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1. Introduction

### Acknowledgements

### Abstract
Responsibilities:

All errors, misunderstandings, etc., remain our sole

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Followed by some text that is not legible due to the image quality.
ORANI 76 is a large multisectoral model of Australian industry structure. Whereas various types of arable and pastoral land distinguished in the model serve as fixed factors which set a limit to the volatility of the simulated long run behaviour of rural industries, no analogous constraints yet apply (March 1981) in the case of the fishing and mining industries. This paper explores the relevance of biological and institutional constraints for the reprogramming of ORANI so as to make its long run behaviour more realistic in the case of fishing. It is concluded that the latter industry needs disaggregation at least as far as two groups: predominantly exported seafood (lobsters and prawns), and the remainder. In the case of the former sector the capital stock should be treated exogenously both in long and in short run simulations. The parameter file should be revised so that the capital/labour substitution elasticity in this sector is close to zero (thus making output effectively exogenous). For the domestic market oriented sector of the industry the existing standard ORANI treatment will suffice in view of the fact that this sector's linkage to domestic consumption will effectively curb any tendency for implausibly volatile behaviour in long run simulations.
The aim of this paper is to explore how industrial policies, targeted at specific industries, influence the economy. The model used in this study is an extended version of the model used in previous studies.

The model is an endogenous growth model, where the long-run growth of the economy is determined by the accumulation of physical and human capital. The model is calibrated to fit the data for a specific country, in this case, Japan.

The main conclusions of the paper are:

1. The long-run growth of the economy is determined by the accumulation of physical and human capital.
2. Industrial policies, targeted at specific industries, can influence the economy in the long run.
3. The long-run growth of the economy is sensitive to changes in the labor market and the accumulation of physical capital.

The model is an extension of the model used in previous studies, and it is calibrated to fit the data for Japan. The model is used to explore the long-run effects of industrial policies on the economy.
the relevance of biological and institutional constraints for respecification of ORANI so as to make its long run behaviour more realistic in the case of fishing.

The paper is structured as follows. Section 2 contains a brief overview of the structure of the fishing industry. In Section 3 an examination is made of the relevant theoretical considerations pertaining to a reproducible resource. These theoretical results are related to the behaviour of important sub-sectors of the fishing industry in Section 4. The question of how ORANI should be respecified in the light of the insights provided by Sections 3 and 4 is taken up in Section 5, while brief concluding remarks are offered in Section 6.

In the export sector of fishing (three quarters of the total in 1978/79) the conditions pertaining either approximate those described above (lobsters and prawns with non-estuarine breeding habitats), or else involve a combination of licensed capacity and highly erratic output which is almost 100 per cent climatically determined (prawns with estuarine breeding habitats). In either case capacity and (given limited scope for capital/labour substitution) output are exogenous to ORANI, in both long and in short run modes for predominantly export commodities, prices are, to a good approximation, determined in ORANI by output and by overseas demand conditions. The endogenization of prices for lobsters and prawns in ORANI would therefore be likely to be reliable. Given the imperfect nature of the property rights bestowed by licensing, however, it follows that cost and profitability variables endogenized for these industries in ORANI should be viewed with caution.

The non-export oriented segment of fishing is a very diverse one. This heterogeneity would make it difficult to quantify the extent to which this sector's long run supply curve slopes upward as the result of bio-feedback and/or regulation. Given resources and priorities, the work involved cannot at this stage be mounted. In the meantime treatment of the non-export sector of fishing as a standard industry (with capital stock exogenous in short run simulations and with rate of return exogenous in long run simulations) will not cause the model to behave implausibly. This is because any tendency for wild variations in the simulated size of the non-export sector of fishing will be prevented by the relatively low income and price elasticities assigned to the products of this sector in the ORANI parameter file.
In the case of the Australian Pelagic, which takes a major portion in the export of the fishery, the export sector consists of all the sectors of the export sector which, in the second section, should be in the top ranking sector which is ranked in the second sector. The Australian Pelagic Industry essentially consists of 5.2 Major Export Commodities Exported.

<table>
<thead>
<tr>
<th>Code</th>
<th>Landings: 1978-79</th>
<th>Per cent</th>
<th>Value of Catch</th>
<th>Per cent of Australian Fishery's Total Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>96.67</td>
<td>Total catch.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>73.62</td>
<td>Total value.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>69.73</td>
<td>Total weight.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63.84</td>
<td>Total revenue.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>57.88</td>
<td>Total export.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51.94</td>
<td>Total import.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Major Components of Australian Fishing Industry.

1978-79 data.

The table, which details the volume of the export sector for the Australian Pelagic Industry, shows that the Australian Pelagic Industry contributes significantly to the export sector. The export sector is majorly comprised of the Australian Pelagic Industry. In the second section, the Australian Pelagic Industry is ranked in the top ranking sector which is ranked in the second sector. The Australian Pelagic Industry essentially consists of 5.2 Major Export Commodities Exported.
The Table shows that the prawn industry contributed about 40 per cent of total output, whilst the rock lobster industry contributed approximately 30 per cent. The importance of these two sectors is further demonstrated in Table 2 which shows the values of exports of each of three principal fishing sectors in 1978-79 and the composition of fishing exports by value for 1974-75 to 1978-79.

<table>
<thead>
<tr>
<th>Species</th>
<th>Percentage Composition of Value of Fishing Exports</th>
<th>Value of Exports 1978-79 ($'000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prawn</td>
<td>36 37 39 41 49</td>
<td>93,567</td>
</tr>
<tr>
<td>Rock Lobster</td>
<td>48 46 43 44 36</td>
<td>70,428</td>
</tr>
<tr>
<td>Other</td>
<td>16 17 18 15 15</td>
<td>30,334</td>
</tr>
<tr>
<td>Total</td>
<td>100 100 100 100 100</td>
<td>194,129</td>
</tr>
</tbody>
</table>


In 1978-79 prawns and rock lobsters contributed more than 80 per cent of total fishing exports. Given their importance, these two sectors will be considered in some detail. It is these two sectors especially that contribute to the problems faced in a long run ORANI simulation, for they are subject to a highly elastic overseas demand and hence their output is not constrained effectively by the demand side of the market; that is, for a given export price, they could, in the absence of supply considerations, expand virtually indefinitely.

While (24) would give the appropriate price determination mechanism, care would be needed in interpreting some other variables. Consider, for example, the consequences of a windfall gain consisting of an exogenous 4 per cent increase in world demand ($e_{11}^p = 4$ per cent). At the initial level of exports (viz., $x_{11}^p = 0$) this translates into a four per cent increase in the f.o.b. price ($p_{11}^p = 4$). According to the ORANI specification, such a price increase, if unmatched by corresponding cost increases, leads to a short run increase in the rentals on capital equipment, i.e. in profitability. In the standard way of computing longer run ORANI simulations it would lead to increased investment and a higher capital stock; in the case of fishing this would mean more or larger boats, etc. But as we have seen above in Section 4, neither of these conclusions is warranted in the case of a regulated natural resource industry like lobsters and/or prawns.

In the short run the windfall price rise does not necessarily translate fully into higher short run profitability as the intensity of fishing effort may rise competitively within the fishery to eliminate part or all of the windfall gain. Such activity is not modelled in ORANI. To put it slightly differently, ORANI would get the price right but the changes in costs and rentals wrong.

In standard long run ORANI simulations the rates of return on assets are set exogenously by the going international supply prices of capital of various sorts; capital stocks then adjust to yield Australian industries whose sizes are consistent with these externally set rates of return at the future date to which the model solution applies. Under the proposals made above, however, the rates of return on prawning and lobster catching would remain endogenous in both long and short run simulations.

1. See Vincent, op. cit.
6. Within each fishery, the level of fishing activity is controlled to a greater or lesser extent by the relevant statutory authorities. Such control usually originates from the past, when periods of severe overfishing caused the authorities to intervene in order to protect the long term interests of the industry. Such control usually consists of a licensing system to limit entry into the fishery -- this being the case for the Western Australian rock lobster and the North Queensland prawn fisheries -- and/or of a set of regulations controlling one or more of the following: the amount and type of fishing equipment that is permissible, the size of fish that may be caught and the times when fishing may be undertaken. All of these are designed to limit the level of fishing activity and the size of the fish catch.

35. demand for their output is primarily domestically based. Scale fish are almost entirely domestically consumed and are thus subject to domestic demand constraints. Abalone however, is primarily exported -- although the size of the exports is relatively insignificant.1

5. Specification of ORANI Simulations

The foregoing description of Australian fishing has been partial, particular emphasis being given to the northern prawn fishery and the Western Australian rock lobster fishery. With respect to lobsters, it is believed that broadly similar considerations would apply to the fisheries in other states.

Given sufficient data on cost structures and sales patterns, the optimal procedure from the viewpoint of ORANI would involve a three way split along the following lines:

(a) Mainly Exported Seafood
   (a.i) Prawns
   (a.ii) Lobsters

(b) Mainly Import Competing Seafood.

5.1 Mainly Exported Seafood

Under such a classification output of prawns and lobsters would be set effectively exogenously in ORANI simulations (both long and short run). The direct instrument controlling output is capital capacity, and it is this variable which would be declared as exogenous

test
gap \( (1 - \frac{N(t)}{N_S}) \) between that existing population and the limiting population \( N_S \) which the given species would achieve in the given habitat in the absence of artificial competition (viz., fishing). Thus the logistic growth law may be written as

\[
N(t) = r N(t) \left(1 - \frac{N(t)}{N_S}\right)
\]

(1)

where the constant of proportionality \( r \) may also be interpreted as the growth rate of the population in its earliest stages (viz., when totally unfettered by competition, even from itself). That is,

\[
\frac{\dot{N}(t)}{N(t)} = r
\]

(2.1)

when \( N(t) \) is small relative to its ceiling value \( N_S \); viz., when

\[
\frac{N(t)}{N_S} \ll 1
\]

(2.2)

In the levels the logistic law (1) takes the form

\[
\frac{N(t)}{N_S - N(t)} = e^{rt}
\]

(3)

which demonstrates that the sigmoidal curve (3) has three parameters: \( N_S \), \( r \), and \( a \). The last mentioned may, for a given value of \( N_S \), be found from an initial condition,

\[
N(0) = \bar{N}
\]

(4) \( \bar{N} \) being given, or, given known values of \( N_S \) and \( r \), from knowledge of the value of \( N \) at some other \( t \).

4.3 Other Species

The remainder of the Australian fishing industry accounts for 34 per cent of the value of output, but only 16 per cent of total exports. It consists of a wide variety of species which are fished under varying levels of regulation. There are essentially three groups of species: scale fish, molluscs and crustaceans.

The scale fish sector comprises mainly shark, tuna and whiting, all of which are found in 'deep sea' areas. It appears to be the conventional wisdom that deep sea fish are not particularly susceptible to climatic conditions in their reproductive capacity and that their population dynamics follow the theory expounded in Section 3 - but there has been little work done in this area.

The level of regulation depends not only upon the species but also upon the statutory authority controlling the fishery. In the case of Southern Blue Fin Tuna, entry into the New South Wales and South Australian fisheries is licensed (and restrictions in equipment also apply), whereas entry into the Western Australian fishery is unrestricted. Shark fishing takes place under open access conditions in all three of the important shark fishing states (Victoria, South Australia, and Tasmania), although minor restrictions on equipment are in force. For the minor scale fish fisheries, regulations vary from open access in Western Australia to tightly controlled non-tradeable licences in Victoria's beach, estuarine and inlet fisheries.

1. Refer to Section 2, Tables 1 and 2.
2. Derived from personal communications with the Victorian Division of Fisheries and Wildlife, February 1981.
\[ 0 \leq \int_{0}^{x} \left( \int_{0}^{y} f(x,y) \, dy \right) \, dx \leq \int_{0}^{1} \left( \int_{0}^{x} f(x,y) \, dy \right) \, dx \]

1. The general form of the solution is

\[ f(x,y) = \frac{\int_{0}^{x} \left( \int_{0}^{y} f(x,y) \, dy \right) \, dx}{\int_{0}^{1} \left( \int_{0}^{x} f(x,y) \, dy \right) \, dx} \]

where the new parameters are

\[ q = \frac{N - 1}{\frac{N}{N - 1}} \]

and

\[ \frac{\frac{N}{N - 1}}{1 - E} = \frac{N}{N - 1} \]

The equation is useful in practice when the parameters are

\[ p_{x} = \frac{[N - 1]}{(N - 1)N} \]

with the assumption that

\[ N \geq 1 \]

and

\[ N \geq 2 \]

The solution is

\[ f(x,y) = \frac{1}{N} \]

is the solution in the long run. When the parameters are the same, the solution in the long run is

\[ N \geq 1 \]

and

\[ N \geq 2 \]

is the solution. In the case where the solution is

\[ N \geq 1 \]

and

\[ N \geq 2 \]

the solution is

\[ N \geq 1 \]

and

\[ N \geq 2 \]

is the solution.
Equation (7) tells how sustained fishing effort affects the long-run population. At any given sustained effort level \( f \) there is a unique asymptote \( K \) to which the fish population tends over time. The elasticity of this long-run population level with respect to sustained effort is

\[
\frac{\delta N}{\delta N_f} = \frac{f}{K - f}.
\]

Let

\[
X(t) = N(t)f(t)
\]

be the time rate of catch (numbers of individual fish caught per week, say). Equation (9) is a production function in which \( f \) (after multiplication by a unit, but dimensioned, constant) must have dimensions "proportion of the fish stock caught per unit time." This is not entirely inconsistent with measuring effort (as an input) in trawler hours per week. In the case of the trawling activity, for example, we would choose the number of trawler hours which, with the population at some base period reference level \( N(t_0) \), results in one fish being caught. Note that the conversion factor from trawler-hours to units of effort is thus time dependent to the extent of variations in \( N \). Let \( g(t) \) trawler hours per week in the period \( t \) be sufficient to catch one fish; let \( G(t) \) be the total number of trawler hours per week expended at \( t \). Then, from (9),

\[
X(t) = \left[ \frac{G(t)}{g(t)} \right]
\]

\[
= \left[ \frac{G(t)}{g(t_0)} \right] \frac{g(t_0)}{g(t)}
\]

at least in part, the increase in resource rental generated by the price rise. In any event, these increases in inputs are unlikely (in the light of Table 3) to lead to any significant response in total yield. An initial autonomous drop in fishing costs at a fixed product price level (due, say, to a major improvement in fishing technology) would similarly lead to increased effort but not to significant increases in catch.

We turn now to (iv), the question of the responsiveness of controls imposed by the regulatory authority to changes in prices and costs in the industry. If the authority followed the MSY criterion, these would be irrelevant — neither prices \( (P) \) nor costs \( (Q) \) appear in (18). This, however, may be too extreme a view of the relative stationarity of the W.A. system of controls. In 1978, for instance

"the length of the season was reduced by six weeks to assist fishermen to maintain a viable economic return."1

This response seems to have been in an attempt to reduce the private impact of the socially unnecessary costs of competition referred to above, rather than a response to a movement in \( P \) or \( Q \) which, if MSY were being strictly followed, would lead to adjustments along the lines of the formulae given in Table 3. On the other hand, the decision to attempt to reduce costs of competition may have been triggered by the cost price situation faced by the industry at that time.

What is the relevance of the above to the closure of

---

an axiom. This treatment measure the relative size of

\[ \frac{N^2}{\bar{N}} = \frac{\bar{N}^2}{N} \]

where

\[ (\bar{N}) \]

This equation tells us that if the number of treatments increases, the relative size of the treatment decreases.

In order to progress, we must first address the problem of...
3.2 Fishery Management

(a) Maximum Sustainable Yield

In the theory of optimal fishery management the basic question often is formulated along the following lines:

What sustained level of fishing effort, \( F_{\text{MSY}} \), is consistent with achieving the maximum sustainable catch \( X_{\text{MSY}} \)?

In other words, what is the maximum sustainable yield (MSY) of the fishery, and what limitations should be placed on fishing effort to achieve it? An associated problem is the computation of the stationary population level \( N_{\text{MSY}} \), uniquely consistent with \( F_{\text{MSY}} \).

Before proceeding to the standard solution of this problem we note that the MSY policy is not necessarily socially optimal: first, it fails to take explicit account of demand-side factors such as pure time preference discounting and possibly non-stationary expectations about the future value of the resource; secondly, cost considerations are completely left out of the MSY criterion. Thus there is no reason to suppose that the exploitation rate equating marginal social cost with marginal social benefit will correspond to MSY. Finally, the licensing arrangements used to implement the MSY policy may result in given levels of output being produced at more than minimum feasible cost. Our interest in this paper is not in the normative significance of MSY, however, but derives solely from its apparent use as a reference point by licensing authorities.

<table>
<thead>
<tr>
<th>Year</th>
<th>Effort ( (f \times 10^6) )</th>
<th>Catch ( (kg \times 10^6) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960/61</td>
<td>3.777</td>
<td>7.790</td>
</tr>
<tr>
<td>1961/62</td>
<td>5.700</td>
<td>8.744</td>
</tr>
<tr>
<td>1962/63</td>
<td>7.500</td>
<td>9.324</td>
</tr>
<tr>
<td>1963/64</td>
<td>4.648</td>
<td>8.119</td>
</tr>
<tr>
<td>1964/65</td>
<td>4.798</td>
<td>7.486</td>
</tr>
<tr>
<td>1965/66</td>
<td>5.036</td>
<td>8.120</td>
</tr>
<tr>
<td>1966/67</td>
<td>5.147</td>
<td>8.635</td>
</tr>
<tr>
<td>1967/68</td>
<td>5.173</td>
<td>9.953</td>
</tr>
<tr>
<td>1968/69</td>
<td>4.292</td>
<td>8.078</td>
</tr>
<tr>
<td>1969/70</td>
<td>5.771</td>
<td>8.918</td>
</tr>
<tr>
<td>1970/71</td>
<td>7.888</td>
<td>8.013</td>
</tr>
<tr>
<td>1971/72</td>
<td>7.536</td>
<td>8.171</td>
</tr>
<tr>
<td>1972/73</td>
<td>7.253</td>
<td>6.809</td>
</tr>
<tr>
<td>1973/74</td>
<td>7.127</td>
<td>6.780</td>
</tr>
<tr>
<td>1974/75</td>
<td>8.035</td>
<td>8.877</td>
</tr>
<tr>
<td>1975/76</td>
<td>8.100</td>
<td>8.873</td>
</tr>
</tbody>
</table>

Average change per year

\( +0.48 \)  \( -0.016 \)

Source: Morgan 1979 (op. cit.)

(a) \( f \) is measured as effective effort, where not only pot lifts but also the spatial and temporal distributions of pot lifts are considered.

(b) Differs significantly from zero at 0.1 per cent level.

(c) Fails to differ significantly from zero at 5 per cent level.
The maximum error

\[
\frac{\sigma^2}{S^2} = \frac{\ln N}{S^2}
\]

is given by

\[
\frac{\ln N}{S^2} \approx \frac{1}{2}
\]

where \( N \) is the size of the sample.

The maximum error with maximum variance \( S^2 \) is

\[
\frac{S^2}{\ln N} - 1 \approx \frac{1}{2}
\]

and with the population constant

\[
N \approx \frac{S^2}{\ln N} - 1
\]

For \( \frac{S^2}{\ln N} \) to be very large, the sample constant

\[
N \approx \frac{S^2}{\ln N}
\]
the optimum application of effort is one half of the inherent biological growth rate. To translate effective effort ($E$) into physical input units ($G$) we use (13) and (18):

$$G_{\text{MSY}} = \frac{x}{2} g(t^0) N(t^0).$$

If the base year $t^0$ is one in which the MSY regime applies, then we may identify $N(t^0)$ with $N_{\text{MSY}}$ in (16), and so obtain

$$G_{\text{MSY}} = \frac{x}{4} g(t^0) N_S.$$

(b) **Maximum Economic Yield**

The neglect of the cost side in the formulation of the MSY criterion has been recognized (at least in the literature) and has led to the concept of a maximum economic yield (MEY).

The analysis is simplified by (i) assuming a zero social pure time preference discount rate, and (ii) a flat (infinitely

Morgan has estimated the values of $N_S$ (the natural upper limit on the biomass) to be (approx) 21 million kilograms, whilst the inherent biological growth rate is estimated to be 1.6. From the latter value it can be deduced that the rate of mass growth in the early stages of the logistic process will be 52 per cent per annum (although as the mass rises, this rate of increase of course will fall).\footnote{1 In the exponential growth phase, $N(t) = N(0)e^{rt}$. Putting $t = 1$ and $r = 1.647$ gives $N(1) = 5.19N(0)$.}

Comparison of equation (13) in Section 3 with Morgan's formulation identifies the term

$$\frac{1}{g(t^0) N(t^0)}$$

as the 'catchability coefficient', which represents the proportion of the base period biomass caught by expanding one real unit of fishing effort. In the rock lobster industry, the latter concept is measured by 'number of pot lifts'. This coefficient was estimated by Morgan to be of the order of $1.4 \times 10^{-7}$ (or $1.4 \times 10^{-5}$ per cent of the base period biomass per pot lift). The reciprocal of the catchability coefficient, $7 \times 10^6$, is the number of pot lifts required to annihilate the base period population. The actual number of pot lifts in that period was $1.4 \times 10^5$, or 2 per cent of the theoretical fishing intensity which would have destroyed the fishery.

The remaining issues are institutional and economic. In particular,

(i) Is the level of effort currently being applied consistent with the maximum sustainable yield, the maximum economic yield, on some other criterion?
\[ (\frac{dN}{dt}) = (\frac{dN}{dS})(1 - \frac{S}{N}) \]

1. \( (\frac{dN}{dS}) = \frac{AS}{S} \)

2. \( S_N = (\frac{A}{S}) \)

3. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

4. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

5. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

6. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

7. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

8. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

9. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

10. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

11. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

12. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

13. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

14. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

15. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

16. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

17. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

18. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

19. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

20. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

21. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

22. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

23. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

24. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

25. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)

26. \( S_N(1 - \frac{A}{S}) = \frac{A}{S} \)
4.2 The Rock Lobster Industry

The Shafer model, described above in Section 3, is far more appropriate to the rock lobster industry than to trawling. The relatively slow growth rate of the lobster and the dependence of its current population size upon previous levels place it clearly within Shafer's 'self-regulating resource category' (i.e., the one for which his model was developed). The suitability of the Shafer framework for the analysis of the Western Australian rock lobster fishery has been examined by Morgan who concluded that Shafer's model provided '... a surprisingly good fit to the observed catch versus effort data',

In Shafer's 1957 formulation the variable whose growth was assumed to follow the logistic growth law was population stock (i.e., number of individuals). Catch, however, was specified as mass of fish. Later uses of the Shafer model work entirely in terms of biomass, i.e., the combined weight of all individuals in the population replaces nominal population size, while catch continues to be measured in tons or kilogrammes. Whereas the logistic story might be expected on a priori grounds to work well with population measured by count, its symmetry is

1. If the nominal price of fish is deflated by the cost, in base year \( t^0 \), of purchasing \( g(t^0) \) units of real fishing effort, then \( Q = 1 \).

4. In Section 3 we have developed the model with both variables measured as numbers of individuals. Only slight (and obvious) changes in assumptions are required to cast the story in terms of biomass.
Table 3: Values of Resource Rental, Population Size, Effective Effort and Real Cost associated with Maximum Economic Yield (MEY)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Notation for MEY Solution Value</th>
<th>Solution in terms of Biological and Economic Parameters (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource Rental</td>
<td>( P_{MEY} )</td>
<td>[ \frac{r}{4} \left( 1 - g(t^0) \frac{Q}{P} \frac{N(t^0)}{N} \right)^2 ]</td>
</tr>
<tr>
<td>Fish Population</td>
<td>( N_{MEY} )</td>
<td>[ \frac{N}{2} \left( 1 + g(t^0) \frac{Q}{P} \frac{N(t^0)}{N} \right) ]</td>
</tr>
<tr>
<td>Effective Effort</td>
<td>( f_{MEY} )</td>
<td>[ \frac{r}{2} \left( 1 - g(t^0) \frac{Q}{P} \frac{N(t^0)}{N} \right) ]</td>
</tr>
<tr>
<td>Real Cost of Effort</td>
<td>( C_{MEY} )</td>
<td>[ \frac{r}{2} N(t^0) g(t^0) \left( 1 - g(t^0) \frac{Q}{P} \frac{N(t^0)}{N} \right) ]</td>
</tr>
</tbody>
</table>

(a) Notation is as follows: 
- \( r \) = inherent biological growth rate (proportional increase per unit time);
- \( p \) = real price of fish (real $ per fish), assumed stationary;
- \( N \) = maximum carrying capacity of fishery (number of fish);
- \( g(t^0) \) = real fishing resource input per fish caught in the base period \( t^0 \);
- \( Q \) = cost in constant dollars of one unit of real fishing resource input;
- \( N(t^0) \) = fish population in base period \( t^0 \).

An example of the units of \( g \) would be 'number of standard trawler hours per fish caught'. In that case the units of \( Q \) would be 'real dollars per standard trawler hour'.
The number of prawning licences is strictly controlled in each state. In some states there are additional regulations limiting the type of fishing gear and the season within which prawning is allowed. Licences are fully transferable and the prices at which they are traded currently range between $100,000 and $500,000 (see Table 4). These prices clearly represent the present valuation placed by the market.

Table 4: Estimated Average Market Values of Prawning Licences, Major Prawn Producing States, 1980

<table>
<thead>
<tr>
<th>Fishery</th>
<th>Average Market Value of a Prawning Licence ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shark Bay, W.A.</td>
<td>500,000</td>
</tr>
<tr>
<td>Exmouth Gulf, W.A.</td>
<td>375,000</td>
</tr>
<tr>
<td>Spencer &amp; St. Vincent Gulfs, S.A.</td>
<td>350,000</td>
</tr>
<tr>
<td>Northern Prawn Fishery, N.T. and Queensland</td>
<td>100,000</td>
</tr>
</tbody>
</table>

a Excludes value of boat.

Source: Department of Primary Industry, Canberra.

on the access rights to the fishery. If one believes that fishing has no feedback on yields, then, since additional current harvesting has no opportunity cost in terms of future production foregone, this


2. The Department gives as its source T.G. Kailis, "Limited Entry, Not a Miracle Measure, An Industry View," paper prepared for the seminar cited in footnote 1.
Section 2: The Flow of Food Production to Professionality

Section 3: The Flow of Education to Professionalization

Section 4: The Family Industry

Section 5: Innovation in the Family Industry

Section 6: The Family Industry in the Light of the Political and Social Contexts

Section 7: The Family Industry in the Light of the Political and Social Contexts
qualitatively similar results could be expected to continue to apply. Under positive social discounting open access will still lead to overfishing at the point A in Figure 1: prospective pure profits are driven to zero in all periods regardless of the discount rate. The MEY will, however, alter. The reason is that a higher level of effort in the short term will yield a higher short term catch and hence revenue, but at the expense of smaller future yields. Given discounting, this smaller future catch is acceptable in view of the higher immediately obtainable yield. This current increase in output is unsustainable, being made possible by a decline in the size of the fish population. Analysis of stationary states as in Figure 1 becomes inadequate for the truly intertemporal social utility maximization problem now involved -- Euler-Lagrange variational methods, and/or control theory become the relevant tools. 1

Various methods are used by statutory authorities in their attempts to internalize the resource rental cost of the fishery. These include effort control (control of inputs), licence limitations (eliminating open access) and catch control. Effort controls include limitations on the times and places at which fishing may be undertaken, and limitations on the amount and type of equipment that may be used. Such controls usually result in cost increases because they encourage input substitutions that are uneconomic at the socially relevant supply prices of the resources. Thus more intensive fishing methods will be used to compensate for an arbitrary shortening of the times at which fishing may be legally carried out, etc.

The issuance of a limited number of licences establishes a system of shared property rights to the fishery which will allow, at least to some extent, internalization of its resources rent cost. The present value of the rents may initially be given to the licensee, or accrue to the government (as in sale of licences by auction). In either case transferability of the licences ensures that the resources rent (to the extent that it is successfully imbedded in the licence in the first place) continues to act as a real private production cost.

1. Clark, op. cit., pp. 58 et seq.