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AN ANALYSIS OF MAXIMUM ECONOMIC YIELD IN THE WESTERN ROCK LOBSTER FISHERY

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An Analysis of Maximum Economic Yield in the Western Rock Lobster Fishery

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Chris Reid – Department of Fisheries

1 Introduction

This paper seeks to address the issue of maximum economic yield (MEY) in the Western Rock Lobster Fishery (WRLF). MEY occurs at the catch or effort level that maximises profits for the fishery as a whole, that is, creates the largest difference between total revenues and the total costs of fishing. While MEY relates to a given catch or effort level, for the potential profits associated with it to be realised requires not only that the appropriate management targets be set correctly but that the management regime under which the targets are set is enforced cost-effectively, delivered in a least cost manner and provide incentives to operators that are compatible with the objective of maximising the fishery's profitability.

In this paper we focus on two of these issues. First, what effort/catch level in the WRLF is that associated with MEY given the current cost/price structure of the fishery. Second, the compatibility of incentives provided to operators under input controls and ITQs to the objective of maximising the fishery's profitability.

2 Maximum Economic Yield and the Western Rock Lobster Fishery

2.1 Overview of Maximum Economic Yield

In this section the concept of maximum economic yield is outlined. This is done within a sustainable catch framework, that is, it compares economic yields from a fishery's sustainable catch under various effort levels, where effort is defined as the number of days fished. The overview is taken from that presented by Kompass (2005)[1].

Maximum economic yield (MEY) occurs when the sustainable catch or effort level for the fishery as a whole maximises profits, or creates the largest difference between total revenues and the total costs of fishing. For profits to be maximised it must also be the case that the fishery applies a level of boat capital and other resources in combinations that minimise the costs of harvest at the MEY catch level. The fishery, in other words, cannot be overcapitalized and vessels must use the right combinations of such inputs as gear, engine power, fuel, hull size, and crew to minimise the cost of a given harvest.

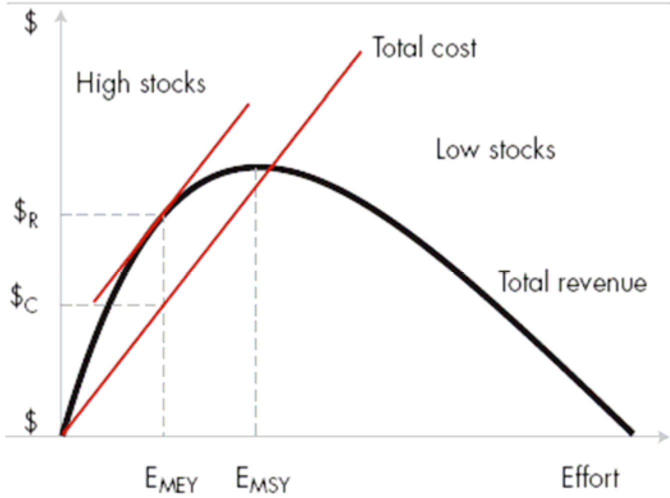
There are several things to note about MEY at the outset. First, in most cases MEY will imply that the equilibrium stock of fish is larger than that associated with 'maximum sustainable yield' (MSY). Second, the catch and effort levels associated with MEY will vary, as will profits, with a change in the price of fish or the cost of fishing. This is as it should be. If the price of fish increases it pays to exploit the fishery more intensively, albeit at yields still less than MSY. If the cost of fishing rises, it is preferable to have larger stocks of fish and thus less effort and catch. Finally, as long as the cost of fishing increases with days fished, as it generally will, MEY as a target will always be preferred to MSY and of course to any catch or effort level that corresponds to stocks that are smaller than those associated with MSY. The reason is simple. Regardless of what happens to prices and costs, targeting catch and effort at MEY will always ensure that profits are maximised. Profits may be relatively low when the price of fish is low and the cost of fishing is high, but profits will still be maximised. With a biological target of MSY alone, however, it is quite possible that profits will be very small or even zero. The fishery would thus be sustainable at MSY but may not be profitable.

The management structure, stock level and nature and extent of fishing effort that generates MEY depends on a combination of biological and economic factors. In particular, it depends on the relationships between harvest, stocks and recruitment and on the way in which fishing behavior, revenue and costs relate to those factors. A simplified representation of these relationships is given in Figure A.

[1] Kompass, T. 2005, "Fisheries Management: economic efficiency and the concept of 'maximum economic yield'", Australian Commodities, Vol. 12, No. 1, March Quarter.

Figure A illustrates a typical production surplus model for the fishery as a whole, expressed in terms of the relevant economic relationships. The vertical axis is simply dollar amounts and the horizontal measures effort as nominal days fished. The total revenue curve is drawn from a biological stock–recruitment relationship, translated into effort units, showing the relationship between effort and yield in dollar amounts. The larger is effort the smaller is stock size. Every point along this curve represents an effort and yield combination that is sustainable, with effort at MSY generating the largest total revenue. The total cost curve is taken as the total cost of fishing, assumed to be increasing and linear in effort, for convenience. MEY in Figure A occurs at the effort level E_{MEY} and corresponding value of catch $\$_R$ that creates the largest difference between the total revenue and total cost of fishing, thus maximising profits, given by the difference between $\$_R$ and $\$_C$. The value of E_{MEY} will change given a change in the price of fish, which shifts the total revenue curve up or down, or the cost of fishing, which rotates the total cost curve. Given prices and costs, Figure A illustrates a point made above, namely that targeting MSY will in this case generate very small profits. With a small increase in the cost of fishing, these could easily go to zero — if so, this would replicate a common property or open access equilibrium even though a management regime was in place and operating. Note as well that a profit maximising movement away from effort at MSY toward effort at MEY implies a smaller value of harvest. This is often the case with overexploited fisheries — maximising profits requires less effort and smaller catches. The reason of course is that decreases in effort, which also increases the stock of fish in the future, decrease the cost of fishing more than the corresponding fall in revenue.

A Maximum economic yield



Maximum economic yield (MEY) is the difference between the dollar amounts of revenue and costs at the optimal effort level, or $\$_R$ less $\$_C$. Note that MEY occurs at effort levels less than effort at maximum sustainable yield and thus at stock levels that are larger than those associated with MSY.

Source: Kompass (2005)

In the next section an examination of the catch-effort relationship and recent prices and effort production costs in the WRLF is undertaken. Following this MEY is estimated and the sensitivity of the results to changes in costs and prices examined.

2.2 The catch-effort relationship and recent prices and effort production costs in the WRLF

In the analysis conducted in this paper we do not use the sustainable catch framework used to illustrate the concept of MEY in the previous section. Instead we look at predicted catches over six seasons – 2008/09 to 2013/14 – under varying effort levels. It is also important to note that in the previous section it was noted that for profits to be maximised it must also be the case that the fishery applies a level of boat capital and other resources in combinations that minimise the costs of harvest at the MEY catch level. In the analysis conducted in this paper we use costs based on the current cost structure of the fishery, which may or may not meet this condition. In other words we are estimating MEY where

MEY is defined as the maximum net present value (NPV) of potential profits in the fishery over the period 2008/09 to 2013/14 under the current cost structure of the fishery.

2.2.1 The catch-effort relationship

In this section the results of DoF Research Division modelling undertaken in October 2008 of the relationship between total fishery effort, as measured by the number of pot lifts made, and total fishery catch is presented. The results are generated for each Zone of the fishery by running the stock assessment model under effort levels that range from 10 to 100 per cent of the number of pot lifts made in the 2007/08 season to obtain a predicted catch for each season over the period 2008/09 to 2013/14. In doing this it is assumed that the distribution of the effort over the season remains constant.

The result of the analysis are provided in Table 1 which shows the predicted catch in tonnes for each Zone by season for the period 2008/09 to 2013/14 under the range of effort levels indicated.

Table 1: Predicted catch (tonnes) by Zone by season for the period 2008/09 to 2013/14 under given level of effort

	Effort (as a percentage of pot lifts made in 2007/08 season)									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Zone A										
2007/08[a]	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	2092
2008/09	668	1082	1356	1547	1688	1754	1883	1952	2009	2056
2009/10	930	1321	1521	1638	1711	1739	1788	1807	1819	1826
2010/11	1002	1310	1445	1514	1551	1563	1580	1585	1587	1587
2011/12	1062	1338	1449	1499	1522	1529	1535	1536	1535	1534
2012/13	1215	1545	1694	1774	1823	1843	1879	1896	1910	1921
2013/14	1324	1664	1812	1889	1934	1952	1982	1995	2005	2012
Total predicted catch 2008/09 – 2013/14)	6,202	8,260	9,275	9,861	10,229	10,379	10,647	10,772	10,865	10,936
Zone B										
2007/08[a]	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	3570
2008/09	645	1173	1610	1976	2286	2550	2778	2975	3148	3300
2009/10	867	1429	1809	2075	2265	2404	2507	2584	2641	2684
2010/11	975	1516	1843	2051	2188	2280	2342	2383	2409	2426
2011/12	984	1467	1738	1902	2005	2071	2112	2138	2154	2163
2012/13	1208	1822	2194	2438	2606	2726	2815	2882	2934	2976
2013/14	1363	2028	2417	2663	2826	2938	3018	3076	3119	3152
Total predicted catch 2008/09 – 2013/14)	6,041	9,435	11,611	13,105	14,177	14,970	15,571	16,038	16,406	16,702
Zone C										
2007/08[a]	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	4488
2008/09	801	1499	2110	2645	3115	3528	3892	4215	4500	4754
2009/10	1297	2240	2924	3417	3771	4023	4199	4320	4402	4453
2010/11	1487	2385	2916	3221	3384	3461	3485	3479	3454	3420
2011/12	1469	2202	2546	2689	2728	2716	2681	2637	2591	2547
2012/13	1703	2563	3029	3309	3497	3638	3753	3851	3938	4016
2013/14	2136	3247	3891	4302	4583	4785	4935	5048	5135	5201
Total predicted catch 2008/09 – 2013/14)	8,892	14,136	17,417	19,583	21,078	22,151	22,946	23,550	24,019	24,391

Notes: **a.** Actual catch.

The results of the analysis indicates that effort reductions introduced in 2008/09 would result in reductions in total catches over the period 2008/09 to 2013/14 of a far lesser magnitude than the effort reduction itself (Figure 1). For example, a 50 per cent effort reduction introduced in 2008/09 results in a catch reduction over the period 2008/09 to 2013/14 of 6 per cent in Zone A, 15 per cent in Zone B and 14 per cent in Zone C. As illustrated in Figure 2, much of the reduction in catch is borne in the first year and to a lesser extent the second year of the effort reduction.

Given this, it is predicted that under substantial effort reductions declines in catch levels are substantially mitigated by increases in catch per unit effort. A comparison of predicted CPUE under 2007/08 effort levels and under 50 per cent of 2007/08 effort levels is provided in Figure 3.

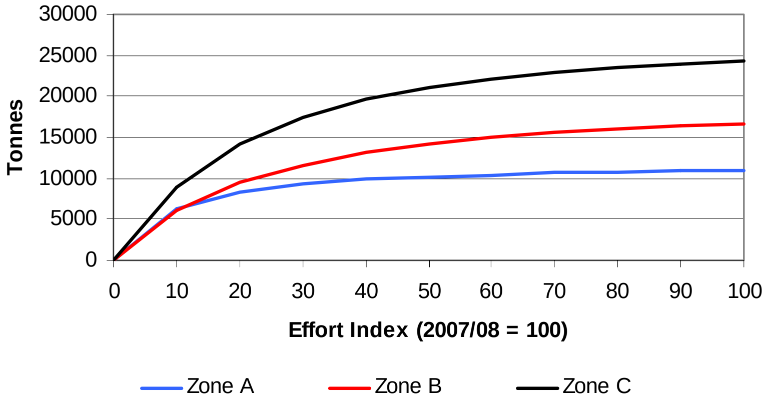


Figure 1: Predicted total catch over the period 2008/09 to 2013/14 seasons under various effort levels

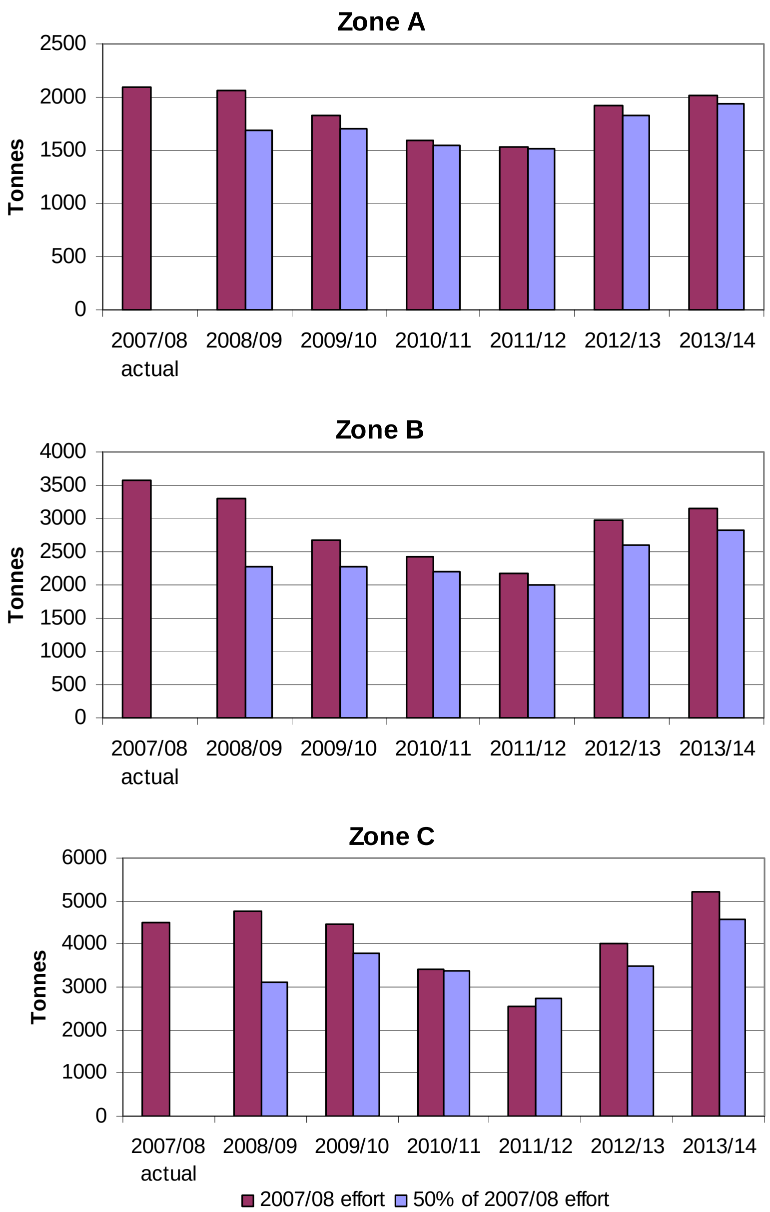


Figure 2: Predicted catch for 2008/09 to 2013/14 seasons under 2007/08 effort levels and 50 per cent of 2007/08 effort levels by Zone

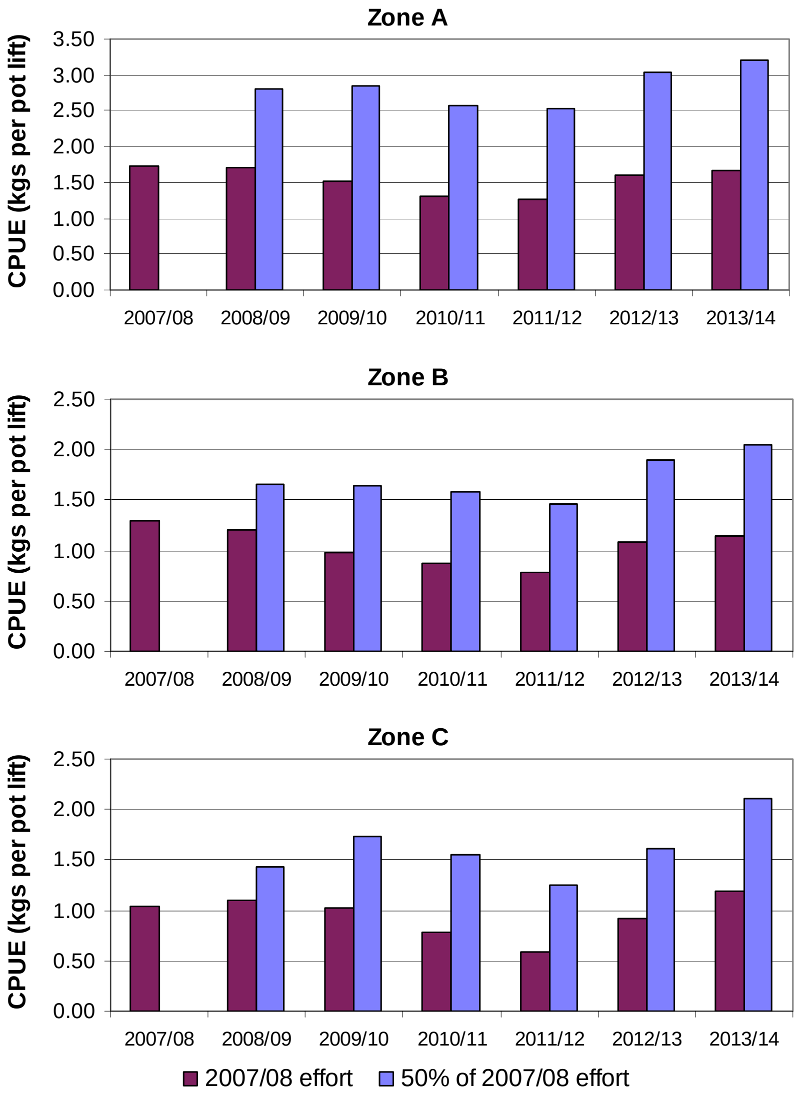


Figure 3: Predicted CPUE between 2008/09 and 2013/14 under 2007/08 effort levels and 50 per cent of 2007/08 effort levels by Zone

2.2.2 Prices and the value of the catch

Figure 4 below provides average ex-vessel (or beach) prices for western rock lobster over the last 10 years. As can be seen the average annual price have varied considerably over the past decade, from a low of \$19/kg in 2003/04 to a high of just under \$34/kg in 2001/02. In the analysis conducted for this paper we use a price of \$27/kg based on the average price over the period 2005/06 to 2007/08. To obtain an indication of the sensitivity of the effort/catch level associated with MEY to variations in price levels the analysis is also conducted with prices set at ±20 per cent of the initial \$27/kg price used.

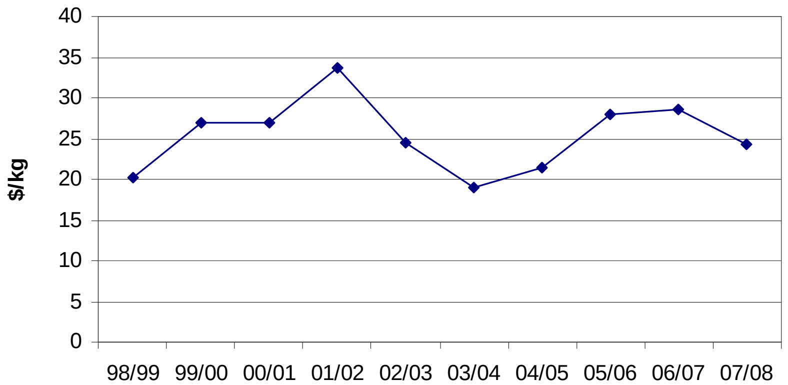


Figure 4: Average ex-vessel prices for western rock lobster 1998/99 to 2007/08

As for the catch, effort reductions result in reductions in the value of catch over the period 2008/09 to 2013/14 of a far lesser magnitude than the effort reduction itself as illustrated in Figure 5.

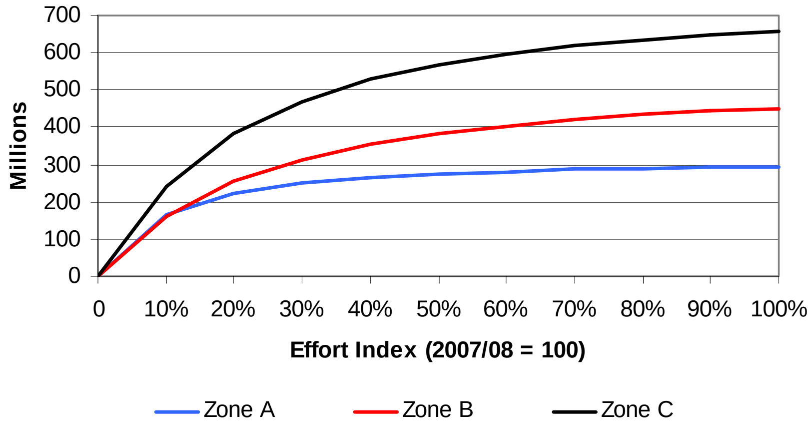


Figure 5: Value of the predicted catch by Zone between 2008/09 and 2013/14 under given effort levels and a price of $27/kg

2.2.3 The cost of producing effort

A model developed for the Western Rock Lobster Council (WRLC) by Morrison contains estimates of fishing costs for "typical" vessels operating 90 and 130 pots (pers. com., A. Wizner, WRLC, 31 October 2008).[2] Based on these figures and defining fishing cost as operating costs (excluding licensing fees) plus asset depreciation the cost of producing a unit of effort (that is, one pot lift) is estimated to have been $25.

Where effort reductions are imposed on the fishery though pot reductions the number of pots per vessel available will be dependent upon the number of vessels that exit the fishery. For example, if under a 50 per cent pot reduction vessels numbers fall by 25 per cent, the number of pots per vessel will fall by one third (33 per cent). Given that some cost are independent or only partially related to the number of pots worked, for example insurance and fuel. It would be expected that as pot per vessel numbers fall, the effective cost per pot lift would rise. In this analysis we assume that under a given effort reduction the fleet adjusts so that the number of pots per vessel returns to it pre-effort reductions level in three years with the fall in vessel numbers constant over the three-year adjustment period. It is also assumed that 75 per cent of costs are independent of pot numbers. Thus, for example, under an effort reduction of 50 per cent achieved through a 50 per cent reduction in pot numbers, in the first year 17 per cent of vessels exit the fishery and the number of pots per vessel falls by 40 per cent with the cost per pot rising by 50 per cent. Total fishery costs declines 25 per cent. In the second year a further 17 per cent of the original fleet leave the fishery and the number of pots per vessel is 22 per cent less than before the effort reduction and the cost per pot is 21 per cent higher than before the effort cut. Total fishery costs declines 40 per cent compared with before the effort reduction. In the third year once again a further 17 per cent of the original fleet leave the fishery for a total reduction of 50 per cent of the pre effort reduction fleet and the number of pots per vessel is now the same as before the effort reduction as are the cost per pot and total fishing costs are 50 per cent of that compared with before the effort reduction Figure 6 illustrates this for Zone C under 2007/08 effort levels and an effort reduction of 50 per cent using an initial cost of $25 per pot lift.

Finally to obtain an indication of the sensitivity of the effort/catch level associated with MEY to variations in costs the analysis is also conducted with costs set at ±20 per cent of the initial $25 per pot lift costing used.

[2] These estimates are in based on 2005 data from Thomson, J and Wass C. 2007, *Baseline Economic Data Survey of the Western Rock Lobster Industry*.

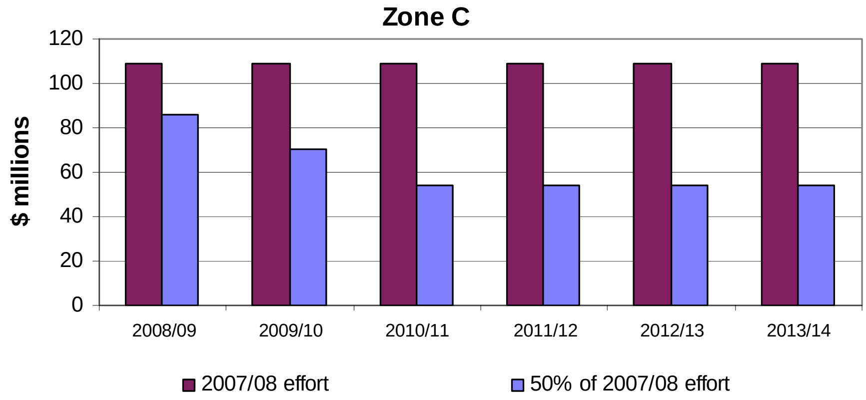


Figure 6: Estimated cost of effort under 2007/08 effort levels and 50 per cent of 2007/08 effort levels for Zone C by season 2008/09 to 2013/14

2.3 Estimating effort/catch levels associated with MEY

In this section we estimate by Zone the level of catch and effort associated with MEY based on the catch-effort relationship, cost and price structure outlined in Sections 2.1 to 2.3. We do this over the immediate term, that is, over the period 2008/09 to 2013/14. In addition future profits are discounted at a rate of 10 per cent per annum, that is profits in 2009/10 are counted as being with 10 per cent less than profits in 2008/09 and so on. As profits up to 2013/14 only are considered we are effectively discounting profits from the 2014/15 season and onwards completely.

2.3.1 Base Case

Under the base case prices are set at $27/kg and initial costs at $25 per pot lift. As outlined in Section 2.3 it is assumed that under a given effort reduction the fleet adjusts so that the number of pots per vessel returns to it pre-effort reductions level in three years with the fall in vessel numbers constant over the three year adjustment period and that 75 per cent of costs are independent of pot numbers.

Figure 7 provides the estimated net present value (NPV) of the potential additional future profits under varying effort levels over the period 2008/09 to 2013/14 by Zone. In all Zones the NPV of potential additional future profits is maximised with effort levels at 30-50 per cent of 2007/08 levels. In Zone A NPV of potential additional future profits is around $40-45 million dollars levels over the period 2008/09 to 2013/14 or roughly $7 million per season on average, in Zone B it is around $70-80 million in total or roughly $12-13 million per season on average and in Zone C around $135-145 million in total or roughly $22-24 million per season. It is important to note that as the fleet adjusts in the initial period following the effort reduction fishery profitability may be less than if no action was taken place. This is illustrated for a 50 per cent effort reduction in Zone C in Figure 8.

The results of the analysis indicate that MEY (measured as the NPV of future profits between 2008/09 and 2013/14) would be achieved with effort levels that are in the order of 50-60 lower than 2007/08 effort levels in all Zones. In terms of catch the analysis indicates that MEY is associated with levels requiring far lower reductions than required to achieve effort levels associated with MEY. MEY is achieved with catch levels in the order of 10 per cent lower over the period 2008/09 to 2013/14 than that which be taken if effort levels were maintained at 2007/08 levels in Zone A and 15-20 per cent lower in Zones B and C.

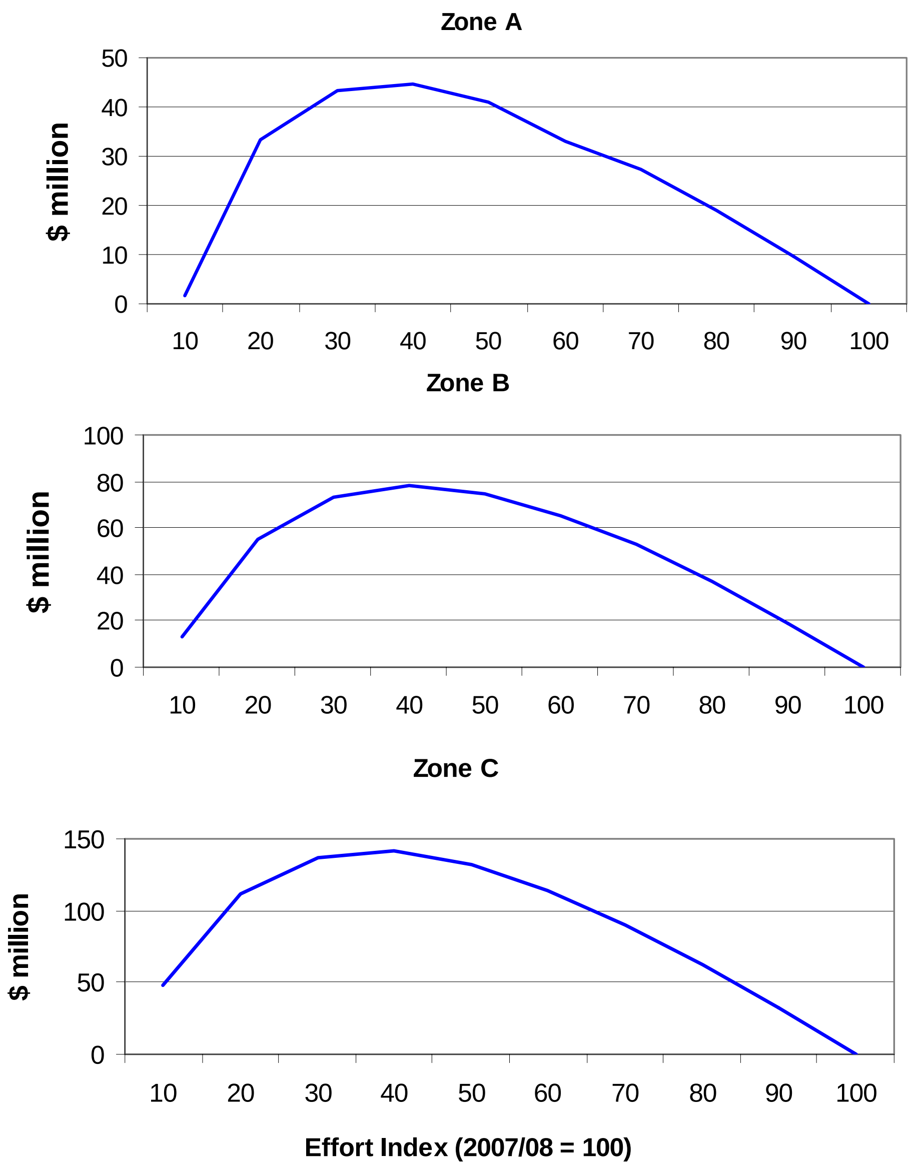


Figure 7: NPV of potential additional fishery profit over the period 2007/08 and 2013/14 under varying effort levels by Zone

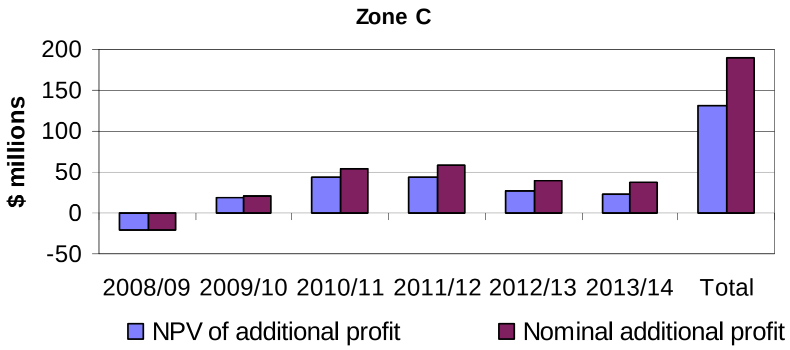


Figure 8: Nominal value and NPV of potential additional fishery profit by season for Zone C with effort at 50 per cent of 2007/08 levels compared with at 2007/08 levels

2.3.2 Sensitivity analysis

As previously noted MEY is dependent on prices and costs and both can move significantly over short time frames. To obtain an indication of the sensitivity of the results of the analysis to variation in prices and cost the analysis was rerun under six scenarios:

1. Costs are 20 per cent higher than estimated and price remains as estimated.
2. Costs are 20 per cent lower than estimated and price remains as estimated.
3. Prices are 20 per cent higher than estimated and costs remains as estimated.
4. Prices are 20 per cent lower than estimated and costs remains as estimated.
5. Costs are 20 per cent higher than estimated and prices are 20 per cent lower than estimated.
6. Costs are 20 per cent lower than estimated and prices are 20 per cent higher than estimated.

The results of the sensitivity analysis are presented in Table 2 below. As can be seen while changes in prices and costs influence the effort level associated with MEY even under the most optimist scenario where costs are 20 per cent lower and prices are 20 per cent higher the effort level associated with MEY is still in the order of 50-60 per cent of 2007/08 effort levels for Zone B and C and 40-50 per cent of 2007/08 effort levels for Zone A.

Table 2: Results of sensitivity analysis

Scenario	Level of effort associated with MEY as percentage of 2007/08 effort levels		
	Zone A	Zone B	Zone C
Base case	40-50	40-50	40-50
C+20%, P same	30-40	30-40	30-40
C-20%, P same	40-50	50-60	40-50
C same, P+20%	40-50	40-50	40-50
C same, P-20%	30-40	30-40	30-40
C+20%, P-20%	20-30	20-30	20-30
C-20%, P+20%	40-50	50-60	50-60

3 Achieving MEY under input controls and ITQs

The results of the analysis presented in Section 2 indicate that potentially fishery profitability could be significantly improved if the level of effort in the fishery was significantly lower than that which prevailed in 2007/08. Based on recent price and cost structure the net present value of the potential additional profits in the fishery over the period 2008/09 to 2013/14 are estimated to be in the order of $40-45 million for Zone A, $70-80 million for Zone B and $135-145 million for Zone C.

Since the 2007/08 season additional restrictions have been put in place in the fishery, including a reduction in the pot usage ratio for the 2008/09 season of between 23.9 and 28.5 per cent on 2007/08 levels with a further reduction of 15 per cent on 2007/08 levels to be implemented in 2008/09. In addition Sunday closures all season have been introduced in Zone B and C and Sunday closures from April 1 introduced in Zone A. These effort reductions will move the fishery significantly toward the estimated effort levels associated with MEY and give rise to a potential increase in the profitability of the fishery.

However, as previously mentioned for the potential profits associated with MEY to be realised requires not only that the appropriate management targets be set correctly but that, among other things, the management regime under which the targets are set provide incentives compatible with the objective of maximising the fishery’s profitability as a whole.

The form of management constraints imposed on operators will determine what strategy an individual operator can implement to maximises their own profits and hence give rise to different incentives. The different incentives produced and strategies adopted in turn will affect the overall profitability of the fishery through their impact on not only the operator in question’s profitability but also the profitability of other operators.

Under input controls managers try, whether explicitly or implicitly, to restrict catch to a given level through controlling a set of inputs used in the production of fishing effort. For example, in the WRLF restrictions are placed on, among other things, the number of pots used, the days on which fishing activity can take place and the design of pots. However, inevitably under any input control regime there are some inputs or potential inputs that can be used to produce effort that are not and/or cannot be controlled. At the same time there is no direct constraint on what an operator can catch.

A profit maximising operator facing such constraints will endeavour to find ways to cost-effectively maximise their share of the catch by using more unconstrained inputs or adopting better technology. Such a strategy from the operator's perspective is rational and results in an increase in the profitability of their operation in the immediate term. However, other operators in order to protect their share of the catch will also use more unconstrained inputs and/or adopt better technology. The effect is that effort creep will occur, whereby the effective amount of effort applied to the fishery increases even though the nominal amount remains the same. A simple example of this would be the introduction of GPS. The use of GPS is effectively an additional input used in the production of a pot lift and improves the average effectiveness of a pot catching lobster. However, as effort is measured by the mangers as a pot lift there is now increase in the measured level of effort in the fishery.

In terms of Figure A, attempting to target E_{MEY} can only be successful for a short time, with effort creep moving the fishery to the right and thus dissipating profits, or decreasing the distance between total costs and revenues. Thus, in order for the fishery to remain at MEY a manager relying on input controls must frequently assess the level of effort associated with MEY as effort changes and adjust the input controls to return the fishery to MEY. The management response in this environment is to continuously and repeatedly find ways to cut effort (for example, pot reductions, area and time closures), 'winding the fishery down' over time to a smaller number of pot lifts and boats.

Under ITQs managers set a total allowable catch (TAC) and this is allocated to entitlements holders who then either catch the allocation or lease it to an operator to catch (the term operator is used in this paper for those operate vessel that take the catch). As an operator is restricted in their ability to take more than their owned/leased allocation they cannot increase their profits by increasing their catch. At the same they are guaranteed the right to catch their quota. However, in the WRLF a 'race to fish' incentive may still exist due to the fact that fishing during the whites results in stock depletion over the course of the season, implying that even though there is a catch entitlement it will be less costly to catch during the whites when stocks are more abundant. This problem could be addressed by quota dated by period — say a white and reds quota — with a market for trade across periods or by starting the quota period at a date that follows the completion of the whites. If this potential problem can be overcome and the incentive to race to fish removed, there is no reason for effort to increase beyond E_{MEY}, and MEY can be effectively targeted. The regulator simply needs to set total allowable catch (TAC) correctly.

The proposed quota management system developed detailed in the paper *Proposed Quota Settings for the West Coast Rock Lobster Managed Fishery* retains many input controls. As noted in the review of this paper this will mean that the economic and financial benefits that often flow from an ITQ system are unlikely to be realised until further reforms are implemented. These benefits arise as a result of reductions in costs and improved marketing. However, the introduction of ITQs if structured properly to ensure the abatement of the race to fish will nonetheless mean that the likelihood of realising the potential increases in profitability arising from setting catch targets at levels associated with MEY will be greater than from setting effort targets at levels associated with MEY under a pure input control system.