A BIOECONOMIC EVALUATION OF FUTURE MANAGEMENT OPTIONS FOR THE AUSTRALIAN WEST COAST ROCK LOBSTER FISHERY

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ABSTRACT

The West Coast Rock Lobster fishery is Australia's most valuable commercial fishery. Around 550 vessels harvest 10,500 tonnes of lobster per annum. The industry has an enviable track record of biological management which has been based on a variety of input controls. In recent years this has necessitated three significant pot reduction interventions. This paper reports the results of an evaluation of a range of possible future management regimes. The results are based on the development of a detailed bio-economic model of the fishery that uses non linear optimization to produce ten year steady state solutions for alternative management options. Options analysed include the current pot control system, and versions of variable transferable catch quota. Key outputs for each scenario are presented include: net economic benefits, breeder biomass index, annual catch, annual pot lifts, number of pots and vessel numbers. The model specifically allows for the three biological zones in the fishery. The results indicate significant potential net economic gains from moving away from the current input control regime. The range of scenarios modelled allows fisheries managers and fishers to analyse the tradeoffs between maximizing net economic returns and biological risks as well as assessing the impact of specific policy changes such as improved pot design and extended fishing seasons. The research has involved extensive consultation with fishers and fisheries managers and the results will be used by the industry in developing a new management system during 2006 to 2008.

Keywords: rock lobster, quotas, ITQs, Western Australia, bioeconomic, economic benefits.

INTRODUCTION.

The West Coast Rock Lobster fishery is the most valuable single species fishery in Australia, typically representing around 20 per cent of the gross value of the catch of Australian fisheries, or, on average, around $200 million to $390 million (at ‘beach’ prices) annually in recent years. Around 95 per cent of the catch is exported. Annual harvests average around 10,500 tonnes from 550 vessels.

The fishery was the first fishery in Western Australia to be declared limited entry in March 1963. The fishery is divided into three geographical access or commercial fishing zones, A, B and C and there is a limited harvest season from the 15th November to end of June. The industry has an enviable track record in terms of biological management. In 1999/2000, it was the first fishery in the world to be certified ecologically sustainable by the Marine Stewardship Council.

The fishery uses baited traps (pots). Pot numbers are restricted by zone and pot licences are tradable. Reliance on input controls in recent years has necessitated three significant pot reduction interventions, the last one of 18% occurred in 1993/94. Minor adjustments happen quite frequently based on interventions such as moon closures as occurred in the 2005/2006 season.

The investment in effort creep that underpinned the need for pot reductions has been combined in recent years with rising input prices (especially diesel) and more competitive world lobster markets. This has exposed the industry to greater financial pressure and increased interest by fishers and fisheries managers in ways to achieve increased industry wide efficiency and greater returns.
This paper reports the results of an evaluation of a range of possible future management options, including the use of transferable quota, that might improve industry efficiency and returns. The modeling has involved extensive consultation with fishers and fisheries managers and the results will be used by the industry in developing a new management system during 2006 to 2008. The full model development and results are documented in McLeod et al [3] and McLeod et al [4]. Earlier analysis of the potential for the use of quota in the industry can be found in Lindner [2].

The alternative management options are being assessed against a backdrop of ongoing rationalization as shown in Figure 1. Between 1964/65 and 2003/04, pot numbers have been reduced by management interventions from around 76,000 to around 56,000 in three adjustments. Vessel numbers have declined continuously from around 850 to around 550. Over the period average catch has not fallen. Fluctuations in catch per unit of effort closely mirror the Puerulus Index 3 years earlier (PI-3) which is the leading predictor of abundance. Effort measured as pot lifts per vessel has more than doubled over the period.

![Figure 1: Overview of pattern of change in the industry](image)

**MODEL STRUCTURE AND DATA**

**Overview of Model**
The assessment of the alternative options uses a bio-economic model comprised of:

- a biological model with up to 3 “age” cohorts of lobster to simulate the population dynamics of the West Coast Rock Lobster Fishery; embedded within:
- a highly non-linear mathematical programming model used to optimise industry annual net economic benefits; embedded within:
- a recursive algorithm that links the biological population of one year to the next, and uses a sequence of puerulus indices (PI) from the fishery to simulate recruitment variation over ten year period.
The model simultaneously optimizes across the biological and economic sub models to maximize the net economic return to the fishery by searching for the optimal combination across key decision variables including: vessel numbers, pot numbers, days fished by month, number of boat trips by month, pot lifts by month, aggregate and monthly catch, available breeders, recruits and survivors by month and closing biomass for recruits, breeders and survivors for each of the ten years in the model. The biological models for Zones A, B, and C are separate and completely self contained. In the economic optimization there is one model for Zone C, and another for Zones A and B combined. Some vessels have licences to fish in both the A & B zones at different times of the year and this requires that the economic optimization deal simultaneously with Zones A and B.

The model runs recursively for a ten year period. From the biological perspective, this means that the model starts with given opening stocks, and then simulates recruits, survivors, and breeders on an annual basis. Closing stocks are transferred to the next year. The model then optimizes annual net economic benefits for each year of the ten-year evaluation period. The final closing stocks of recruits, breeders and survivors at the end of ten years relative to opening stocks at the start of the ten year period provide an indication of sustainability of alternative management scenarios.

The structure of the economic component of the model is based on the concept of a representative boat being the unit of production. Cost data was provided by fishers for a variety of vessels by zone and this was used to construct a cost profile that was representative of boats operating in the fishery. The costs for the representative boat are different for each zone. In all three cases, the representative boat is crewed by a skipper and two deckhands.

The robustness of the biological models was evaluated using historical data over the period 1993/94 to 2003/04 using monthly catch data from the three zones. One measure of this robustness is the correlation between predicted and actual catches. This is shown in Figures 2 and 3. The model tracks actual catch well, with the R square between actual and fitted catch being very high at 0.93 for Zones A and B combined and 0.87 for zone C.

MANAGEMENT OPTIONS

Management options in the model are defined by the selection of parameter values (e.g. monthly prices for lobster and monthly catchability coefficients) and by the specification of constraints (e.g. maximum annual catch limit or TACC or a specified number of pots). The management options evaluated fell into three broad classes namely:

- the current management rules based on pot controls with the continuing need for periodic effort adjustments to ensure resource sustainability over time. This is Scenario 1;

- a mix of ITQ based on a variable inter-seasonal TACC and input (pot number) controls with an extended fishing season, and permitted changes in pot design that allow for a modest increase in productivity. This is Scenario 3.

- an ITQ based on a variable inter-seasonal TACC with an extended fishing season, no controls over pot numbers, and few restrictions over pot design allowing for a greater increase in productivity. This is Scenario 4.

Scenario 1 based on current input controls recognizes the need for pot reductions to maintain biomass and places them at about the point (year 11) that they would typically tend to occur based on current management approaches. To get the biomass back to opening stock levels by year 20 requires pot reductions of between 7 % and 10% at the end of year 10. The ITQ scenarios 3 and 4 have annual catch limits set to bring biomass back to opening stock levels at the end of year ten.

The full set of model options are summarized in Table 1. In the discussion below we concentrate on options 3z and 3u and 4z and 4u. Option 3u incorporates the most generous set of assumptions used under Scenario 3 whilst 3z reflects the most conservative set of assumptions used. Option 4u incorporates the most generous set of assumptions used under Scenario 4 whilst 4z reflects the most conservative set of assumptions used.
The table shows the various combinations modelled and indicates the nature of the differences. For example, comparisons such as comparing 3v to 3y or 4v to 4y are based only on varying pot efficiency, whilst others such as comparing 3u to 3v or 4u to 4v show only the effect of varying prices. For some scenarios there are differences that were not subject to sensitivity analysis. In particular, Scenario 4 has a 20% higher pots per boat and a lower starting boat number.
Table 1: Features of the Alternative Management Options Modelled

<table>
<thead>
<tr>
<th>Features</th>
<th>Existing Rules</th>
<th>Mix of Output (Variable TACC Quota) and Input (Pot # Controls)</th>
<th>Pure ITQ (Variable TACC Quota with no Pot # Controls)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zones</td>
<td>Scenario Code</td>
<td>End of Season</td>
<td>Price Differentials</td>
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<tr>
<td></td>
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<td></td>
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<tr>
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<tr>
<td></td>
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Notes: ¹ Extended season increases firm cost by $7,200 and ITQ’s reduces firm cost by $7,200.
² CPUE in July and August adjusted to limit catch to around 100-200 tonnes in each of these months.
³ Variable TACC= (90% of ‘predicted’ current year catch for Scenario 1+90% of the ten year average catch for Scenario 1)
RESULTS

Economic Benefits

The model is a non linear optimization model that solves for the best combination across all inputs that maximizes the net benefit associated with a given option subject to the various constraints specified for that option.

The focus is on the estimated economic benefits of each option relative to the base case of continuing with the current input controls and, as explained above, requiring a further pot reduction of around 7% to 10% in year ten to have an equivalent biomass outcome to the quota scenarios. Comparative net economic benefit results for the fishery as a whole for each of the alternative options are presented below. The estimates reported are based on the present value of the net benefits over the period of the model (ten years for quota based Scenarios 3 and 4 and twenty years for Scenario 1) and are expressed as net present values converted to an annual net benefit figure.

Additional monitoring and enforcement options have been deducted from the relative net benefits for each of the quota scenarios. These are deducted at $2.178 million per annum based on estimates provided by the Department of Fisheries. Differences in net benefits across scenarios reflect differences in specified constraints and in assumptions about parameter values as specified in Table 1 above.

For the pure ITQ scenarios (options 4u to 4z) the model is allowed to choose the best combination across all inputs to harvest the specified TACC over the extended season without any constraint on pot numbers and with improved pot designs and higher numbers of pots per boat. In this case, the optimal solution can be expected to continue in longer term steady state without change, because all variables have been freely adjusted in the optimization and the TACC determination rules are used to ensure resource sustainability. For the pot controlled quota scenarios (Scenarios 3u to 3z) the model optimizes subject to the constraint that the number of pots used must remain the same as in the base case and only limited increases in pot efficiency are permitted.

Figure 4 below shows the additional annual net benefits for the fishery overall for the alternative quota based options 3u and 4u and 3z and 4z. Relative to the base case the results indicate that the net benefit outcomes for the quota based options under both Scenario 3 and Scenario 4 are higher than those for the input control base case. Scenario 4 has higher net gains than Scenario 3. Scenario 3z has a $4.6 million higher annual benefit than the base case. Moving to the most generous assumptions under Scenario 3 with the highest price premium and a 15% improvement in catch efficiency increases the additional annual net benefit to $14 million above the base case.

Relative to the base case, Scenario 4z has a $20.9 million higher annual benefit. Moving to the most generous assumptions under Scenario 4 with the highest price premium, a 40% improvement in catch efficiency and an increase in pots per boat of 20% increases the additional annual net benefit to $44.9 million above the base case.

Relative to the base case, all of the options produce increases in net benefits in each year and this is the case across all zones. Scenario 4 options have consistently bigger net benefit estimates than the options in Scenario 3 and this applies in every year. Within each scenario moving to higher price premiums and higher catchability through pot design changes increases net benefits. Figure 5 shows the effect of price and pot efficiency improvements on relative net benefits within Scenario 4. Having higher pots/boat and associated reduced fleet numbers as occurs in Scenario 4, increases net benefits even further. Again this is true for each year of the model period and for all fishing zones.

Breeder Biomass and Catch

The model optimizes subject to biomass not being unacceptably decreased. To ensure sustainable outcomes, options were constrained to bring biomass back to opening values at the end of ten years. For the quota based options biomass equals or is a little above opening biomass at year 10. These management options work directly on catch levels and catch quota can be set in the model to ensure the biomass is maintained at a sustainable level. For the base case using only input controls biomass declines over the first ten years reflecting effort creep and pot numbers have to be reduced at the end of this period sufficient to bring the biomass back to its starting point by the end of year 20. The pot reduction required in the model is 7% in Zone C and 10% in Zone B and 7% in Zone A. These required pot reductions are estimates based on the underlying modelling. Actual pot reductions required would likely be different and would reflect the on-going monitoring of the fishery and the information that this provides to managers over time. The breeder biomass indexes for the base case and for the various options in Zone C, Zone B and Zone A are shown in Figures 6, 7, 8 and 9.
Figure 4. Annual net benefit for options 3u, 3z, 4u and 4z relative to the base case.

Figure 5. Sensitivity of annual net benefits to price and pot efficiency assumptions.
Year 11 Pot reduction required for biological sustainability by year 20 is 7\% in Zone C, 10\% in Zone B and 7\% in Zone A.

Figure 6. Breeder biomass index in the base case

Figure 7. Breeder Biomass Index Zone C
The base case has the highest catches, but reduces biomass over the ten years (Figure 6). Pot reductions are needed at the end of this period to move biomass back to a sustainable level. All other options use the same quota setting rule which is 90% of the average catch in the industry over the last ten years plus 10% of the variation between actual and average catch over the same period. Hence these options have the same catch patterns but a lower average catch consistent with achieving biomass sustainability over the period. Annual catch averages 10,975 tonnes over the ten year model period under the base case but is on average 750 tonnes lower under the quota options.
Boat Numbers

There are two aspects to boat numbers in the modelling. For each scenario, there is an implicit transition period, followed by the ten year equilibrium modelling.

In 1993/94 boat numbers were 639 and they reduced to 549 in 2003/2004. This period was after an 18% pot reduction. In the modelling opening boat numbers are 445 for Scenarios 1 and 3 and 235 for Scenarios 4u and 4v and 296 for Scenarios 4x, 4y and 4z. Pots per boat and boats are closely related. If pot numbers are set there is less scope for vessel reductions. Boat numbers are very much reduced under Scenario 4 options when the model is allowed to solve without constraint for the optimal number of pots and can use up to 20% more pots per boat compared to Scenarios 1 and 3 where pot numbers are constrained.

Effort

Figure 10 shows average annual pot lifts over the ten years. These are highest for the base case which is constrained to use the current level of pots and has no increase in pot efficiency. They are lowest for option 4u which has the highest increase in pot efficiency, lower pot numbers, fewer boats and an increase of 20% in pots/boat. Pot lifts under option 4z are higher than option 4u and higher than for Scenario 3. Whilst option 4z has an increase of 20% in pots/boat, and fewer pots, it has only a 10% increase in pot efficiency.
Overview of Bio Physical Results

Option 4u has a 40% increase in pot efficiency and no constraints on pot numbers. It has a 20% increase in pots per boat and fewer boats. Optimization occurs in 4u with the lowest number of pots of all scenarios and with the lowest number of pot lifts but with more days fished than for the options under scenario 3. In the presence of the increase in pot efficiency and a smaller fleet, option 4u works the capital in the industry harder.

Scenario 3 is constrained to use the current number of pots, has no increase in pots per boat and only modest 10% and 15% increases in pot efficiency. With pots fixed at current numbers, with smaller efficiency gains and with more boats than option 4u, optimization involves significantly reduced fishing days, compared to 4u but with more pot lifts than for option 4u.

Scenario 4x has all the attributes of 4u but only a modest increase in pot efficiency (10%) which is comparable to that built into Scenario 3. It has no constraint on pot numbers. It has a 20% increase in pots per boat. It uses more boats than 4u but less than in Scenario 3. In optimization it uses fewer pots than Scenario 3 but more than under option 4u. Days fished are similar to option 4u but higher than options 3x and 3u. Pot lifts are higher than for Scenario 3 and significantly higher in option 4u which has the lowest pot lifts. In effect under option 4x, higher pot lifts are making up for the reduced pot efficiency compared to option 4u given the larger boat numbers

CONCLUSION

The modeling results indicate that there are potentially large gains for the Western Rock Lobster industry from moving to a quota based management regime. Depending on the exact assumptions used quota based options can increase industry average annual net benefits from around $4 million up to over $40 million. The higher benefits are associated with options having the greatest flexibility to adjust key inputs. Estimated net gains arise primarily from fleet rationalization, reducing the number of pots used, from fishing the extended season and smoothing effort over the season. Higher net gains can accrue if pot design is deregulated to allow greater productivity improvements.

Whilst the modelling indicates the potential gains from a move to quota based management, there are challenges in implementing such a change. The most significant of these is likely to be the rules for the initial allocation of quota and the implications that any given initial allocation system has for the financial position of individual fishers.
REFERENCES


ENDNOTES

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i For a technical and economic overview of the fishery see Western Australian Department of Fisheries [5].

ii The model is similar to the Hall and Chubb model [1] in terms of the way it approaches modelling key elements, such as variable recruitment from a series of *Puerulus* settlement indices, as well as death rates. Of necessity, it is considerably simpler than the Hall and Chubb model. The objective in developing the model structure was to capture the key aspects of the biology but keep the model simple enough to allow tractable integration with the economic aspect of the modelling.

iii The existing biological controls that disallow the taking of setose and tarspots and undersized lobster remain under all three alternative approaches.

iv In the previous reports fixed quotas and a variable quota rule based on 50% of the average plus 50% of the variation were modelled. These produced unacceptable fluctuations in the biomass and have not been carried through into the current analysis.

v The magnitude of the potential gains suggest that it would be possible to design and allocation system that is Pareto optimal in the sense that no individual fisher is worse off through the allocation process.