fishing: March



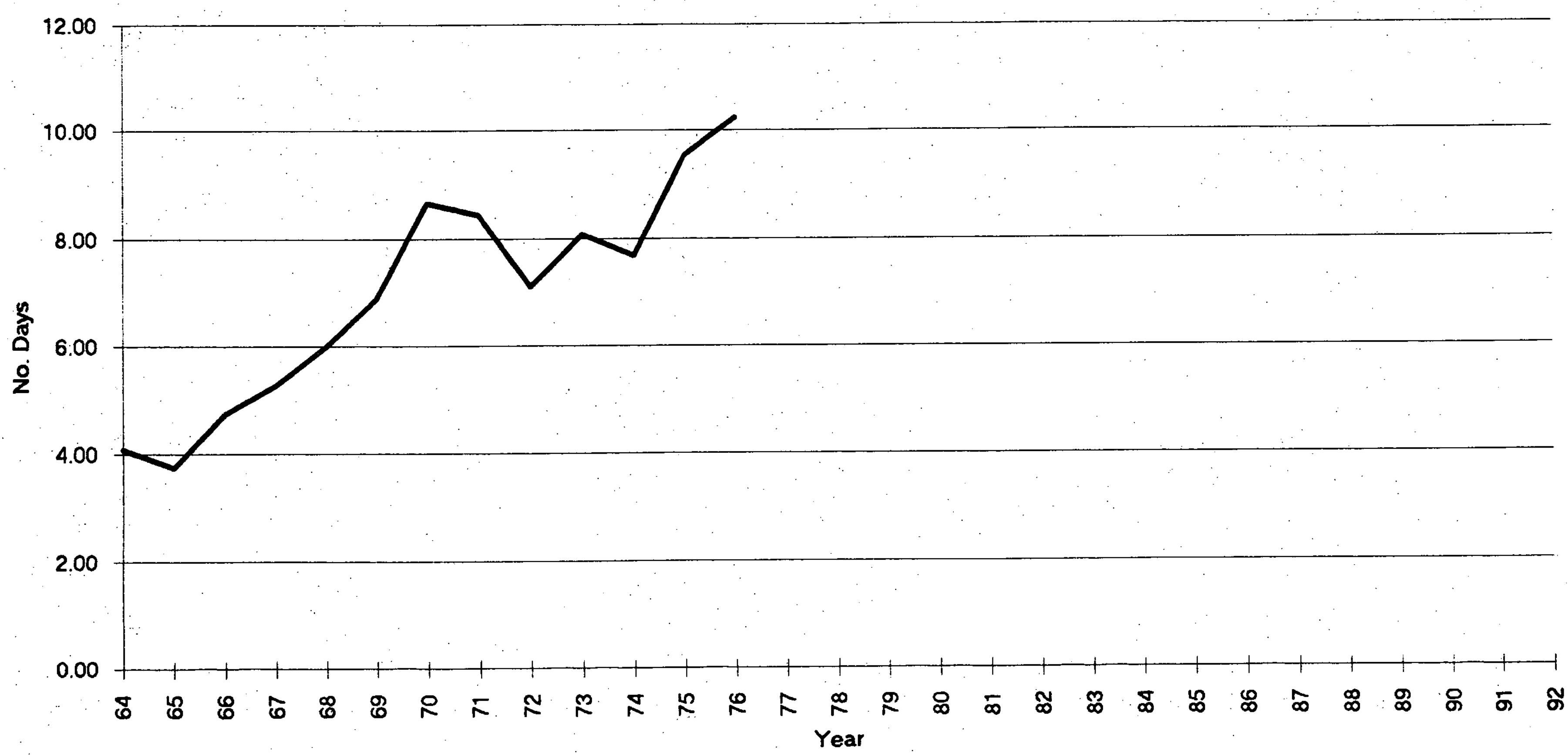

No. Days Fishing: April
No. Days
30.00
25.00
20.00
15.00
10.00
5.00
0.00
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
Year

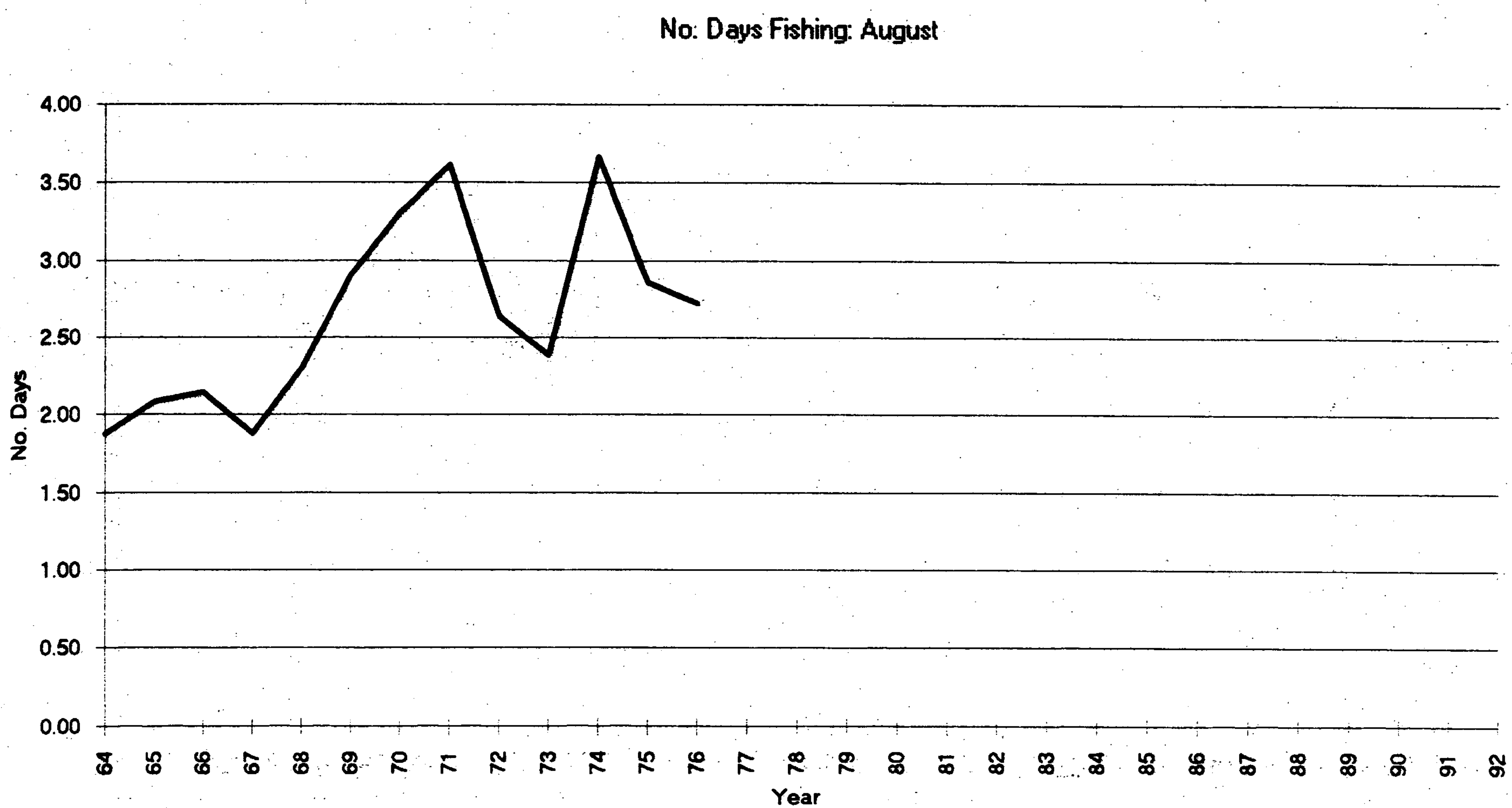
No. Days Fishing: May




No. Days Fishing: June
No. Days
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
Year

No. Days Fishing: July



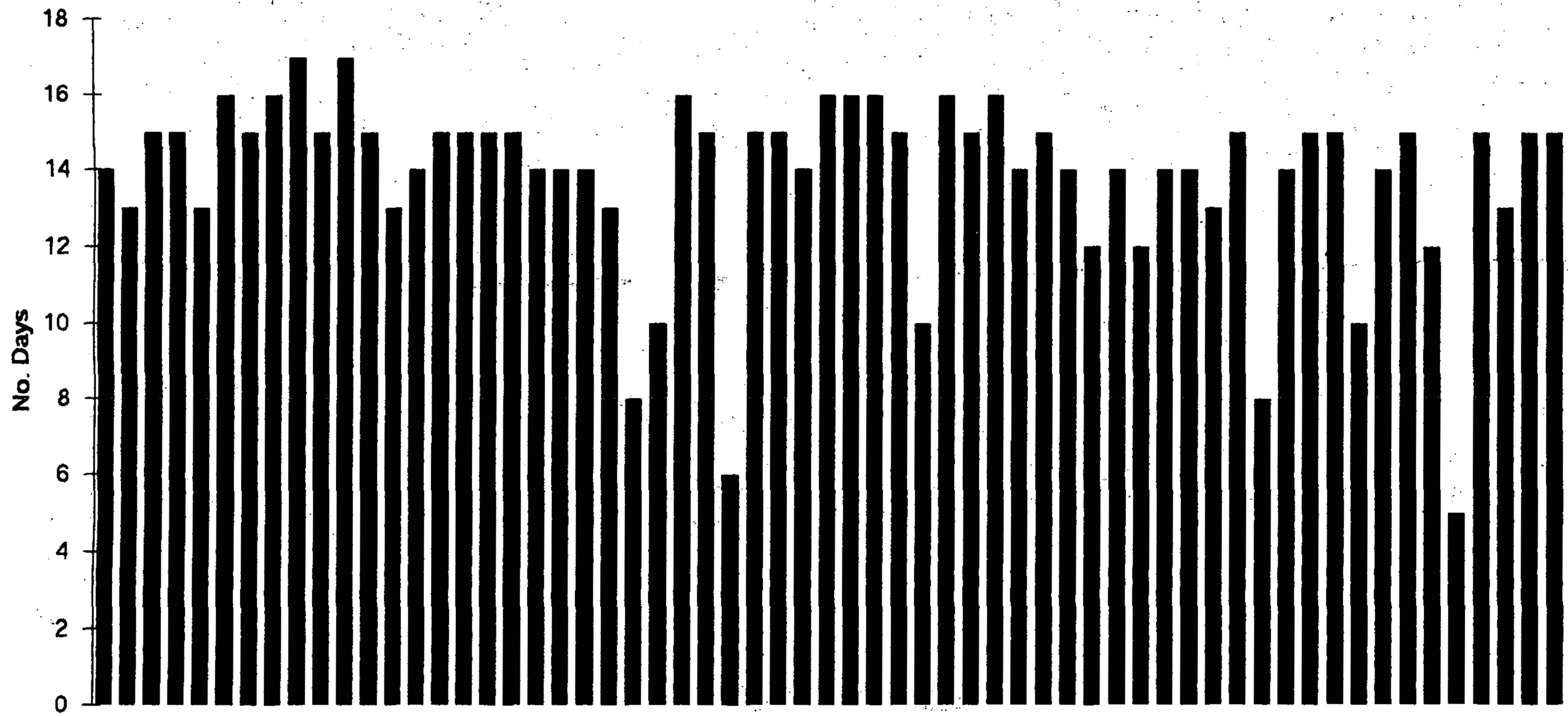

No: Days Fishing: August
No. Days
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92
Year

APPENDIX 7:

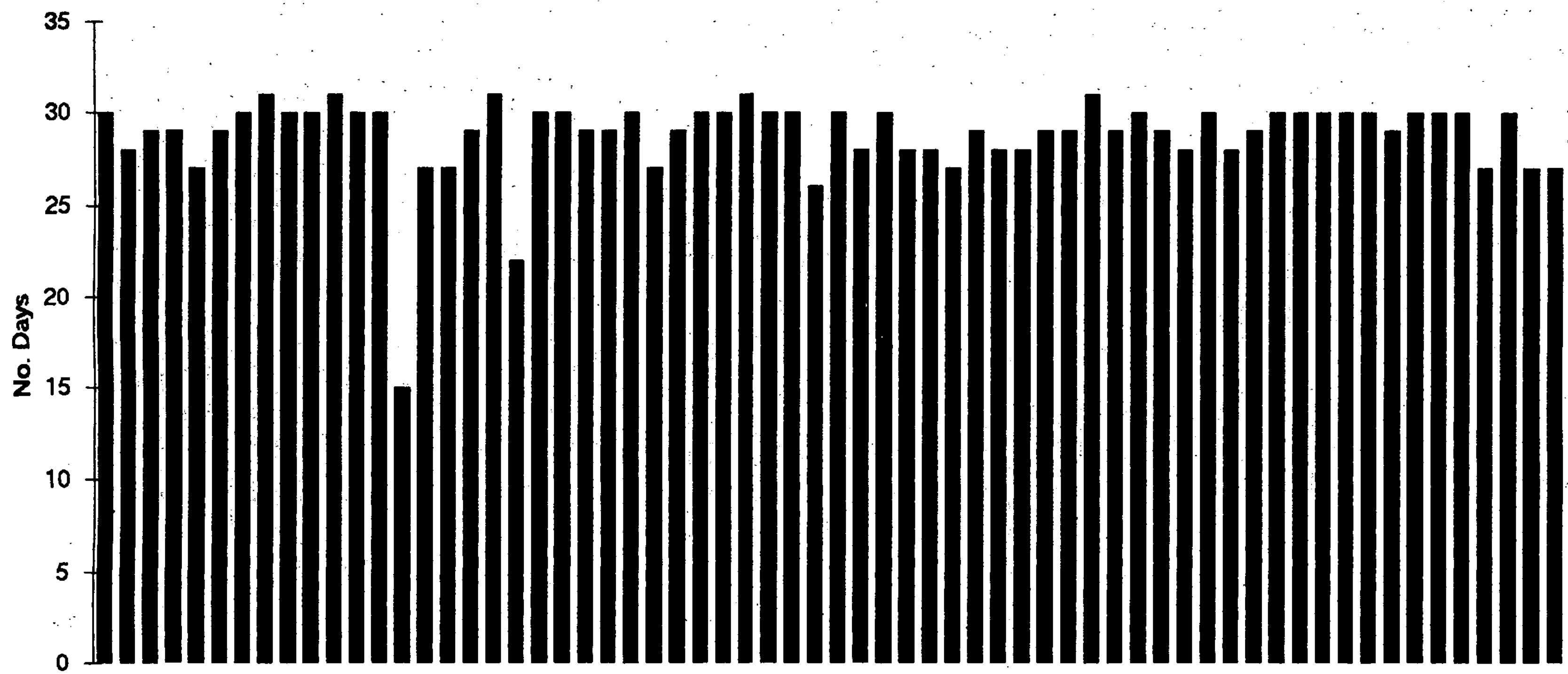
Individual Boat Fishing Patterns

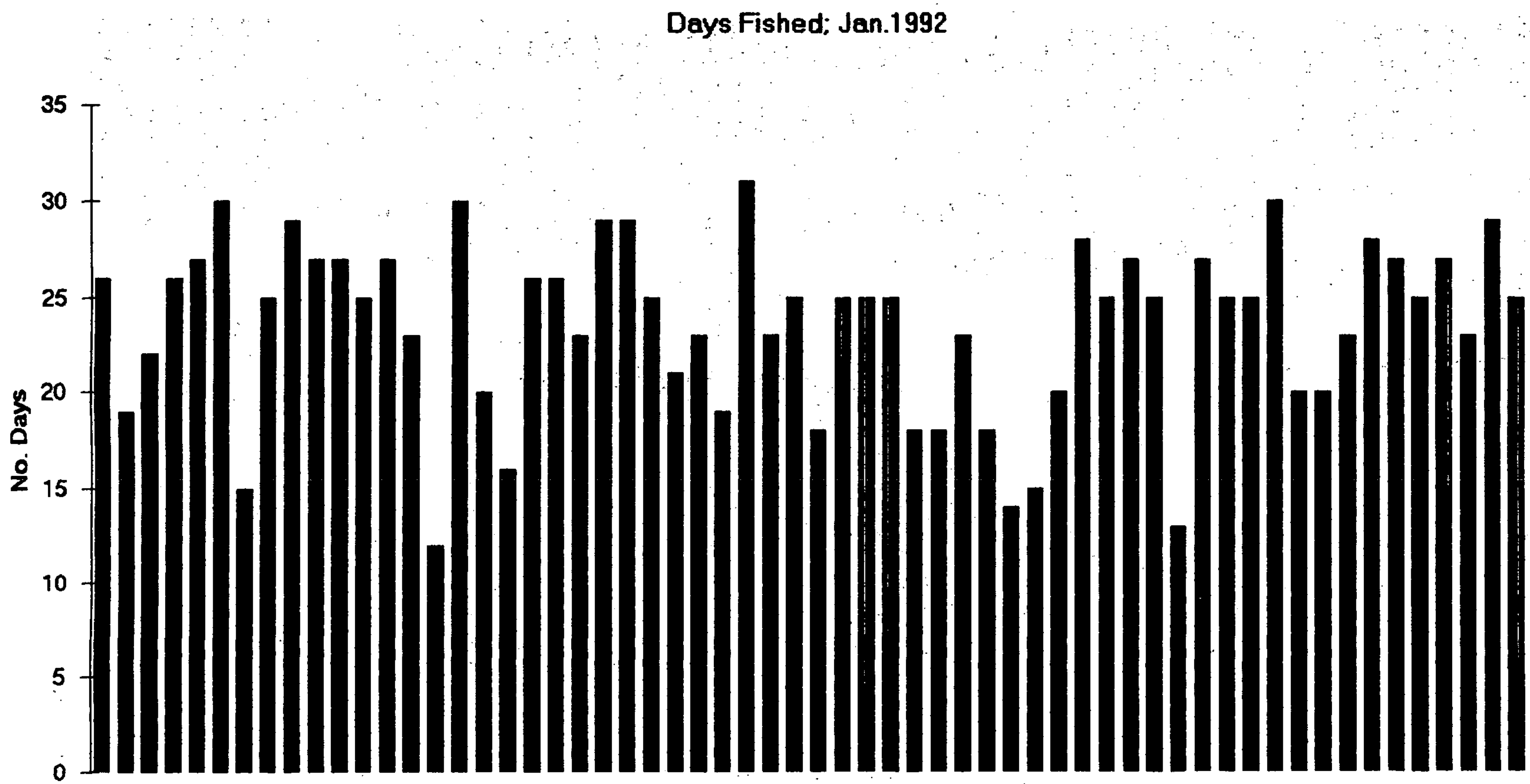
by Selected Months

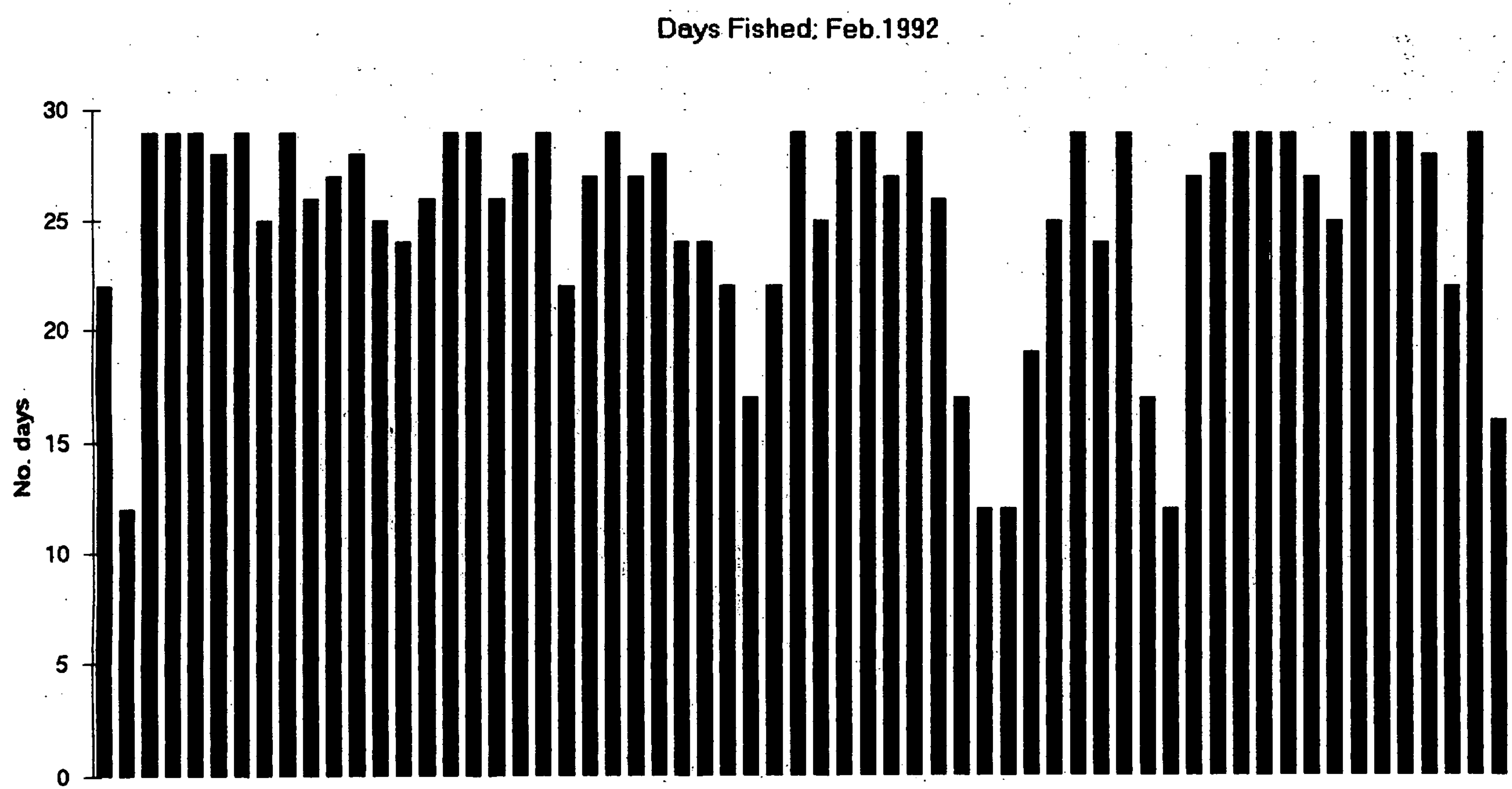
Days Fished; Nov.1991

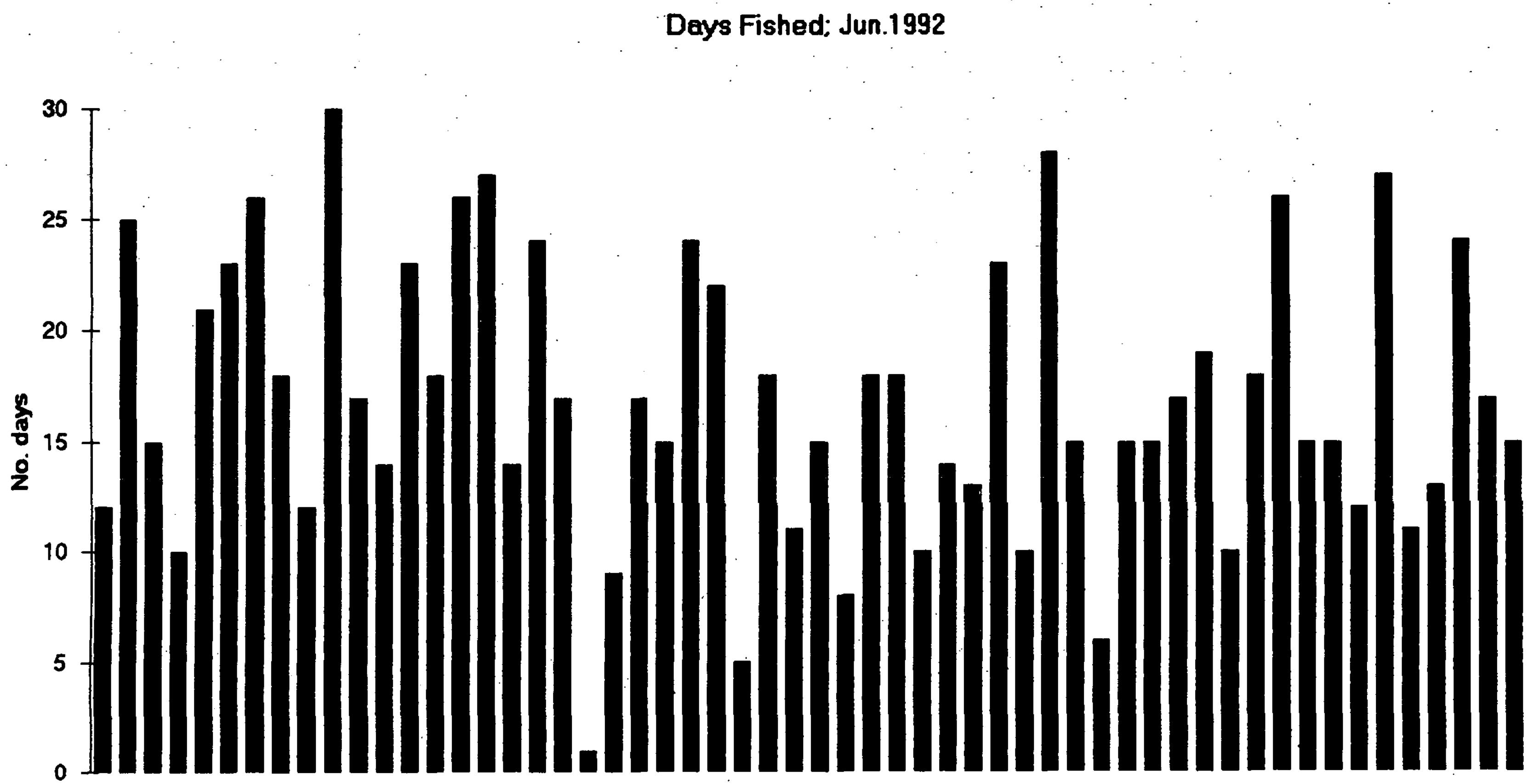


Days Fished; Dec.1991




Days Fished; Jan.1992
No. Days
35
30
25
20
15
10
5
0


Days Fished: Feb.1992
No. days
30
25
20
15
10
5
0


Days Fished; Jun.1992
No. days
30
25
20
15
10
5
0

APPENDIX 8:

Individual Spreadsheets for the Accounting Model

SCEANARIO 0 - Base Case Involving Unsustainable Catch

	YEAR	Nov.	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
% Catch	100.0%	7.57%	27.41%	9.94%	9.22%	18.40%	14.94%	7.91%	4.60%				
TAC	10,796,313	817,441	2,958,997	1,073,505	995,765	1,986,984	1,612,919	853,892	496,808				
Revenue($m)	$196.295	$16.676	$47.758	$17.745	$18.173	$37.614	$30.533	$17.180	$10.617				
CPUE(kg/pl)	0.94	0.80	1.47	0.86	0.68	1.10	0.97	0.65	0.55				
Pot Lifts	11,434,579	1,024,278	2,018,782	1,243,343	1,464,628	1,801,387	1,663,190	1,310,311	908,661				
Days fished	188	15	29	22	25	27	27	25	18				
Pot nos.	69,613	68,285	69,613	56,516	58,585	66,718	61,600	52,412	50,481				
Pots/boat	104												
Boat nos.	669												
pot costs ($m)	$10.094												
boat costs ($m)	$76.976												
trip costs ($m)	$18.247												
potlift costs ($m	$24.013												
catch costs($m)	$34.548												
Total costs($m)	$163.877												
Surplus($m)	$32.418	Ref =	$32.418	% incr =	0.00%								
$rent/pot	$466	Ref =	$466	% incr =	0.00%								

SCENARIO 1 - Reduce Catch by reducing Pot Nos. AND Boat Nos.

	YEAR	Nov.	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
% Catch	100.0%	7.57%	27.41%	9.94%	9.22%	18.40%	14.94%	7.91%	4.60%				
TAC	9,000,000	681,434	2,466,673	894,893	830,088	1,656,386	1,344,558	711,820	414,148				
Revenue($m)	$163.635	$13.901	$39.812	$14.793	$15.149	$31.355	$25.452	$14.322	$8.850				
CPUE(kg/pl)	0.94	0.80	1.47	0.86	0.68	1.10	0.97	0.65	0.55				
Pot Lifts	9,532,070	853,856	1,682,893	1,036,473	1,220,940	1,501,668	1,386,465	1,092,298	757,476				
Days fished	188	15	29	22	25	27	27	25	18				
Pot nos.	58,031	56,924	58,031	47,112	48,838	55,617	51,351	43,692	42,082				
Pots/boat	104												
Boat nos.	558												
pot costs ($m)	$8.414												
boat costs ($m)	$64.169												
trip costs ($m)	$15.211												
potlift costs ($m	$20.017												
catch costs($m)	$28.800												
Total costs($m)	$136.611												
Surplus($m)	$27.024	Ref.=	$32.418	% incr.=	-16.64%								
$rent/pot	$466	Ref.=	$466	% incr.=	0.00%								

SCENARIO 2 - Reduce Catch by Reducing Pot Nos. ONLY (Boat Nos. Constant)

	YEAR	Nov.	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov.
% Catch	100.0%	7.57%	27.41%	9.94%	9.22%	18.40%	14.94%	7.91%	4.60%					
TAC	9,000,000	681,434	2,466,673	894,893	830,088	1,656,386	1,344,558	711,820	414,148					
Revenue($m)	$163.635	$13.901	$39.812	$14.793	$15.149	$31.355	$25.452	$14.322	$8.850					
CPUE(kg/pl)	0.94	0.80	1.47	0.86	0.68	1.10	0.97	0.65	0.55					
Pot Lifts	9,532,070	853,856	1,682,893	1,036,473	1,220,940	1,501,668	1,386,465	1,092,298	757,476					
Days fished	188	15	29	22	25	27	27	25	18					
Pot nos.	58,031	56,924	58,031	47,112	48,838	55,617	51,351	43,692	42,082					
Pots/boat	87													
Boat nos.	667													
pot costs ($m)	$8.414													
boat costs ($m)	$76.707													
trip costs ($m)	$18.183													
potlift costs ($m	$20.017													
catch costs($m)	$28.800													
Total costs($m)	$152.122													
Surplus($m)	$11.513	Ref =	$32.418	% incr =	-64.49%									
$rent/pot	$198	Ref =	$466	% incr =	-57.40%									

SCENARIO 3 - Reduce Catch by reducing Pot Nos. while Increasing Pots/Boat

	YEAR	Nov.	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
% Catch	100.0%	7.57%	27.41%	9.94%	9.22%	18.40%	14.94%	7.91%	4.60%					
TAC	9,000,000	681,434	2,466,673	894,893	830,088	1,656,386	1,344,558	711,820	414,148					
Revenue($m)	$163.635	$13.901	$39.812	$14.793	$15.149	$31.355	$25.452	$14.322	$8.850					
CPUE(kg/pl)	0.94	0.80	1.47	0.86	0.68	1.10	0.97	0.65	0.55					
Pot Lifts	9,532,070	853,856	1,682,893	1,036,473	1,220,940	1,501,668	1,386,465	1,092,298	757,476					
Days fished	188	15	29	22	25	27	27	25	18					
Pot nos.	58,031	56,924	58,031	47,112	48,838	55,617	51,351	43,692	42,082					
Pots/boat	144													
Boat nos.	403													
pot costs ($m)	$8.414													
boat costs ($m)	$46.344													
trip costs ($m)	$10.986													
potlift costs ($m	$20.017													
catch costs($m)	$28.800													
Total costs($m)	$114.561													
Surplus($m)	$49.074	Ref =	$32.418	% incr =	51.38%									
$rent/pot	$846	Ref =	$466	% incr =	81.59%									

SCENARIO 4 - Reduced Catch and Extended Season - reduced Pot Nos. AND Boat Nos.

	YEAR	Nov.	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
% Catch	100.0%	6.00%	21.85%	9.70%	8.70%	15.00%	13.45%	8.00%	5.00%	0.048	0.04	0.035
TAC	9,000,000	540,000	1,966,500	873,000	783,000	1,350,000	1,210,500	720,000	450,000	432,000	360,000	315,000
Revenue($m)	$172.457	$11.345	$33.765	$14.640	$14.540	$25.650	$22.963	$14.630	$9.770	$9.737	$8.114	$7.302
CPUE(kg/pl)	0.86	0.80	1.47	0.86	0.68	1.10	0.97	0.65	0.55	0.63	0.65	0.50
Pot Lifts	10,448,597	676,636	1,341,648	1,011,116	1,151,680	1,223,901	1,248,228	1,104,851	823,049	686,466	551,020	630,000
Days fished	230	15	29	22	25	27	27	25	18	15	12	15
Pot nos.	46,264	45,109	46,264	45,960	46,067	45,330	46,231	44,194	45,725	45,764	45,918	42,000
Pots/boat	104											
Boat nos.	445											
pot costs ($m)	$6.708											
boat costs ($m)	$51.157											
trip costs ($m)	$14.836											
potlift costs ($m	$21.942											
catch costs($m)	$28.800											
Total costs($m)	$123.443											
Surplus($m)	$49.014	Ref =	$32.418	% Incr =	51.20%							
$rent/pot	$1,059	Ref =	$466	% Incr =	127.51%							

SCENARIO 5 - Reduced Catch and Extended Season - reduced Pot Nos. and Constant Boat Nos.

	YEAR	Nov.	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
% Catch	100.0%	6.00%	21.85%	9.70%	8.70%	15.00%	13.45%	8.00%	5.00%	0.048	0.04	0.035
TAC	9,000,000	540,000	1,966,500	873,000	783,000	1,350,000	1,210,500	720,000	450,000	432,000	360,000	315,000
Revenue($m)	$172.457	$11.345	$33.765	$14.640	$14.540	$25.650	$22.963	$14.630	$9.770	$9.737	$8.114	$7.302
CPUE(kg/pl)	0.86	0.80	1.47	0.86	0.68	1.10	0.97	0.65	0.55	0.63	0.65	0.50
Pot Lifts	10,448,597	676,636	1,341,648	1,011,116	1,151,680	1,223,901	1,248,228	1,104,851	823,049	686,466	551,020	630,000
Days fished	230	15	29	22	25	27	27	25	18	15	12	15
Pot nos.	46,264	45,109	46,264	45,960	46,067	45,330	46,231	44,194	45,725	45,764	45,918	42,000
Pots/boat	69											
Boat nos.	669											
pot costs ($m)	$6.708											
boat costs ($m)	$76.883											
trip costs ($m)	$22.296											
potlift costs ($m	$21.942											
catch costs($m)	$28.800											
Total costs($m)	$156.630											
Surplus($m)	$15.827	Ref=	$32.418	% incr =	-51.18%							
$rent/pot	$342	Ref=	$466	% incr =	-26.54%							

SCENARIO 6 - Reduced Catch and Extended Season - reduced Pot Nos. and Increased Pots/Boat

	YEAR	Nov.	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
% Catch	100.0%	6.00%	21.85%	9.70%	8.70%	15.00%	13.45%	8.00%	5.00%	0.048	0.04	0.035
TAC	9,000,000	540,000	1,966,500	873,000	783,000	1,350,000	1,210,500	720,000	450,000	432,000	360,000	315,000
Revenue($m)	$172.457	$11.345	$33.765	$14.640	$14.540	$25.650	$22.963	$14.630	$9.770	$9.737	$8.114	$7.302
CPUE(kg/pl)	0.86	0.80	1.47	0.86	0.68	1.10	0.97	0.65	0.55	0.63	0.65	0.50
Pot Lifts	10,448,597	676,636	1,341,648	1,011,116	1,151,680	1,223,901	1,248,228	1,104,851	823,049	686,466	551,020	630,000
Days fished	230	15	29	22	25	27	27	25	18	15	12	15
Pot nos.	46,264	45,109	46,264	45,960	46,067	45,330	46,231	44,194	45,725	45,764	45,918	42,000
Pots/boat	144											
Boat nos.	321											
pot costs ($m)	$6.708											
boat costs ($m)	$36.947											
trip costs ($m)	$10.715											
potlift costs ($m	$21.942											
catch costs($m)	$28.800											
Total costs($m)	$105.112											
Surplus($m)	$67.346	Ref =	$32.418	% Incr =	107.74%							
$rent/pot	$1.456	Ref =	$466	% Incr =	212.59%							

APPENDIX 9:

Individual Scenario Results for the Programming Model

Microsoft Excel 5.0 Answer Report
Worksheet: [WRLITQ.XLS]WRLITQ6 (1)

Case 1: Variable Boat & Pot Nos. -Season ends June 30
LLS management - TAE set to ensure sustainable catch & breeding stock

Target Cell (Max)

Cell	Name	Original Value	Final Value
C5	Profit Total	34,282,366	28,578,394

Adjustable Cells

Cell	Name	Original Value	Final Value
D4	#'s Catch	10,795,339	8,999,188
E4	#'s Boats	669	558
F4	#'s Pots	69,576	58,000
G4	#'s Nov Pot Lifts	1,020,278	850,522
H4	#'s Dec Pot Lifts	2,018,782	1,682,893
I4	#'s Jan Pot Lifts	1,243,343	1,036,473
J4	#'s Feb Pot Lifts	1,464,628	1,220,940
K4	#'s Mar Pot Lifts	1,801,387	1,501,668
L4	#'s Apr Pot Lifts	1,663,190	1,386,465
M4	#'s May Pot Lifts	1,310,311	1,092,298
N4	#'s Jun Pot Lifts	908,661	757,476
O4	#'s Jul Pot Lifts	0	0
P4	#'s Aug Pot Lifts	0	0
Q4	#'s Sep Pot Lifts	0	0
R4	#'s Oct Pot Lifts	0	0
S4	#'s Nov/Dec	20850533.74	17781072.35
T4	#'s Dec/Jan	15193842.75	13057959.21
U4	#'s Jan/Feb	13009709.79	11229776.95
V4	#'s Feb/Mar	10997060.48	9544688.088
W4	#'s Mar/Apr	7407667.372	6545336.2
X4	#'s Apr/May	4.5E+06	4.1E+06
Y4	#'s May/Jun	3.0E+06	2.8E+06
Z4	#'s Jun/Breed	2.1E+06	2.1E+06

Microsoft Excel 5.0 Answer Report
Worksheet: [WRLITQ.XLS]WRLITQ6 (4)

Case 2: Variable Pot Nos. but Constant Boat Nos. - Season ends June 30
LLS management - TAE set to ensure sustainable catch & breeding stock

Target Cell (Max)

Cell	Name	Original Value	Final Value
C5	Profit Total	34,282,366	15,777,789

Adjustable Cells

Cell	Name	Original Value	Final Value
D4	#'s Catch	10,795,339	8,999,188
E4	#'s Boats	669	669
F4	#'s Pots	69,576	58,000
G4	#'s Nov Pot Lifts	1,020,278	850,522
H4	#'s Dec Pot Lifts	2,018,782	1,682,893
I4	#'s Jan Pot Lifts	1,243,343	1,036,473
J4	#'s Feb Pot Lifts	1,464,628	1,220,940
K4	#'s Mar Pot Lifts	1,801,387	1,501,668
L4	#'s Apr Pot Lifts	1,663,190	1,386,465
M4	#'s May Pot Lifts	1,310,311	1,092,298
N4	#'s Jun Pot Lifts	908,661	757,476
O4	#'s Jul Pot Lifts	0	0
P4	#'s Aug Pot Lifts	0	0
Q4	#'s Sep Pot Lifts	0	0
R4	#'s Oct Pot Lifts	0	0
S4	#'s Nov/Dec	20850533.74	17781072.35
T4	#'s Dec/Jan	15193842.75	13057959.21
U4	#'s Jan/Feb	13009709.79	11229776.95
V4	#'s Feb/Mar	10997060.48	9544688.088
W4	#'s Mar/Apr	7407667.372	6545336.2
X4	#'s Apr/May	4.5E+06	4.1E+06
Y4	#'s May/Jun	3.0E+06	2.8E+06
Z4	#'s Jun/Breed	2.1E+06	2.1E+06

Microsoft Excel 5.0 Answer Report
Worksheet: [WRLITQ.XLS]WRLITQ6 (1)

Case 3: Constant Boat & Pot Nos. - Variable Closed Season
Competitive TAC set to ensure sustainable catch & breeding stock

Target Cell (Max)

Cell	Name	Original Value	Final Value
C5	Profit Total	34,282,366	13,233,586

Adjustable Cells

Cell	Name	Original Value	Final Value
D4	#'s Catch	10,795,339	8,996,809
E4	#'s Boats	669	669
F4	#'s Pots	69,576	69,576
G4	#'s Nov Pot Lifts	1,020,278	1,020,278
H4	#'s Dec Pot Lifts	2,018,782	2,018,782
I4	#'s Jan Pot Lifts	1,243,343	1,243,343
J4	#'s Feb Pot Lifts	1,464,628	1,464,628
K4	#'s Mar Pot Lifts	1,801,387	1,801,387
L4	#'s Apr Pot Lifts	1,663,190	1,202,299
M4	#'s May Pot Lifts	1,310,311	0
N4	#'s Jun Pot Lifts	908,661	0
O4	#'s Jul Pot Lifts	0	0
P4	#'s Aug Pot Lifts	0	0
Q4	#'s Sep Pot Lifts	0	0
R4	#'s Oct Pot Lifts	0	0
S4	#'s Nov/Dec	20850533.74	17444203.49
T4	#'s Dec/Jan	15193842.75	11852232.78
U4	#'s Jan/Feb	13009709.79	9731590.409
V4	#'s Feb/Mar	10997060.48	7781225.371
W4	#'s Mar/Apr	7407667.372	4252933.129
X4	#'s Apr/May	4.5E+06	2.2E+06
Y4	#'s May/Jun	3.0E+06	2.1E+06
Z4	#'s Jun/Breed	2.1E+06	2.1E+06

Microsoft Excel 5.0 Answer Report
Worksheet: [WRLITQ.XLS]WRLITQ6 (7)

Case 4: Variable Boat & Pot Nos. -Season ends June 30
ITQ's & TAC set to ensure sustainable catch & breeding stock

Target Cell (Max)

Cell	Name	Original Value	Final Value
C5	Profit Total	34,282,366	38,631,710

Adjustable Cells

Cell	Name	Original Value	Final Value
D4	#'s Catch	10,795,339	9,000,000
E4	#'s Boats	669	477
F4	#'s Pots	69,576	49,600
G4	#'s Nov Pot Lifts	1,020,278	744,007
H4	#'s Dec Pot Lifts	2,018,782	1,488,013
I4	#'s Jan Pot Lifts	1,243,343	1,289,611
J4	#'s Feb Pot Lifts	1,464,628	1,240,011
K4	#'s Mar Pot Lifts	1,801,387	1,388,812
L4	#'s Apr Pot Lifts	1,663,190	1,339,212
M4	#'s May Pot Lifts	1,310,311	1,289,611
N4	#'s Jun Pot Lifts	908,661	1,091,210
O4	#'s Jul Pot Lifts	0	0
P4	#'s Aug Pot Lifts	0	0
Q4	#'s Sep Pot Lifts	0	0
R4	#'s Oct Pot Lifts	0	0
S4	#'s Nov/Dec	20850533.74	17963528.02
T4	#'s Dec/Jan	15193842.75	13744763.75
U4	#'s Jan/Feb	13009709.79	11517628.12
V4	#'s Feb/Mar	10997060.48	9804081.78
W4	#'s Mar/Apr	7407667.372	7011585.094
X4	#'s Apr/May	4.5E+06	4.7E+06
Y4	#'s May/Jun	3.0E+06	3.1E+06
Z4	#'s Jun/Breed	2.1E+06	2.1E+06

Microsoft Excel 5.0 Answer Report
Worksheet: [WRLITQ.XLS]WRLITQ6 (3)

Case 5: Variable Pot Nos. but Constant Boat Nos. - Season ends June 30
ITQ's & TAC set to ensure sustainable catch & breeding stock

Target Cell (Max)

Cell	Name	Original Value	Final Value
C5	Profit Total	34,282,366	18,862,472

Adjustable Cells

Cell	Name	Original Value	Final Value
D4	#'s Catch	10,795,339	9,000,000
E4	#'s Boats	669	669
F4	#'s Pots	69,576	69,576
G4	#'s Nov Pot Lifts	1,020,278	1,043,640
H4	#'s Dec Pot Lifts	2,018,782	1,484,522
I4	#'s Jan Pot Lifts	1,243,343	0
J4	#'s Feb Pot Lifts	1,464,628	0
K4	#'s Mar Pot Lifts	1,801,387	1,948,128
L4	#'s Apr Pot Lifts	1,663,190	1,878,552
M4	#'s May Pot Lifts	1,310,311	1,808,976
N4	#'s Jun Pot Lifts	908,661	1,530,672
O4	#'s Jul Pot Lifts	0	0
P4	#'s Aug Pot Lifts	0	0
Q4	#'s Sep Pot Lifts	0	0
R4	#'s Oct Pot Lifts	0	0
S4	#'s Nov/Dec	20850533.74	17542944.19
T4	#'s Dec/Jan	15193842.75	13341267.69
U4	#'s Jan/Feb	13009709.79	13087783.6
V4	#'s Feb/Mar	10997060.48	12839115.72
W4	#'s Mar/Apr	7407667.372	8939352.144
X4	#'s Apr/May	4.5E+06	5.7E+06
Y4	#'s May/Jun	3.0E+06	3.5E+06
Z4	#'s Jun/Breed	2.1E+06	2.1E+06

Answer Report 11

Microsoft Excel 5.0 Answer Report
Worksheet: [WRLITQ.XLS]WRLITQ6 (1)

Case 11: Variable Boat & Pot Nos. + more pots/boat -Season ends June 30
LLS management - TAE set to ensure sustainable catch & breeding stock

Target Cell (Max)

Cell	Name	Original Value	Final Value
C5	Profit Total	34,282,366	46,393,504

Adjustable Cells

Cell	Name	Original Value	Final Value
D4	#'s Catch	10,795,339	8,999,188
E4	#'s Boats	669	403
F4	#'s Pots	69,576	58,000
G4	#'s Nov Pot Lifts	1,020,278	850,522
H4	#'s Dec Pot Lifts	2,018,782	1,682,893
I4	#'s Jan Pot Lifts	1,243,343	1,036,473
J4	#'s Feb Pot Lifts	1,464,628	1,220,940
K4	#'s Mar Pot Lifts	1,801,387	1,501,668
L4	#'s Apr Pot Lifts	1,663,190	1,386,465
M4	#'s May Pot Lifts	1,310,311	1,092,298
N4	#'s Jun Pot Lifts	908,661	757,476
O4	#'s Jul Pot Lifts	0	0
P4	#'s Aug Pot Lifts	0	0
Q4	#'s Sep Pot Lifts	0	0
R4	#'s Oct Pot Lifts	0	0
S4	#'s Nov/Dec	20850533.74	17781072.35
T4	#'s Dec/Jan	15193842.75	13057959.21
U4	#'s Jan/Feb	13009709.79	11229776.95
V4	#'s Feb/Mar	10997060.48	9544688.088
W4	#'s Mar/Apr	7407667.372	6545336.2
X4	#'s Apr/May	4.5E+06	4.1E+06
Y4	#'s May/Jun	3.0E+06	2.8E+06
Z4	#'s Jun/Breed	2.1E+06	2.1E+06

Microsoft Excel 5.0 Answer Report
Worksheet: [WRLITQ.XLS]WRLITQ6 (5)

Case 14: Variable Boat & Pot Nos. + more pots/boat -Season ends June 30 ITQ's & TAC set to ensure sustainable catch & breeding stock

Target Cell (Max)

Cell	Name	Original Value	Final Value
C5	Profit Total	34,282,366	53,866,888

Adjustable Cells

Cell	Name	Original Value	Final Value
D4	#'s Catch	10,795,339	9,000,000
E4	#'s Boats	669	344
F4	#'s Pots	69,576	49,600
G4	#'s Nov Pot Lifts	1,020,278	744,007
H4	#'s Dec Pot Lifts	2,018,782	1,488,013
I4	#'s Jan Pot Lifts	1,243,343	1,289,611
J4	#'s Feb Pot Lifts	1,464,628	1,240,011
K4	#'s Mar Pot Lifts	1,801,387	1,388,812
L4	#'s Apr Pot Lifts	1,663,190	1,339,212
M4	#'s May Pot Lifts	1,310,311	1,289,611
N4	#'s Jun Pot Lifts	908,661	1,091,210
O4	#'s Jul Pot Lifts	0	0
P4	#'s Aug Pot Lifts	0	0
Q4	#'s Sep Pot Lifts	0	0
R4	#'s Oct Pot Lifts	0	0
S4	#'s Nov/Dec	20850533.74	17963528.02
T4	#'s Dec/Jan	15193842.75	13744763.75
U4	#'s Jan/Feb	13009709.79	11517628.12
V4	#'s Feb/Mar	10997060.48	9804081.78
W4	#'s Mar/Apr	7407667.372	7011585.094
X4	#'s Apr/May	4.5E+06	4.7E+06
Y4	#'s May/Jun	3.0E+06	3.1E+06
Z4	#'s Jun/Breed	2.1E+06	2.1E+06

Microsoft Excel 5.0 Answer Report
Worksheet: [WRLITQ.XLS]WRLITQ6 (7)

Case 21: Variable Boat & Pot Nos. - Extended Season ends September 30
LLS management - TAE set to ensure sustainable catch & breeding stock

Target Cell (Max)

Cell	Name	Original Value	Final Value
C5	Profit Total	20,100,105	49,283,960

Adjustable Cells

Cell	Name	Original Value	Final Value
D4	#'s Catch	9,000,000	9,000,000
E4	#'s Boats	669	445
F4	#'s Pots	69,576	46,231
G4	#'s Nov Pot Lifts	676,636	676,636
H4	#'s Dec Pot Lifts	1,331,648	1,331,648
I4	#'s Jan Pot Lifts	1,011,116	1,011,116
J4	#'s Feb Pot Lifts	1,152,990	1,151,680
K4	#'s Mar Pot Lifts	1,224,385	1,223,901
L4	#'s Apr Pot Lifts	1,248,228	1,248,228
M4	#'s May Pot Lifts	1,104,851	1,104,851
N4	#'s Jun Pot Lifts	823,049	823,049
O4	#'s Jul Pot Lifts	636,466	636,466
P4	#'s Aug Pot Lifts	551,020	551,020
Q4	#'s Sep Pot Lifts	600,000	600,000
R4	#'s Oct Pot Lifts	0	0
S4	#'s Nov/Dec	21337889.33	21337889.33
T4	#'s Dec/Jan	17436408.83	17448394.08
U4	#'s Jan/Feb	15563692.06	15575449.59
V4	#'s Feb/Mar	13879744.3	13886469.43
W4	#'s Mar/Apr	11319279.3	11314875.59
X4	#'s Apr/May	9.0E+06	9.0E+06
Y4	#'s May/Jun	7.6E+06	7.6E+06
Z4	#'s Jun/Jul	6754765.677	6750608.239
AA4	#'s Jul/Aug	6.0E+06	6.0E+06
AB4	#'s Aug/Sep	5.3E+06	5.3E+06
AC4	#'s Sep/Oct	4.6E+06	4.6E+06
AD4	#'s Oct/Breed	4.5E+06	4.5E+06

Microsoft Excel 5.0 Answer Report
Worksheet: [WRLITQ.XLS]WRLITQ6 (7)

Case 22: Variable Pot Nos. & Constant Boat Nos. - Season ends September30
LLS management - TAE set to ensure sustainable catch & breeding stock

Target Cell (Max)

Cell	Name	Original Value	Final Value
C5	Profit Total	20,100,105	20,084,344

Adjustable Cells

Cell	Name	Original Value	Final Value
D4	#'s Catch	9,000,000	9,000,000
E4	#'s Boats	669	669
F4	#'s Pots	69,576	69,576
G4	#'s Nov Pot Lifts	676,636	676,636
H4	#'s Dec Pot Lifts	1,331,648	1,331,648
I4	#'s Jan Pot Lifts	1,011,116	1,011,116
J4	#'s Feb Pot Lifts	1,152,990	1,151,680
K4	#'s Mar Pot Lifts	1,224,385	1,223,901
L4	#'s Apr Pot Lifts	1,248,228	1,248,228
M4	#'s May Pot Lifts	1,104,851	1,104,851
N4	#'s Jun Pot Lifts	823,049	823,049
O4	#'s Jul Pot Lifts	636,466	636,466
P4	#'s Aug Pot Lifts	551,020	551,020
Q4	#'s Sep Pot Lifts	600,000	600,000
R4	#'s Oct Pot Lifts	0	0
S4	#'s Nov/Dec	21337889.33	21337889.33
T4	#'s Dec/Jan	17436408.83	17448394.08
U4	#'s Jan/Feb	15563692.06	15575449.59
V4	#'s Feb/Mar	13879744.3	13886469.43
W4	#'s Mar/Apr	11319279.3	11314875.59
X4	#'s Apr/May	9.0E+06	9.0E+06
Y4	#'s May/Jun	7.6E+06	7.6E+06
Z4	#'s Jun/Jul	6754765.677	6750608.239
AA4	#'s Jul/Aug	6.0E+06	6.0E+06
AB4	#'s Aug/Sep	5.3E+06	5.3E+06
AC4	#'s Sep/Oct	4.6E+06	4.6E+06
AD4	#'s Oct/Breed	4.5E+06	4.5E+06

Microsoft Excel 5.0 Answer Report
Worksheet: [WRLITQ.XLS]WRLITQ6 (6)

Case 24: Variable Boat & Pot Nos. - Extended Season ends September 30
ITQ's & TAC set to ensure sustainable catch & breeding stock

Target Cell (Max)

Cell	Name	Original Value	Final Value
C5	Profit Total	34,282,516	55,314,285

Adjustable Cells

Cell	Name	Original Value	Final Value
D4	#'s Catch	10,795,339	9,000,000
E4	#'s Boats	669	402
F4	#'s Pots	69,576	41,804
G4	#'s Nov Pot Lifts	1,020,278	627,061
H4	#'s Dec Pot Lifts	1,058,252	1,254,122
I4	#'s Jan Pot Lifts	1,043,343	1,086,906
J4	#'s Feb Pot Lifts	1,064,628	1,045,102
K4	#'s Mar Pot Lifts	1,501,387	1,170,514
L4	#'s Apr Pot Lifts	1,363,190	1,128,710
M4	#'s May Pot Lifts	1,310,311	1,086,906
N4	#'s Jun Pot Lifts	908,661	919,690
O4	#'s Jul Pot Lifts	908,661	752,473
P4	#'s Aug Pot Lifts	908,661	752,473
Q4	#'s Sep Pot Lifts	908,661	752,473
R4	#'s Oct Pot Lifts	0	0
S4	#'s Nov/Dec	20861600	21406598.93
T4	#'s Dec/Jan	15204699	14679580.19
U4	#'s Jan/Feb	13020360	12743703.14
V4	#'s Feb/Mar	11007508	11241805.1
W4	#'s Mar/Apr	7417916	8831645.881
X4	#'s Apr/May	4.5E+06	6.8E+06
Y4	#'s May/Jun	3.0E+06	5.5E+06
Z4	#'s Jun/Jul	2.1E+06	4.5E+06
AA4	#'s Jul/Aug	2.1E+06	3.7E+06
AB4	#'s Aug/Sep	2.0E+06	2.9E+06
AC4	#'s Sep/Oct	2.0E+06	2.1E+06
AD4	#'s Oct/Breed	2.0E+06	2.1E+06

Microsoft Excel 5.0 Answer Report
Worksheet: [WRLITQ.XLS]WRLITQ6 (6)

Case 25: Variable Pot Nos. & Constant Boat Nos. - Season ends September30
ITQ's & TAC set to ensure sustainable catch & breeding stock

Target Cell (Max)

Cell	Name	Original Value	Final Value
C5	Profit Total	34,282,516	27,824,391

Adjustable Cells

Cell	Name	Original Value	Final Value
D4	#'s Catch	10,795,339	9,000,000
E4	#'s Boats	669	669
F4	#'s Pots	69,576	69,576
G4	#'s Nov Pot Lifts	1,020,278	1,043,640
H4	#'s Dec Pot Lifts	1,058,252	0
I4	#'s Jan Pot Lifts	1,043,343	0
J4	#'s Feb Pot Lifts	1,064,628	0
K4	#'s Mar Pot Lifts	1,501,387	1,948,128
L4	#'s Apr Pot Lifts	1,363,190	1,878,552
M4	#'s May Pot Lifts	1,310,311	1,544,047
N4	#'s Jun Pot Lifts	908,661	1,530,672
O4	#'s Jul Pot Lifts	908,661	1,252,368
P4	#'s Aug Pot Lifts	908,661	1,252,368
Q4	#'s Sep Pot Lifts	908,661	1,252,368
R4	#'s Oct Pot Lifts	0	0
S4	#'s Nov/Dec	20861600	20829227.8
T4	#'s Dec/Jan	15204699	17428110.4
U4	#'s Jan/Feb	13020360	17096976.3
V4	#'s Feb/Mar	11007508	16772133.75
W4	#'s Mar/Apr	7417916	12797642.83
X4	#'s Apr/May	4.5E+06	9.4E+06
Y4	#'s May/Jun	3.0E+06	7.6E+06
Z4	#'s Jun/Jul	2.1E+06	6.0E+06
AA4	#'s Jul/Aug	2.1E+06	4.7E+06
AB4	#'s Aug/Sep	2.0E+06	3.4E+06
AC4	#'s Sep/Oct	2.0E+06	2.1E+06
AD4	#'s Oct/Breed	2.0E+06	2.1E+06

Microsoft Excel 5.0 Answer Report
Worksheet: [WRLITQ.XLS]WRLITQ6 (7)

Case 31: Variable Boat & Pot Nos. + more pots/boat - Season ends Sept. 30
LLS management - TAE set to ensure sustainable catch & breeding stock

Target Cell (Max)

Cell	Name	Original Value	Final Value
C5	Profit Total	20,100,105	63,484,087

Adjustable Cells

Cell	Name	Original Value	Final Value
D4	#'s Catch	9,000,000	9,000,000
E4	#'s Boats	669	321
F4	#'s Pots	69,576	46,231
G4	#'s Nov Pot Lifts	676,636	676,636
H4	#'s Dec Pot Lifts	1,331,648	1,331,648
I4	#'s Jan Pot Lifts	1,011,116	1,011,116
J4	#'s Feb Pot Lifts	1,152,990	1,151,680
K4	#'s Mar Pot Lifts	1,224,385	1,223,901
L4	#'s Apr Pot Lifts	1,248,228	1,248,228
M4	#'s May Pot Lifts	1,104,851	1,104,851
N4	#'s Jun Pot Lifts	823,049	823,049
O4	#'s Jul Pot Lifts	636,466	636,466
P4	#'s Aug Pot Lifts	551,020	551,020
Q4	#'s Sep Pot Lifts	600,000	600,000
R4	#'s Oct Pot Lifts	0	0
S4	#'s Nov/Dec	21337889.33	21337889.33
T4	#'s Dec/Jan	17436408.83	17448394.08
U4	#'s Jan/Feb	15563692.06	15575449.59
V4	#'s Feb/Mar	13879744.3	13886469.43
W4	#'s Mar/Apr	11319279.3	11314875.59
X4	#'s Apr/May	9.0E+06	9.0E+06
Y4	#'s May/Jun	7.6E+06	7.6E+06
Z4	#'s Jun/Jul	6754765.677	6750608.239
AA4	#'s Jul/Aug	6.0E+06	6.0E+06
AB4	#'s Aug/Sep	5.3E+06	5.3E+06
AC4	#'s Sep/Oct	4.6E+06	4.6E+06
AD4	#'s Oct/Breed	4.5E+06	4.5E+06

Microsoft Excel 5.0 Answer Report
Worksheet: [WRLITQ.XLS]WRLITQ6 (8)

Case 34: Variable Boat & Pot Nos. + more pots/boat - Season ends Sept. 30
ITQ's & TAC set to ensure sustainable catch & breeding stock

Target Cell (Max)

Cell	Name	Original Value	Final Value
C5	Profit Total	34,282,516	68,154,747

Adjustable Cells

Cell	Name	Original Value	Final Value
D4	#'s Catch	10,795,339	9,000,000
E4	#'s Boats	669	290
F4	#'s Pots	69,576	41,804
G4	#'s Nov Pot Lifts	1,020,278	627,061
H4	#'s Dec Pot Lifts	1,058,252	1,254,122
I4	#'s Jan Pot Lifts	1,043,343	1,086,906
J4	#'s Feb Pot Lifts	1,064,628	1,045,102
K4	#'s Mar Pot Lifts	1,501,387	1,170,514
L4	#'s Apr Pot Lifts	1,363,190	1,128,710
M4	#'s May Pot Lifts	1,310,311	1,086,906
N4	#'s Jun Pot Lifts	908,661	919,690
O4	#'s Jul Pot Lifts	908,661	752,473
P4	#'s Aug Pot Lifts	908,661	752,473
Q4	#'s Sep Pot Lifts	908,661	752,473
R4	#'s Oct Pot Lifts	0	0
S4	#'s Nov/Dec	20861600	18295174.08
T4	#'s Dec/Jan	15204699	14679580.19
U4	#'s Jan/Feb	13020360	12743703.14
V4	#'s Feb/Mar	11007508	11241805.1
W4	#'s Mar/Apr	7417916	8831645.881
X4	#'s Apr/May	4.5E+06	6.8E+06
Y4	#'s May/Jun	3.0E+06	5.5E+06
Z4	#'s Jun/Jul	2.1E+06	4.5E+06
AA4	#'s Jul/Aug	2.1E+06	3.7E+06
AB4	#'s Aug/Sep	2.0E+06	2.9E+06
AC4	#'s Sep/Oct	2.0E+06	2.1E+06
AD4	#'s Oct/Breed	2.0E+06	2.1E+06

Fisheries management papers

No.1	The Report of the Southern Western Australian Shark Working Group. Chairman P. Millington (1986).
No.2	The report of the Fish Farming Legislative Review Committee. Chairman P.Rogers (1986).
No.3	Management Measures for the Shark Bay Snapper 1987 Season. P. Millington (1986)
No.4	The Esperance Rock Lobster Working Group. Chairman A. Pallot (1986).
No.5	The Windy Harbour - Augusta Rock Lobster Working Group. Interim Report by the Chairman A. Pallot (1986).
No.6	The King George Sound Purse Seine Fishery Working Group. Chairman R. Brown (1986).
No.7	Management Measures for the Cockburn Sound Mussel Fishery. H. Brayford (1986).
No.8	Report of the Rock Lobster Industry Advisory meeting of 27 January 1987 . Chairman B. Bowen (1987).
No.9	Western Rock Lobster Industry Compensation Study. Arthur Young Services (1987).
No.10	Further Options for Management of the Shark Bay Snapper Fishery. P. Millington (1987).
No.11	The Shark Bay Scallop Fishery. L. Joll (1987).
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No.13	A Development Plan for the South Coast Inshore Trawl Fishery. (1987)
No.14	Draft Management Plan for the Perth Metropolitan Purse Seine Fishery. P. Millington (1987).
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No.16	The South West Trawl Fishery Draft Management Plan. P. Millington (1988).
No.17	The final report of the pearling industry review committee . F.J. Malone, D.A. Hancock, B. Jeffriess (1988).
No.18	Policy for Freshwater Aquaculture in Western Australia. (1988)
No.19	Sport Fishing for Marron in Western Australia - Management for the Future. (1988)
No.20	The Offshore Constitutional Settlement, Western Australia 1988.
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No.22	Economics and marketing of Western Australian pilchards. SCP Fisheries Consultants Pty Ltd (1988).
No.23	Management of the south-west inshore trawl fishery. N.Moore (1989)
No.24	Management of the Perth metropolitan purse-seine fishery. Noel Moore (1989).
No.25	Rock Lobster Industry Advisory Committee report to the Minister for Fisheries November 1988. (1989)
No.26	A report on marron fishing in Western Australia. Chairman Doug Wenn MLC (1989).
No.27	A review of the Shark Bay pearling industry. Dr. D.A.Hancock, Ph.D, D.Sc (1989).
No.28	Southern demersal gillnet and longline fishery. (1989)
No.29	Distribution and marketing of Western Australian rock lobster. P. Monaghan (1989).
No.30	Foreign investment in the rock lobster industry. (1989)
No.31	Rock Lobster Industry Advisory Committee report to the Hon Minister for Fisheries September 1989. (1989)
No.32	Fishing Licences as security for loans. P. Rogers (1989)
No.33	Guidelines for by-laws for those Abrolhos Islands set aside for fisheries purposes. N. Moore (1989).
No.34	The future for recreational fishing - issues for community discussion. Recreational Fishing Advisory Committee (1990).
No.35	Future policy for charter fishing operations in Western Australia. P. Millington (1990).
No.36	Long term management measures for the Cockburn Sound restricted entry fishery. P. Millington (1990).
No.37	Western rock lobster industry marketing report 1989/90 season. MAREC Pty Ltd (1990).
No.38	The economic impact of recreational fishing in Western Australia. R.K. Lindner, P.B. McLeod (1991).
No.39	Establishment of a registry to record charges against fishing licences when used as security for loans.P. Rogers. (1991)
No.40	The future for Recreational Fishing - Forum Proceedings. Recreational Fishing Advisory Committee (1991)
No.41	The future for Recreational Fishing - The Final Report of the Recreational Fishing Advisory Committee. Recreational Fishing Advisory Committee (1991).
No.42	Appendix to the final report of the Recreational Fishing Advisory Committee. (1991)
No.43	A discussion of options for effort reduction. Southern Gillnet and Demersal Longline Fishery Management Advisory Committee (1991).
No.44	A study into the feasability of establishing a system for the buy-back of salmon fishing authorisations and related endorsements. (1991)

No.45 Draft Management Plan, Kimberley Prawn Fishery. (1991)

No.46 Rock Lobster Industry Advisory Committee, Chairman's report to the Minister (1992)

No.47 Long term management measures for the Cockburn Sound restricted entry fishery. Summary of submissions and final recommendations for management. P. Millington (1992).

No.48 Pearl oyster fishery policy guidelines (Western Australian Pearling Act 1990). Western Australian Fisheries Joint Authority (1992).

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